Indigenous Perspectives in the Alberta Science Classroom:
the factors that impact how teachers incorporate Indigenous perspectives in their science classroom

by

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Abstract

In Alberta, there has been renewed focus on the integration of Indigenous perspectives in the classroom within curricular and teacher quality documents. While research has been done to explore how and why Indigenous perspectives should be included in the classroom, there is a lack of research linking this action with the factors that impact teaching practice. This study explores the factors that impact how teachers incorporate Indigenous perspectives in the science classroom. To explore these factors, a mixed methods approach was taken. Participating high school teachers were asked to respond to an online survey which explored their epistemic beliefs of science. Once the survey was completed, teachers read through constructed teaching scenarios which described different ways in which Indigenous perspectives could be incorporated into a science classroom. Teachers wrote answers to two questions regarding these scenarios. The final step in data collection was a semi-structured interview. The data collected from the three parts of the study were analyzed separately and together to construct findings. It was found that there were several factors which impact teachers' practice and perception of Indigenous perspectives in the science classroom. These included the context that teachers taught in, their epistemic beliefs of science, and goals that they had of teaching. Recommendations from these findings included actions that could be taken by the individual teacher, school districts, governing bodies, and post-secondary institutions.

Preface

This thesis is an original work by Christa King. The research project, of which this thesis is a part, received ethics approval from the University of Alberta Research Ethics Board, "The impact of teachers' epistemic beliefs of science on the inclusion of Indigenous perspectives in the science classroom," No. 00066200, August 23, 2017.

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Chapter 1: Introduction

Introduction

In Alberta, curricular and teacher quality documents have increasingly emphasized the integration of Indigenous perspectives in the classroom. There has been considerable scholarship on ways Indigenous perspectives could and have been incorporated in the science classroom and the ethical implications of doing so. The factors that impact teachers' practices have also been widely studied. However, there is a gap in the literature that explores the factors that impact how teachers do and might incorporate Indigenous perspectives in the science classroom.

This thesis opens with the background of the study that explores the current sociopolitical landscape influencing education in Alberta. The literature review begins with an introductory discussion that contrasts Indigenous ways of knowing and Western science, looking at the different conceptions of each from prominent scholars. The factors that have been shown to influence teaching practice are surveyed with a focus on beliefs/epistemic beliefs, goals, and contexts of teachers. Research around the influence that these factors have on pedagogical practice, particularly in the science classroom, is then explored. The literature review concludes with the various ways that scholars see teachers incorporating Indigenous perspectives in the science classroom, with a discussion about the ethical implications around these particular pedagogical actions.

With this background, the purpose of this study is highlighted, looking at the gaps that are present within the literature presented and exploring the implications for the study on areas of research, curriculum, and classroom pedagogy.

Background for the study

In 2015, the Truth and Reconciliation Commission in Canada, released its final report as part of reconciliation between Indigenous peoples who were directly or indirectly affected by the residential school system and other Canadians (Truth and Reconciliation Commission of Canada, 2015). As part of this document, the Commission released “Calls to Action.” These included statements around building curricula in schools that explore Aboriginal people’s contributions, both historical and contemporary, to Canada (Call to Action 62i) and for governments to provide funding to teacher education programs for processes on integrating into classrooms Indigenous knowledge and teaching practices (Call to Action 62ii).

In Alberta, there has been a shift in curricular and teaching quality documents that increases the emphasis on Indigenous perspectives in the curriculum. This is evident in the recently revised Teaching Quality Standard (TQS) document and Program of Studies. Teachers in Alberta are mandated to adhere to the TQS developed by Alberta Education. The most recent version of this document (Alberta Education, 2019) applies to teachers certificated in Alberta (Alberta Education, 2019). The TQS states that “quality teaching occurs when the teacher’s ongoing analysis of the context, and the teacher’s decisions about which pedagogical knowledge and abilities to apply, result in optimum learning for all students” (p. 3). There are several statements within the document that refer to First Nations, Metis, and Inuit (FNMI) students and knowledge. Within “Engaging in Life-Long Learning,” teachers are expected to continually enhance “understanding of First Nations, Metis, and Inuit worldviews, cultural beliefs, languages, and values” (p. 4). One section of the document relates to “Applying Foundational Knowledge about First Nations, Metis, and Inuit” and states that a teacher must “develop and apply foundational knowledge about First Nations, Metis, and Inuit for the benefit of *all* students” (p. 6, emphasis added). This mandate includes the responsibility of the teacher to use programs of study to give all students opportunities to construct knowledge, understanding, and respect for, among others, contributions, experiences, and perspectives of FNMI peoples. As well, teachers are to use resources which “accurately reflect and demonstrate the strength and diversity of First Nations, Metis, and Inuit” (p. 6).

In accordance with the above mandates, curricula in Alberta include statements around Aboriginal perspectives. For instance, in the Program Rationale and Philosophy of the Science 10 Program of Studies, states that “Science 10 incorporates Aboriginal perspectives in order to develop, in all students, an appreciation of the cultural diversity and achievements of First Nations, Metis, and Inuit (FNMI) peoples” (Alberta Education, 2014, p. 2). To accomplish this, the curriculum in Science 10 has been designed to: (a) acknowledge the influence of Aboriginal peoples to knowledge about the natural world, (b) integrate different disciplines in science to promote relational thinking, (c) cultivate an understanding of connection to and care for the natural environment, and (d) help students experience confidence in their capability of succeeding in science (Alberta Education, 2014).

Despite the call from the Truth and Reconciliation Commission to integrate Indigenous knowledge and teaching practices into classrooms, there is a lack of research that explores the interrelated factors that impact teachers’ preferred and actual pedagogical actions with regard to integration. The research question for this study is: “What factors impact the preferred and actual practices of teachers when integrating Indigenous perspectives in the science classroom?” This study is built on the recognition that several factors impact teachers’ pedagogical actions, focusing on the context that teachers teach in, their goals as educators, and their beliefs. These three factors were identified by McRobbie and Tobin (1995) as interrelated and impacting teacher behavior. These factors are supported throughout the literature, as is explained in the literature review (Chapter 2). The beliefs considered in this thesis are narrowed to specifically examine the influence of epistemic beliefs because scholars have noted the importance of addressing epistemological concerns when discussing Indigenous science (e.g., Brayboy & Castagno, 2008). Further, what teachers believe about Western science knowledge has been shown to impact students' perception of what is legitimate knowledge (Gaskell, 1992; Sund & Wickman, 2011).

This study evolved from an original question that focused solely on the impact of epistemic beliefs on teacher practice to incorporate Indigenous perspectives, to include other factors that also influence teachers' practice. It became evident throughout the data collection and analysis that there is more than one factor that influences teachers' practices. Teacher pedagogical choices and subsequent actions were found to be complex and isolating one element affecting these choices and actions was increasingly problematic. The evolution of the research question in response to ideas that emerged from the data is consistent with the constructivist paradigm. In the constructivist paradigm, the research question might shift with what is learned from the data. Because of this, however, the literature review was modified to reflect the change in question from a focus on epistemic beliefs and their impact on teacher practice, to additional factors that influence teacher practice as reflected in the data and emerging assertions. The methodology originally developed for this study did focus on epistemic beliefs. Similarly, the initial analysis of the quantitative and qualitative data reflected more attention to epistemic beliefs. However, as is evident in analysis and presentation of data that employ case studies of teachers, other factors impact teachers' pedagogical decisions. This process has demonstrated to me the non-linear nature of research. While at times challenging, it has been interesting and illuminating to follow the ideas that emerge from the data and the influence that such an emergence of ideas has on writing a thesis.

Chapter 2: Literature Review

Outline of the literature review

This literature review is organized into four sections. First, distinction is made between what is meant by Indigenous knowledge and Western science. The contrast that scholars see between the two is discussed. Following this section is an exploration of the factors that affect teachers' classroom actions, focusing on the context, goals, and beliefs (particularly epistemic beliefs) that teachers have around teaching and scientific knowledge. The inter-relatedness of these three factors and how they impact pedagogical practice is examined. Throughout these sections, the science Program of Studies, which is the curricular document and guide for teachers in Alberta, is referenced as this document guides teacher practice and conceptualization of what science is and how they teach science. The final section shifts the literature review to investigate the field of science education and Indigenous perspectives. Current practices around integrating Indigenous perspectives in the science classroom, the importance of integrating these perspectives, and the challenges in doing so are highlighted. This review purposely begins and concludes with Indigenous perspectives, which frame exploration of teacher action in the classroom. This is done to ensure that the focus of Indigenous perspectives and how they are and might be integrated in the science classroom is not interpreted as an afterthought. The literature review concludes with a summary of ideas in relation to the research question.

Indigenous Ways of Knowing and Western Science

Introduction.

This section explores how Indigenous knowledge and Western science are defined and understood in the literature. The direct comparisons that are made by scholars between these two domains of knowledge is discussed. In regard to the distinction between the terms Indigenous and Aboriginal, Kim (2015) states that Aboriginal is used “to refer to people of First Nations, Metis, and Inuit ancestry” (p. 3). “Indigenous” is a term established by the United Nations and Indigenous scholars that broadens the scope of “Aboriginal” to include contexts from around the world (Kim, 2015; Wiseman, 2016). The Ontario curricular documents that Kim (2015) used in her research referred to Indigenous ways of knowing as “Aboriginal,” as do the science curricular documents that are examined in this study. Kim used “Indigenous” and “Aboriginal” interchangeably throughout her study. This will be done in this study as well. Although these terms are used interchangeably, it is important to recognize that there are differences between different Indigenous cultures. The literature builds a blanket understanding for Indigenous ways of knowing in general, but one should be cognizant that differences will and do exist between Aboriginal groups (Wiseman, 2016). For the purpose of this study, Indigenous/Aboriginal perspectives are considered in a broad sense, similar to how they are approached in curricular documents, where no particular Aboriginal group is identified.

Indigenous ways of knowing.

Throughout the literature, distinctions are made between the nature of Indigenous science and Western science. Inherent within an Indigenous epistemology is the interconnectedness of all parts of the universe (Aikenhead & Ogawa, 2007). “All my relations” (Aikenhead & Ogawa, 2007, p. 558) is a phrase commonly used by Indigenous peoples to describe life and connection to everything in time. Indigenous ways of knowing are deeply spiritual, holistic, and embedded within a deep sense of place (Aikenhead, 2001; Aikenhead & Ogawa, 2007; Rich, 2012). There is an emphasis on building practical applications from data collected with observations over a long period of time (Barnhardt & Kawagley, 2005). This knowledge is most commonly passed down through an oral tradition (Barnhardt & Kawagley, 2005).

When describing an Indigenous way of knowing, “Indigenous science” is not a term that is used by all scholars. Many scholars, such as Ochalla and Onyancha (2005), use “Indigenous Knowledge” (IK) and describe it as the “shared knowledge, skills, and attitudes belonging to a community arising from personal and community experiences” (Shizha, 2007, p. 304). Cajete (2000, 2004) uses the term “Native science,” saying that the basic components found in scientific thoughts and applications are represented metaphorically in Indigenous stories, and that Native science has come to similar conclusions about the natural world as Western science through participation in nature. He continues to say that Native science is tied to the spirit, is integrative and ecological, observational, and experiential (Cajete, 2000). Snively and Corsiglia (2001) describe Indigenous science as “Traditional Ecological Knowledge” (TEK) which “represents experience acquired over thousands of years of direct human contact with the environment” (p. 11). TEK exemplifies a much more holistic understanding of things in nature, where observations happen over a lifetime as people make observations in their own communities and place (Snively & Corsiglia, 2001). Aikenhead and Ogawa (2007) consider it more appropriate to identify an Indigenous perspective in Eurocentric science as “ways of living in nature,” rather than using the term “scientific knowledge” (p. 553).

Therefore, there is variation in views of Indigenous perspectives, but the following seem to be the case for most Indigenous ways of knowing: a deep sense of place, history, and relationship between all things, the use of oral tradition to pass on knowledge, and holistic understandings of the physical and metaphysical world.

A position on Western science.

With regard to what is considered Western science, Cobern and Loving (2001) draw on other literature and developed a Standard Account of science to provide an explicit definition of science as a specific domain of knowledge. They use three broad statements to describe science:

(1) "science is a naturalistic, material explanatory system used to account for natural phenomena that ideally must be objectively and empirically testable" (p. 58),

(2) "the Standard Account of science is grounded in metaphysical commitments about the way the world "really is" (p. 60), and

(3) "what ultimately qualifies as science is determined by consensus within the scientific community" (p. 60).

Other scholars limit conclusions in Western science to evidence-based explanations, communicated almost exclusively through a written record (Barnhardt & Kawagley, 2005). Scientific knowledge is considered to be tentative and value and theory-laden (Abd-El-Khalick, 2012; Cobern & Loving, 2001). Classifying this knowledge as "Western" does two things, according to Gaskell (2003). Firstly, describing science as "Western" highlights the Greek and European origins of science (Cobern & Loving, 2001). Secondly, it signifies that there are other types of science other than Western. Gaskell (2003) prefers to use the term "modern" to highlight that there are many non-Western contributions to an understanding of modern science, which is situated in an international community. "Science" in this study, however, is referred to as Western science. This position is consistent with most literature that makes a distinction between different domains of knowledge (e.g. Barnhardt & Kawagley, 2005; Kim, 2015; Shizha, 2007).

In the literature, the Nature of Science (NOS) is often referred to when looking at "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge" (Abd-El-Khalick, Bell, & Lederman, 1998, p. 418). Scholars have described the NOS as being tentative, empirically based on observations made in the natural world, laden with theory or subjective, partly being the production of the creativity and inference of humans, and embedded in a social and cultural context (Abd-El-Khalick, Bell, & Lederman, 1998; Alters, 1997). Hogan (2000) describes two categories of knowledge in NOS: distal knowledge, which is "knowledge about the protocols, practices, and products of the professional science community" (p. 52), and proximal knowledge, which describes "understanding of and perspectives on the nature of their own science knowledge-building practice and the scientific knowledge they form or encounter" (p. 52). Although there are suggestions in the literature regarding the basic tenets of the NOS, there is little consensus between philosophers of science of what ideas around NOS should be included (Alters, 1997; Hipkins, Barker, & Bolstad, 2005). This lack of consensus is important to recognize as it impacts the writing and interpretation of science curriculum in classrooms.

NOS is included alongside the definition of Western science found in the literature as NOS is how a definition of science is presented in Alberta curricular documents (Alberta Education, 2014). In the Program of Studies for science courses in Alberta, one of the foundations of the curricular documents is centered around "understanding the scope and character of science" (Alberta Education, 2014, p. 4). The "scope and character" of science is referred to as the Nature of Science within the document. The Program of Studies describes the NOS, in the following way:

> Science provides an ordered way of learning about the nature of things, based on observation and evidence. Through science, we explore our environment, gather knowledge, and develop ideas that help us interpret and explain what we see. Scientific

> activity provides a conceptual and theoretical base that is used in predicting, interpreting, and explaining natural and technological phenomena. Science is driven by a combination of specific knowledge, theory, and experimentation. Science-based ideas are continually being tested, modified, and improved as new knowledge and explanations supersede existing knowledge and explanations. (Alberta Education, 2014, p. 4)

This explanation of the NOS is at the beginning of every science Program of Studies in Alberta, which aims to inform the teaching practice of teachers in a science classroom. The inclusion of the NOS in the Program of Studies is revisited later in this literature review as part of the context within which teachers practice, as well as within the discussion of epistemic beliefs of teachers.

Comparing Indigenous ways of knowing and Western science.

Efforts are made in the literature to compare and contrast Indigenous ways of knowing and Western science. Shizha (2007) suggested that the differences between Indigenous science and Western science lies in the way of knowing and interpretive framework of the particular knowledge, rather than the content itself. Differences and similarities between what are described as traditional Indigenous knowledge systems and Western science is presented by Barnhardt and Kawagley (2005) through a detailed Venn diagram. Some of the differences identified include Indigenous knowledge being focused on the whole, incorporating both physical and metaphysical aspects of the world with morality, while Western science emphasizes understanding how something works, within the confines of observations made in the physical world (Barnhardt & Kawagley, 2005). Western science develops hypotheses for experimentation and communicates through a written record, whereas Indigenous knowledge utilizes experimentation in a more practical sense, unifying stories and metaphors with observations through an oral record (Barnhardt & Kawagley, 2005). Barnhardt and Kawagley propose several commonalities between the two domains of knowledge, which include categories such as "organizing principles," "habits of mind," "skills and procedures," and "knowledge" (p. 16). Similar organizing principles are the unity of the universe and the stability of the body of knowledge, with room for modifications. Being open-minded, honest, and inquisitive were cited as common habits of mind, and similar skills and procedures included making empirical observations within nature, repeating these observations to verify predictions and inferences, and recognizing patterns. Common knowledge focuses primarily on what can be observed in the natural world (Barnhardt & Kawagley, 2005).

Other scholars have also made distinction between Indigenous perspectives and Western science. Aikenhead (2001) made the distinction between the two perspectives, calling Aboriginal perspectives holistic "with their gentle, accommodating, intuitive, and spiritual wisdom" (p. 32), while describing Western science as reductionist "with its aggressive, manipulative, mechanistic, and analytical explanations" (p. 32). He goes on to say that there are different intellectual and social goals for Indigenous and Western science. Aikenhead says that Indigenous science is focused on the relationship with nature for people's survival, while Western science seeks to explain nature and gain knowledge for the purpose of power. Brayboy and Castagno (2008) described Indigenous knowledge as not "separate[ing] the observer from the observed as is necessary for the presumed objectivity of Western science" (p. 738). Other scholars separate the two perspectives in terms of modes of thought. Bruner (1986), referenced from Bechtel (2016), said that Western science uses a paradigmatic mode of thought, which is centered on explanation, categorization, mathematics, and hypothesis-testing. An Indigenous mode of thought is more narrative, using storytelling and focusing on the value of time and place and experience as context (Bruner, 1986).

Scientific thinking is considered to be different than thinking in an everyday context (Jenkins, 1996). In Ogawa's (1995) article, he looks at science within a multiscience perspective. He defines Western science as "a collective rational perceiving of reality, which is shared and authorized by the scientific community" (p. 589). This is in contrast with Indigenous science, which he defines as "a culture-dependent collective rational perceiving of reality, where collective means held in sufficiently similar form by many persons to allow effective communication" (p. 588).

Summary

Western science and Indigenous ways of knowing are identified as different throughout the literature. This is an important concept when discussing how these two knowledge domains can be integrated together in the classroom, which is mandated by Alberta curricula and the new TQS document. Western science has been defined as an explanatory system for natural phenomena that is based on the consensus of the scientific community. These explanations are based on observations and evidence and are communicated through writing. The NOS is used in the literature when referring to the epistemology of science. Inclusion of the NOS in this discussion is important as this is how the characteristics of science are described in the Alberta Program of Studies for secondary science.

In contrast, Indigenous knowledge has been described as holistic and connected to a deep sense of place and time. Spirituality is tied to an Indigenous way of knowing. Knowledge is passed primarily down through an oral record. Although differences exist between Indigenous groups, these characteristics of Indigenous knowledge seem to be common. The conversation in the literature, as explored above, about the differences between Indigenous knowledge and

Western science, may extend to teachers as well. These perceived and actual differences could impact practice and how/if Indigenous perspectives are integrated in the science classroom.

Factors influencing teacher practice in the classroom

This section explores several factors identified throughout the literature that impact teacher actions in the classroom. It is important to explore the factors that impact teaching because, through their pedagogical actions, teachers give students direction about deciding what counts as knowledge and the ways in which to attain it (Ballone & Czerniak, 2001; Lidar, Lundqvist, & Ostman, 2006). The following section is developed as follows. First, an introduction to the literature surrounding the factors that impact how teachers teach is given to create a foundation. Following this is an examination of the current teaching context in Alberta classrooms with a discussion of the Program of Studies for a science course and how it integrates Indigenous perspectives. From the teaching context, a general definition of beliefs is given, with more in-depth exploration of the literature regarding epistemic beliefs. This leads to a literature review that examines the goals that teachers have and those outlined in Alberta curricular documents. The final section weaves together how goals, epistemic beliefs, and context can interrelate and impact pedagogical action. This is in an attempt to establish a background of teacher practice for the final section of the literature review which examines the current state of science education and Indigenous perspectives.

Introduction.

The literature suggests that teachers' pedagogical choices are impacted by their beliefs, teaching context, and teaching goals (Gess-Newsome, Southerland, Johnston, & Woodbury, 2003; Kang & Wallace, 2004; McRobbie & Tobin, 1995). As a current practicing teacher, I recognize the complex nature that these factors have on my actions in the classroom. The way that I teach is influenced by the curricular documents mandated by the government, the students in my classroom, the time available to me during the day and semester, and by what I perceive as being effective ways to help students learn science. In Alberta, the teaching context has begun to be impacted by the release of the new Teacher Quality Standard (TQS), which highlights the imperative of inclusion of Indigenous perspectives in the classroom. Understanding what influences a teacher's practice around this mandated inclusion in classrooms, however, cannot be distilled to one factor. Rather, beliefs about teaching and learning and subsequent actions are intertwined with other factors that shape teaching in a complex manner (Gregoire, 2003). Because of this complexity, these factors are woven together in this study to examine teacher actions in the classroom.

Research on the interacting factors impacting teacher pedagogical action has not yet included how these elements influence integration of Indigenous perspectives in the classroom. Where possible, the relationship to Indigenous perspectives and literature that have looked at some aspect of integration are included in this review. It is clear from the literature that how learners construct knowledge and beliefs about knowledge is guided by classroom discourse and school practices (Hofer & Pintrich, 2002; Johnston, Woodside-Jiron, & Day, 2001; King & Kitchener, 2004; Maggioni, Riconscente, & Alexander, 2006).

This study looks at a sub-set of beliefs called epistemic beliefs because of the growing recognition in the literature of the impact that epistemic beliefs have on pedagogical actions (Abd-El-Khalick, 2005; Hashweh, 1996; Lyons, 1990; Tsai, 2007) and because these beliefs have rarely, if ever, been explored in relation to teachers' actions regarding Indigenous perspectives. Being explicitly aware of one's personal epistemic beliefs has been suggested as essential to connect those with other beliefs that are necessary for a particular teaching paradigm

(Muis, 2007). The importance of epistemic beliefs also aligns with this study in looking at integration of Indigenous perspectives in the science classroom. It has been recommended that teachers should examine their own epistemology as part of the conversation of Indigenous science and providing a more culturally responsive education (Brayboy & Castagno, 2008).

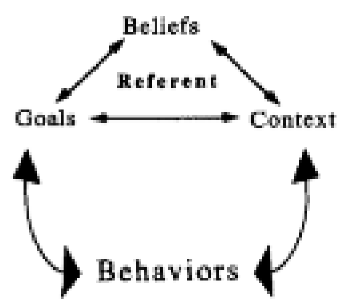
Teaching practice.

There have been various factors identified throughout the literature that affect teacher actions in classrooms. Teachers' personal frameworks or worldviews that have been developed through their own experiences and knowledge have been found to impact how teachers choose to teach (Betchel, 2016; Cobern, 1996; Gess-Newsome & Lederman, 1995; Lantz & Kass, 1987). Lyons (1990) described factors influencing teachers' work as "nested knowing" (p. 162), where a teacher's work is an interaction between knowledge and values, his/her approach to teaching, and assumptions he/she makes about knowing. Lederman and Lederman (2014) found in their review of the literature that there were several variables that impacted how teachers translated the nature of science (NOS), in particular, in their classrooms. These included organizing and managing their classrooms, constraints that they felt from the institution, concerns that they had with the ability and motivations of students, their own teaching experience, the pressure they felt to 'cover the content', and unease with their understanding of the NOS and what they perceived as a lack of resources to adequately assess student understanding of NOS. Similarly, Gess-Newsome and Lederman (1995) suggest that the intention of teachers, their content and pedagogical knowledge, the needs of students, the autonomy of teachers, and time, all have an influence on how teachers envisage the NOS. Scholars consider the "on-the-job social construction of what it means to be a science teacher" (Deneroff, 2016, p. 214) as having a significant influence on teaching practice. Other studies suggest that the epistemic beliefs of teachers influence teaching practices (Brickhouse, 1990; Hashweh, 1996).

These factors that might influence teacher behavior and choice in classrooms can be portioned into three categories: beliefs, goals, and context (McRobbie & Tobin, 1995). McRobbie and Tobin consider an action of a teacher to be holistic in nature. A diagrammatic representation of the factors impacting teacher behavior and action is shown in Figure 1 (McRobbie & Tobin, 1995, p. 381).

Figure 1

Diagrammatic representation of action from McRobbie and Tobin (1995) (p. 381)



McRobbie and Tobin describe an action to be a "set of dialectic interactions involving an individual's goals, the belief that a set of behaviors is viable in a given context, the individual's construction of the context in which the context is embedded, and the behavior of the individual" (p. 381). The "referent" which appears in Figure 1 at the center of the three factors that impact teacher behavior is defined by McRobbie and Tobin as being made up of "a set of goals and a set of beliefs that make the behavior viable in the context of action" (p. 381). One's referential system supports and drives particular behaviors. If a referential system changes, behaviors also have the opportunity to change (McRobbie & Tobin, 1995).

Gess-Newsome et al. (2003) developed a similar framework called the Teachers-Centered-Systemic-Reform (TCSR) model, which "recognizes the influence and interaction of the teaching context (both structural and cultural), teacher personal characteristics, and teaching thinking as a means to understand classroom practices" (p. 735). This model was used in Enderle et al.'s (2014) study as a theoretical lens to examine the changes in teacher practice through professional development. Enderle et al. described the factors that influence teacher behavior as personal factors (demographics, teaching experience, and extent of continued professional learning), general context of reform (teaching thinking and beliefs, and self-efficacy), contextual factors (cultural, school, department, and classroom context), and teachers' practice (Enderle et al., 2014; Gess-Newsome et al., 2003). In Gess-Newsome et al.'s model, "teacher thinking" could be analogous to the "referent" within McRobbie and Tobin's (1995) model for factors impacting teacher action. Teacher-thinking and referent are considered analogous as they are both what the authors consider to be important for any change to teachers' practice (Enderle et al., 2014; Gess-Newsome et al. 2003; McRobbie & Tobin, 1995).

In this study, "action" is understood as "pedagogical action." Pedagogy can be defined as how curriculum manifests, through the teacher and teaching style, classroom management, and strategies for instruction and assessment (Eisner, 1979; Schraw & Olafson, 2002). A teacher's pedagogical approach is related in the literature to craft knowledge, which includes knowledge from previous education and professional development that is influenced by teacher background and teaching environments (van Driel, Verloop & de Vos, 1998). Through their pedagogical actions, teachers give students direction in deciding what counts as knowledge and the ways in which to attain it (Lidar, Lundqvist, & Ostman, 2006). Veal et. al (2016) found three levels of practice in the classroom. These are identified as normative (what "teachers think they should be doing" (p. 1421)), discursive ("what they say they are doing," (p. 1421)), and actual ("what teachers are doing" (p. 1421)). Their study found that discursive claims and normative beliefs were important in determining teacher practice, although they did not always line up. Teachers have unique understandings of what it means to know their subject and as a consequence, will represent that subject differently to their students (Prosser et. al., 2005). The unique nature of the individual teacher and his/her interpretation of curriculum and learning contribute to the complex nature of examining teacher practice and therefore, how they do or might teach Indigenous perspectives.

The current teaching and curricular context in Alberta.

As previously described, the teaching and curricular context in Alberta has changed in recent years. The development of a revised Teacher Quality Standards document that outlines mandates around Indigenous perspectives in education is supported by statements within the Program of Studies documents (Alberta Education, 2014). In addition to the opening sections of the Science 10 Program of Studies (see introduction of this literature review), there is further reference to alternative perspectives in the science classroom in the "Attitudes" category of outcomes. The general outcome "mutual respect," states that "students will be encouraged to appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds" (Alberta Education, 2014, p. 5). Specific examples of how to include Aboriginal perspectives in the classroom are suggestions made throughout the document, such as, "evaluate the traditional Aboriginal method for determining alkaline properties of a substance" (p. 14), and "show awareness of and respect for traditional Aboriginal knowledge about the use of biotic and abiotic materials" (p. 15). Another statement encourages the consideration of "Aboriginal perspectives on taking care of natural resources" (p. 19).

A noticeable aspect of these statements when viewed in the actual document is that they appear in italics, rather than regular print. This distinction becomes important when considering teachers' interpretation of the priority of these statements in the classroom. The Program of Studies document makes a qualification of these italicized statements in the beginning parts of the document. It states that italicized statements "**do not form part of the required curriculum**" (emphasis included) (Alberta Education, 2014, p. 6). These statements are meant to be examples of how the specific knowledge outcome might be approached, rather than as a required part of the teachable outcomes. What are described as teachable outcomes may better be understood as testable outcomes. The required curriculum as described, is part of the assessable curriculum in the form of standardized tests. In Alberta, the diploma exam in 30-level courses (generally written in grade 12), are worth 30% of a student's overall course mark (Alberta Education, 2017). The diploma exam in a science course focuses on the knowledge and skills component of the Program of Studies and assesses students on that in a multiple choice and numerical response format (Alberta Education, 2017). Italicized statements in the curriculum cannot be assessed on a diploma exam. Other studies have shown that teachers did not see Indigenous knowledge as being necessary to teach as they did not appear on standardized assessments administered by the government (Shizha, 2007). Kim (2015) suggests that how Indigenous perspectives are represented in curricula matters as it reflects the value placed on it by policymakers. This in turn impacts how it is taught and presented in classrooms (Kim, 2015). Curricular documents are a product of the writer's reference system and "inevitably include their own interests and assumptions about ways of knowing and how teachers and students are to be understood" (Aoki, 1991, p. 160). Therefore, understanding the curricular context of teaching is important as context influences how beliefs are put into action (Hammer & Elby, 2012; Kang & Wallace, 2004).

Teachers' goals in the science classroom.

Goals in relation to teaching and learning science have been identified in the literature. Teachers have been reported to build an image of what it means to be a science teacher and have allegiance to what they conceive to be Western science (Gaskell, 1992; Kilian-Schrum, 1996). Students are affected by this loyalty and by what they consider to be legitimate knowledge (Gaskell, 1992). For example, Bol and Strage (1996) found that the biology teachers in their study wanted their students to develop an interest and applicable understanding of biology. They were concerned with students building higher order skills to manage their learning and prepare for life in a rapidly changing world (Bol & Strage, 1996). Teachers in another study were found to use various types of science lab activities to achieve their teaching goals (Kang & Wallace, 2004). These goals included developing informed citizens, delivering information, engaging students, and helping them grow an appreciation for science (Kang & Wallace, 2004). Longbottom and Butler (1999) stressed that science education should be built upon several key goals. A goal of science education should be to help students build skills for critical analysis in order to influence society (Longbottom & Butler, 1999). Students should also "develop a scientific view of the world" and "adopt some of the creative and critical attributes of scientists" (p. 473). Science educators should be sure to reflect the constraints of the natural world on the practice and theories of science (Longbottom & Butler, 1999).

Goals for science education are described in the curricular documents that teachers use. In the Science 10 Program of Studies (Alberta Education, 2014), goals for Canadian science education that are addressed by the science program in Alberta include several statements about what science education will give students. Students will be encouraged to “develop a critical sense of wonder and curiosity about scientific and technological endeavors” (p. 1) and use science and technology to solve problems and gain new knowledge to better their lives and those around them. Students will also be prepared to analyze science-related issues in a critical way. A foundational understanding of science is meant to help them in their pursuit of higher-level studies and careers in science. The curriculum is also meant to enable students to develop knowledge of the wide variety of careers available in science.

Roberts (1982, 1988, 1995, 1998) developed seven curricular emphases for science in North America (Chu, 2009). These emphases included: Everyday Coping, Structure of Science, Science, Technology, and Decisions, Scientific Skill Development, Correct Explanation, Self as Explainer, and Solid Foundation (Chu, 2009). A summary of these emphases can be found in Appendix 1. Chu, in her examination of the Physics Program of Studies in Alberta, considered that Roberts’ emphases were related to the four foundations of the program rationale and philosophy in the Alberta science curriculum. These foundations include: (1) Science, Technology, and Society (STS); (2) Knowledge; (3) Skills; and (4) Attitudes (Alberta, 2014). Table 1 shows how Chu related the foundations in the curriculum to Roberts’ curricular emphases.

Table 1

Alberta curricular foundations related to Roberts' science curriculum emphases (Alberta, 2014; Chu, 2009, p. 38)

Foundation in Alberta curriculum	Roberts' curricular emphasis
Science, Technology, and Society	Science, Technology, and Decisions
Knowledge	Correct Explanation Solid Foundation
Skills	Scientific Skill Development Structure of Science
Attitudes	Self as Explainer Everyday Coping

Evident in Roberts' curricular emphases and the relationship to foundations in the Alberta curriculum is a lack of importance placed on other ways of knowing or understanding science (i.e. Indigenous perspectives of science). The foundations identified in Table 1 are as they are listed in the curriculum. While one foundation or emphasis is not meant to supersede another (Chu, 2009), in practical experience as a science teacher, "Attitudes" outcomes are usually not the priority in a science classroom, particularly as they are not something that is easily assessable. This observation has been noted throughout the literature (e.g., Kim, 2015; Shizha, 2007). Knowledge and Skills, along with the Roberts' counterparts, Correct Explanation, Solid Foundation, Scientific Skill Development, and Structure of Science, have more of a presence and emphasis in class and on assessments.

With regard to Indigenous perspectives, Dion (2007) found that teachers were content to be a "perfect stranger." This was because there was a "fear of offending, the fear of introducing controversial subject material, the fear of introducing knowledge that challenges students' understandings of the dominant stories of Canadian history" (Dion, p. 331). The goal of teachers in incorporating alternative perspectives in the classroom has been seen more as a way to level historical and current inequities with students who are marginalized (Ghosh & Abdi, 2013). The tension between goals of the Western science classroom and that of integrating Indigenous perspectives is discussed in later sections within this literature review. For now, this brief section on specific goals for teachers as outlined in Alberta's curricular documents in science classrooms, as well as potential goals for the practice of incorporating Indigenous perspectives is meant to support the upcoming discussion of the interaction between all factors.

Beliefs of teachers.

What is meant by teachers' knowledge and beliefs is explained by Jones and Leagon (2014) with knowledge consisting primarily of a cognitive structure while beliefs are a combination of cognitive and affective factors drawn from personal experiences. Hofer and Pintrich (1997) separate knowledge from beliefs in saying that knowledge is composed of supportable claims. Pratt (1992) separates beliefs in teaching into three groups: epistemic, normative, and procedural. Epistemic beliefs are those beliefs related to knowledge (content of instruction) and learning (how instruction happens) (Pratt, 1992). Beliefs referred to as normative are those related to the relationships, roles, and responsibilities required for teaching (Pratt, 1992). Procedural beliefs focus on the strategies teachers employ in specific teaching actions (Pratt, 1992). Richardson (1996) defines beliefs as "psychologically-held understandings, premises, or propositions about the world that are felt to be true" (p. 3-4).

Classroom instruction and assessment are driven by teachers' underlying personal epistemological outlooks (Fitzgerald & Cunningham, 2012). Personal epistemology and epistemic beliefs have been repeatedly noted throughout the literature as having a significant impact on classroom teaching (see introduction to this section). For this reason, this study shifts from looking at beliefs of teachers about teaching and learning specifically, to look at a sub-set of beliefs: epistemic beliefs. This focus extends the original research of McRobbie and Tobin (1995) to facilitate a connection to Indigenous knowledge systems in the science classroom. The following section defines epistemic beliefs and explores different views from the literature on how epistemic beliefs interact with each other.

Epistemic beliefs.

Epistemology is defined in the literature as the conceptions an individual has of knowledge and knowing (Hofer, 2004; Hofer & Pintrich, 1997; Hofer & Sinatra, 2010). An individual's personal epistemology is divided into two components: the nature of knowledge, and the nature of knowing (Hofer, 2000, 2004; Hofer & Pintrich, 1997). Within these two components, four dimensions are identified by Hofer (2000): Certainty of knowledge, Simplicity of knowledge, Source of knowledge, and Justification of knowledge. These dimensions (defined in Table 2) are the basis for what is understood as epistemic beliefs (Hofer & Pintrich, 1997).

Table 2

Components of epistemology and dimensions of epistemic beliefs, as identified by Hofer (2000)

Components of epistemology	Nature of knowledge		Nature of knowing	
Epistemic belief dimensions	Certainty of knowledge	Simplicity of knowledge	Source of knowledge	Justification of knowledge
	Knowledge is seen as having a fixed or fluid nature.	Progression of knowledge from being a collection of discrete facts to being contextual and relative.	Progression where knowledge is external to the self to recognizing the individual's role as an active constructor of knowledge.	Progression of how one evaluates knowledge claims from being based on personal beliefs to more critical inquiry.

Epistemic beliefs are a sub-set of epistemology and represented in Table 2. These dimensions of epistemic beliefs have been used as the basis of several surveys (e.g., Scientific Epistemic Belief Survey (Tsai et al., 2011)) to measure personal epistemology and further explored in the methodology chapter of this study.

Other scholars have defined epistemic beliefs as applying to the structure, stability, and source of knowledge (Schommer, 1990), as thoughts about the nature of knowledge and knowing (Conley, Pintrich, Vekiri, & Harrison, 2004), and as reflecting the expectations, assumptions, and attitudes affecting the reasoning process (Hofer & Pintrich, 1997). Throughout the literature, the terms "epistemological beliefs" and "epistemic beliefs" are used interchangeably. Buehl and Alexander's (2001) review of the literature suggests that epistemic beliefs are multidimensional and multilayered and that a person's beliefs in one domain may be able to predict their beliefs in another. While there has been some debate about the nature of these beliefs, scholars have come to see epistemic beliefs as both domain-general and domain-specific (Buehl & Alexander, 2001; DeBacker, Crowson, Beesley, Thoma, & Hestevold, 2008; Hofer & Sinatra, 2010; Muis, Bendixen, & Haerle, 2006).

Epistemological frameworks (Jones & Leagon, 2014) or epistemological worldviews (Schraw & Olafson, 2002) come about when one considers the interaction between different, single epistemic beliefs. Epistemological worldviews are defined as a "set of beliefs about knowledge and knowledge acquisition that influence the way that teachers think and make important instructional decisions" (Schraw & Olafson, 2002, p. 99). Schraw and Olafson prefer this term because it describes a particular lens through which to view the world that is beyond single epistemic beliefs. The notion of epistemological worldviews is discussed in the next section which explores the epistemic beliefs of teachers and how they can affect their pedagogical actions.

The impact of epistemic beliefs, context, and goals on pedagogical actions

This section uses the foundation set by the previous exploration of the curricular context of teaching in Alberta, the goals of teachers in a science classroom, and my understanding of epistemic beliefs, to shift focus to the complex interaction of these three factors on pedagogical actions. This exploration begins by establishing a foundation of how teachers understand and interpret knowledge, and the influence this has on their interpretation of curriculum. Three worldviews of how knowledge is understood and the relationship to teaching are presented. Teacher epistemic beliefs of science and their impact on pedagogical practice in the science classroom follows. This section is developed through three parts: (a) teacher epistemic beliefs of science, (b) the development of teacher epistemic beliefs, and (c) the relationship of teachers' epistemic beliefs of science and their pedagogical practices. The restraints that teachers perceive to limit their teaching practice is a common theme throughout the literature. Therefore, how teaching context, goals, and beliefs are perceived as restraints to teacher practice is explored through the myths of teaching, as described by Tobin and McRobbie (1996). These myths are explored in detail as they are pervasive throughout the literature around teacher knowledge, interpretation of curriculum, nature of science and pedagogical actions, and development of epistemic beliefs. Concluding the section is a personal narrative to illustrate the interaction between beliefs, goals, and context in my teaching practice and how they have shifted over time.

How teachers understand and interpret knowledge and curriculum.

One way in which context, goals, and epistemic beliefs impact teacher action is in how teachers understand and interpret knowledge and curriculum. How teachers interpret curriculum and present curricular information is impacted by their personal knowledge, comfort with that knowledge, and their interpretation of their classroom situations (Barnett & Hodson, 2001; Benson, 1989; Jones & Leagon, 2014). van Driel, Verloop and de Vos (1998) term this interpretation as pedagogical content knowledge, which is described as a teacher's "interpretations and transformations of subject-matter knowledge in the contest of facilitating student learning" (p. 673). Teacher practical knowledge or TPK is used by Duffee and Aikenhead (1992) to describe the complexity of the classroom and teacher behavior. They consider a teacher's interpretations of a teaching context to be a series of conscious and unconscious decisions based on past experience and on the teacher's worldview.

Tirri, Husu, and Kansanen (1999) suggest that standards for assessing knowledge claims are created with respect to a teacher's particular understandings and values. In turn, these standards impact pedagogical decisions. This position is supported by Schraw and Olafson (2002), who identified three teacher worldviews: realist, contextualist, and relativist. A realist considers knowledge to originate from a central authority, developed by experts, where students are seen as passive recipients of knowledge from the teacher. A contextualist worldview focuses on the construction of knowledge in a group setting. Teachers reflecting this perspective are facilitators and provide authentic learning experiences where contexts support real-life application (Rule, 2006) in which knowledge is constructed. Finally, the relativist worldview considers each person's knowledge base to be unique, so the teacher's role is to establish an environment that encourages students to think independently. Betchel (2016) suggests that most individuals are unaware of the extent that one's worldview affects what is seen as valid knowledge, and so would be unaware of how this impacts their behavior.

Teachers' interpretation of knowledge has also been found to be impacted by teaching resources. For example, according to Gallagher (1991), there are issues with textbook resources with regard to the nature of science. These resources did not dedicate much space to discuss the nature of science or to formulate or validate knowledge (Gallagher, 1991). For the development of an understanding of Indigenous knowledge, Kim (2015) discovered that students in Ontario did not see Indigenous knowledge as valid knowledge partially because of the way it was presented in textbooks. Resources used in the classroom may signal to teachers how to interpret knowledge, particularly if these have been selected for use by a school or school district.

Pedagogical practice in the science classroom.

This section examines teachers' pedagogical practice in the science classroom in relation to epistemic beliefs of science. Scholars have recognized the worth of research investigating how such beliefs affect pedagogical actions (Abd-El-Khalick, 2005; Tsai, 2007). Epistemic beliefs of science are explored first in this section to establish a framework to review teacher epistemic beliefs and their relationship to teaching practice. This is followed by an overview of how teachers develop epistemic beliefs of teaching. How specific epistemic beliefs of science influence teaching practice in the science classroom concludes this section.

Epistemic beliefs of science.

As previously alluded to, the epistemology of science has been equated to the "nature of science" (NOS) and is said to address "the issues regarding the philosophical assumptions, values, developments, and conceptual inventions in science, consensus making in scientific communities and features of scientific knowledge" (Tsai, 2007, p. 223). Because NOS can be equated to the epistemology of science, it stands to reason that tenets of the NOS could be connected to the dimensions of epistemic beliefs described by Hofer (2000). The study of epistemology and epistemic beliefs is a complex area of endeavor. How I organized these complex ideas to aid understanding is partially displayed in Table 3. Table 3 relates the dimensions of epistemic beliefs (Certainty of knowledge, Simplicity of knowledge, Source of knowledge, and Justification of knowledge as shown previously in Table 2) to features of the NOS as described in the aforementioned literature. This is done in an attempt to demonstrate my thought process in developing an understanding of how NOS, as the epistemology of science, can relate to what teachers might believe about what science is. Each dimension of epistemic beliefs is defined again under each dimension heading. The particular features that were chosen to represent the NOS (bolded in Table 3 for emphasis) in relation to the four different dimensions also represents my understanding of the NOS. Each dimension of epistemic belief is matched with a feature of the NOS. As there is no consensus among scholars about what should be included in the NOS (Alters, 1997; Hipkins, Barker, & Bolstad, 2005), this was considered by me to be appropriate for the purpose of this study.

Table 3

Dimensions of epistemology as developed by Hofer (2000) in relation to NOS in literature

	Epistemic beliefs			
	Certainty of knowledge	Simplicity of knowledge	Source of knowledge	Justification of knowledge
	Knowledge is seen as having a fixed or fluid nature.	Progression of knowledge from being a collection of discrete facts to being contextual and relative.	Progression where knowledge is external to the self to recognizing the individual's role as an active constructor of knowledge.	Progression of how one evaluates knowledge claims.
Nature of Science	**Science knowledge is tentative**	**Science knowledge is based on theory; can be subjective and based within a social and cultural context**	**Science knowledge is a product of the work and creativity of individuals**	**Science knowledge is empirically-based on observations of the natural world**

Table 3 is meant to represent how tenets of the NOS are related to the theory of epistemic beliefs as developed by Hofer (2000). This information also provides support for my understanding of the survey dimensions in the Scientific Epistemic Belief survey (Tsai, et.al, 2011) used in this study and subsequent analysis of the survey results in the data analysis chapter.

Teachers beliefs about the NOS, or particular components of the NOS, have been widely studied. Abd-El-Khalick, Bell, and Lederman (1998) explain that while teachers had an understanding of science being empirical and tentative, of the impact of creativity and subjectivity, and of the difference between an inference and an observation, they did not recognize the role of culture and society on the development of scientific knowledge. Furthermore, teachers often conflated the NOS with a process of science (Abd-El-Khalick, Bell,

& Lederman, 1998). In another study (Gallagher, 1991), teachers stressed the importance of objectivity in science and used that as a benchmark for what makes science superior to other subjects that do not have an experimental way to test their knowledge claims. The presentation of the scientific method in this way stereotypes and mythologizes the production of science (Gough, 1998). How teachers form beliefs about the nature of scientific knowledge is different between the disciplines in science. For example, differences were observed in beliefs of preservice physics and chemistry teachers than that of biology teachers (Loving, 1997; Markis & Eilks, 2012; Rizk, Jaber, Halwany, & BouJaoude, 2012; Schwartz & Lederman, 2008). Munby and Roberts (1998) thought that students' views of the NOS develop coincidentally in a science classroom, more the result of what teachers leave out than what they deliberately include. This suggests that what teachers believe about the NOS and the science classroom may be more implicitly taught than made explicit to students.

Development of epistemic beliefs

It is generally agreed on in the literature that the development of teachers' epistemic beliefs is impacted by several factors. Some factors that have an impact include previous experiences, prior knowledge and study, teachers' personal interests, and teaching peer groups (Benson, 1989; Jones & Leagon, 2014; Sund, 2016). The experience of teaching in a classroom influences the beliefs that teachers have about teaching and about students, but not beliefs about the NOS (Lederman, 1999). This view contrasts with a previous finding by Pomeroy (1993): what teachers think about the NOS may be partially constructed from their teaching experiences and observations, rather than any formal science training. Schraw and Olafson (2002) looked at epistemological worldview, rather than epistemic beliefs, but noted similar influences. They suggest that teacher preparation programs that implicitly endorse a particular worldview impact teachers' epistemological worldviews. Similarly, a school district can be influential when it places emphasis on one view over another with its approach to curriculum and assessment (Schraw & Olfason, 2002). The culture created in teaching with issues such as teacher status and autonomy as well as isolation in the profession was also reported to impact how a teachers' epistemological worldview develops (Schraw & Olafson, 2002).

The development of teachers' epistemic beliefs demonstrates a relationship between epistemic beliefs, teaching and learning contexts, and goals of teachers, school divisions, and post-secondary institutions. The factors described above that impact the development of epistemic beliefs are similar to those that impact pedagogical practice, as explored below.

Epistemic beliefs of NOS and pedagogical practice

Classroom lessons about the explicit epistemology or nature of science have been shown to differ due to varying views of scientific knowledge (Brickhouse, 1990; Gallagher, 1991). Teachers' views of their epistemic beliefs about scientific knowledge have been studied in some detail. These studies have focused primarily on teachers being aligned with either a constructivist or empiricist paradigm (Blanco & Niaz, 1997; Gallagher, 1991; Hashweh, 1996; Tsai, 2007). Teachers with more empiricist epistemic beliefs of science, where science as a discipline is detached, objective, and value-free (Osborne, 2007), focused on instruction in a lecture format, practicing assigned problems, and examinations (Tsai, 2007). Conversely, teachers with more constructivist epistemic beliefs of scientific knowledge (where science is socially situated, and knowledge is constructed within a community of scientists and mediated by language (Osborne, 2007)) have devoted more of their instruction to enhancing student understanding and applying scientific concepts through the use of inquiry activities and interactive discussion (Tsai, 2007). What teachers in these studies believed about the nature of scientific theory, scientific process, and progress influenced their teaching approach (Brickhouse, 1990). Lederman (1992), however, found it difficult to determine the influence that a teacher's concept of the NOS had on his/her teaching practice because of what he/she termed as "the strong influence of curriculum constraints, administrative policies, and teaching context on the translation of teachers' conceptions into classroom practice" (p. 348).

Understanding teachers' epistemic beliefs of the NOS and subsequent practice becomes important when attempting to incorporate different ideas or ways of knowing into the science classroom (Aikenhead, 1987; Tsai, 2002). Scholars have distinguished these approaches as either universalist or multiculturalist in nature (Kim, 2015; Snively & Corsiglia, 2001). From a universalist standpoint, science knowledge is universal and knowledge construction is not based on culture, gender, or race (Cobern & Loving, 2001; Kim, 2015). Teachers who subscribe to a more multiculturalist approach consider science to exist in many different forms as it is socially constructed within particular cultures (Kim, 2015; Ogawa, 1995; Snively & Corsiglia, 2001). Some scholars consider science to be a cultural construct, where science develops from various worldviews and cultures of different groups of people, Western science being but one (Aikenhead, 1996; Ogawa, 1995, Shizha, 2007). Kim's (2015) definition of science as "the methods that construct reality and that also consist of different sets of prior knowledge about the natural world and practices" (p. 3) reinforces the "social construct notion" of science in establishing it as a way in which to view reality. Aikenhead (2001) wrote that "science can be thought of as a culture with its own language and conventional ways of communicating for the purpose of social interaction within the community of scientists" (p. 24). In this way, the science taught in schools is a "sub-culture" of the scientific domain (Aikenhead, 2006). Teachers become "pedagogical cultural workers" whose roles are to "make the culture of science accessible to all their students" (Aikenhead & Jegede, 1999, p. 271; Pomeroy, 1997). Beliefs of teachers about knowledge domains other than Western science are interrelated with their goals of what integration might look like. This notion is explored further in the final section of this literature review. It is briefly mentioned here as it relates to NOS and pedagogical practice.

Perceived restraints to pedagogical practice.

Teachers' perceptions of context, goals, and beliefs have been shown to create restraints on teachers' practice. Through their own research and review of the literature, Tobin and McRobbie (1996) identified four cultural myths of teaching that teachers saw as restraints to their practice. These myths are a result of a teacher's beliefs and goals, as well as his/her teaching contexts. The myths are identified in McRobbie and Tobin (1995) as an example of a referential system (see Figure 1) which supports teachers in maintaining traditional teaching practices. It is important to discuss the myths of teaching, as described by Tobin and McRobbie (1996), as these impact teaching beliefs, pedagogical action, and curriculum interpretation. This section is necessary to contextualize the previous discussion about understanding knowledge, interpreting curriculum, and NOS in the science classroom.

A myth is defined by Tobin and McRobbie (1996) through Barthes (1985) definition as something that "points out and notifies, it makes us understand something important and it imposes it on us" (Barthes, 1985, p. 117). Tobin and McRobbie saw these myths as disempowering teachers in their practice. Myths can become pervasive in teacher thinking. This is because these myths have support from administration, teachers, and parents (Tobin & Imwold, 1993). Throughout this section, a relationship is made to the factors affecting teacher action that were described by McRobbie and Tobin (1995) (i.e. context, goals, and beliefs). Examples of these factors are identified within each myth and emphasized in italics.

The first myth identified is the myth of transmission of knowledge. According to this myth, teachers are viewed as the source of knowledge who pass on that knowledge to students. Knowledge being seen as an entity is a *belief* of teachers, where the *goal* is to transmit it to students. The second myth is that of efficiency. In this myth, teachers are in control of students (*belief*). Time is considered a limited commodity (*belief and context*), which dictates the teaching of knowledge for coverage of curriculum (*goal*) rather than for understanding (Tobin & McRobbie, 1996). Kazempour and Amirshokoohi (2014) described these as "perceived or actual obstacles" (p. 287), which, in their study, included lack of time and resources, and support from administration. The third myth, rigor, means teachers feel the responsibility to ensure that students learn at levels consistent with past students in the same course (*belief and goal*) (Tobin & McRobbie, 1996).

The fourth myth of exam preparation puts emphasis on student success on examinations and the need to prepare them for these assessments (Tobin & McRobbie, 1996). The exams themselves help create a *context* in which teachers work, while success on examinations is a *goal* of teachers. Teachers have reported that with the pressure they feel to cover material and for student success on standardized assessments as limiting the actualization of some of their ideas for teaching (Kazempour & Amirshokoohi, 2014). The influence of examinations influences how Indigenous perspectives are incorporated in the science classroom. As previously mentioned, Shizha (2007) believes that teachers did not see value in including Indigenous perspectives in their classrooms as they did not appear on standardized assessments.

A personal example of the interaction between beliefs, goals, and context.

Couteret, King, and Thomas (2018) explored bridging the gap that exists for pre-service and practicing science teachers between theory and practice. They assert that how this gap is bridged is an ongoing process that is “embedded and contextualized in relation to individuals’ referents” (p. 35) within the framework of McRobbie and Tobin’s (1995) theoretical model (see Figure 1). The ongoing process of “gap bridging” requires personal referents to change, which includes a change in one’s beliefs, goals, and context. As a co-author of Couteret, King, and Thomas, I will provide my personal referential change from the beginning of my teaching career to entering graduate school. This experience is described in a narrative within Couteret, King, and Thomas and is used here as a representation of the interactions between beliefs, goals, and context in my own teaching practice.

As described in Couteret, King, and Thomas (2018), my first year of teaching was challenging in that I did not feel that my teacher education program prepared me for the day-to-day realities of teaching. At this point, my *goal* was to learn how to do tasks such as setting up a gradebook, navigating various online applications that the school used, and how to build a semester plan for the courses I was teaching. Because I was new to the profession with experience that was limited to my two teaching practicums, my teaching *beliefs* were focused on teaching students what the textbook said about science and using that as my primary resource in the classroom. My teaching *context* was a large high school with a large science department with colleagues who were willing to share their experience in teaching to help me through the first year. This created a referential system that was centered around the “how to” of teaching and survival, rather than exploring various education theories that I had learned in my final teaching practicum.

Following five years of teaching, I made the decision to return to graduate school. My professional referential system had changed. My *goal* in the classroom had changed from simply learning how to do administrative tasks to wanting to learn more about how students learn, particularly using metacognition in the classroom. I wanted to improve my teaching now that I felt more comfortable with the day-to-day tasks. I *believed* at this point that I had the teaching experience necessary to make learning more about education theories valuable and impactful on my practice. It was also my belief that metacognition was important for student learning and had begun to integrate one metacognitive tool that I learned in my teaching practicum within my planning and teaching of particular concepts. The *context* of my school environment was an impetus to apply for graduate studies. It had changed from when I first started teaching and I often felt at that point that it was at odds with my goals and beliefs as a teacher.

This narrative demonstrates the interaction between beliefs, goals, and context on the referential system that influenced my teaching practice. In order for my view of teaching and learning to change over the first five years of my career, these three factors had to shift. The decision to enter graduate school could not have been made with the referential system that was built on the context, beliefs, and goals of my first year of teaching. This narrative is included in this section of the literature review to provide a concrete example of how these factors can interact to create a perception of teaching practice, as well as how that can shift over time as beliefs, goals, and context change with experience.

Summary.

This section of the literature review examined the factors that impact teachers' pedagogical choices in the classroom. This, along with previous discussion on what is understood as Western science and Indigenous perspectives, provides the foundation for the final section of the literature review which explores the academic conversation around science and Indigenous perspectives.

Incorporation of Indigenous Perspectives in the Science Classroom

Incorporation of Indigenous perspectives in the science classroom can be seen throughout the literature in three primary areas: the importance of incorporation, how Indigenous perspectives can be incorporated in the classroom, and the challenges to incorporation.

The importance of incorporation.

In addition to the aforementioned TRC and TQS documents, when examining the value of incorporation of Indigenous perspectives in the science classroom, the literature tends to point to the underlying tensions that exist between Western science and Indigenous ways of knowing. It has been suggested that the way science is approached in many classrooms makes schooling a site and tool of colonization when Western ideals and epistemologies are promoted and privileged over others (Aikenhead, 2001; Cobern & Loving, 2001; Siegal, 2002; Southerland, 2000). In this way, schools become another instrument of power, which perpetuates racial and social inequities inherent in society (O'Loughlin, 1992). Brayboy and Castagno (2008) take issue with science curriculum being built only from a Eurocentric tradition as it "fails to consider the sociocultural environments in which students and communities live; it presents scientific knowledge as objective and universal, and thus fails to recognize that scientific knowledge itself is social constructed" (p. 739).

Power is conferred to Western science when teachers have epistemic beliefs based on "scientism" that perceives science as the only valid knowledge domain (Aikenhead, 2001; Cobern & Loving, 2001; Gallagher, 1991; Southerland, 2000). "Scientism," first coined by Habermas in 1974 (Shizha, 2007), views science as objective, completely rational and empirical, impersonal, universal, and detached from human bias (Aikenhead, 2001). This viewpoint gives Western science inappropriate privilege and power within the public sphere and has been described as a sort of “epistemological hegemony and cultural imperialism” (Cobern & Loving, 2001, p. 52). “Hegemony” is defined as the establishment of authority of particular ideas by a dominant professional or educational group, that has popular support and acceptance (Leach, Neutze, & Zepke, 2001; Shizha, 2007). As result of this inappropriate privilege and power, some students feel a sense of alienation within a science classroom when their worldview does not parallel a Western scientific one (Aikenhead, 2001). In this way, these lessons might often lack value for students as they see the way science is taught as a form of cultural assimilation and they disengage (Aikenhead, 2006).

Aikenhead and Jegede (1999) regard teachers as “pedagogical cultural workers,” who help students make cultural border crossings between their cultural knowledge and that of Western science. They felt that student success in science courses depended on how different students found their personal culture and that of the science classroom, how effectively they were able to navigate between the two, and what assistance they received to do so (Aikenhead & Jegede, 1999). Integration of Indigenous perspectives is thought to help students become more critical of the limitations and fallibility of knowledge systems (Brayboy & Castagno, 2008). Brayboy and Castagno also observe that creating a curriculum that is connected and relevant to Aboriginal communities would have a positive influence on Aboriginal students with graduation and future endeavors.

How might we incorporate Indigenous perspectives in the science classroom.

Throughout the literature there are several suggestions regarding how Indigenous perspectives might be incorporated into the science classroom. Shizha (2007) thought that Western science and Indigenous knowledge should be brought together so that Indigenous knowledge could be recognized as an “epistemology of science” (p. 316). Other scholars go further to say that Indigenous knowledge should be re-labelled as Indigenous science in order for this knowledge to have the same privilege as Western science (Aikenhead & Michell, 2011), with the recognition that the label of science acts as a "gate-keeper" for access to school curriculum (Cobern & Loving, 2001; Snively & Corsiglia, 2001). To incorporate Indigenous perspectives in a respectful manner, Aikenhead (2006) suggested that classroom materials and teaching practice follow particular guidelines. He considered it important to avoid stereotyping students by being sensitive to how categories are created and to be cautious when translating between Western science and Indigenous languages as they each have a unique epistemology, ontology, and axiology, and misinterpreting can lead to misunderstanding. As well, he suggested that appropriate authorities should decide what is authentic for that domain of knowledge and both science and Indigenous knowledge should be referred to in the present tense. Teachers should be introduced to members of the Aboriginal community in order to contextualize and build place-based knowledge (Aikenhead & Michell, 2011). When incorporating Indigenous perspectives into the classroom, they should not be an add-on, but rather provide a framework for teaching (Aikenhead, 2006). Aikenhead (2006) also cautions against separating Indigenous knowledge from place and context or from value and spirituality.

Several suggestions have been made in the literature regarding Aikenhead's (2006) concerns. Some scholars have supported a pluralist approach to integrating Indigenous perspectives. There are two distinctions within the literature: plural science and epistemological pluralism. Ogawa (1995) defines science as a "rational perceiving of reality" (p. 588), and is considered by Aikenhead and Ogawa (2007) to be a "pluralist," which is synonymous for these scholars as having a multi-science perspective. Pluralism is used elsewhere in the literature in reference to epistemological pluralism, as defined by Cobern and Loving (2001). These authors suggest that educators need to develop a sense of epistemological pluralism where domains of knowledge are explored and valued for their own merit and insight they can offer (Cobern & Loving, 2001). This approach values both ways of knowing and focuses on students understanding the insights that each knowledge system has to offer without necessarily having to incorporate it into their personal belief system (Aikenhead, 2001; Aikenhead & Michell, 2011; Cobern & Loving, 2001). For the purposes of this study, "pluralism" will refer to epistemological pluralism and Aikenhead and Ogawa's (2007) understanding will be distinguished as a multi-science approach to integration.

A "multi-science" perspective considers some knowledge of a specific culture as being their particular science (Aikenhead & Michell, 2011; Ogawa, 1995; Snively & Corsiglia, 2001). This is done with the recognition that labeling something as "science" gives that knowledge equal status with Western science and access to the classroom (Aikenhead & Michell, 2011; Cobern & Loving, 2001). Snively and Corsiglia (2001) wrote that Indigenous science "interprets how the local world works through a particular cultural perspective" (p. 10). Proponents of multicultural science say that objects and events do happen in consistent patterns, but the way that we interpret them is based on our culture, language, place, and context (Snively & Corsiglia, 2001). Hatcher, Barlett, Marshall and Marshall (2009) suggest that one must have two-eyed seeing, which is "to see from one eye with the strengths of Indigenous ways of knowing, and from the other eye with strengths of Western ways of knowing, and to use both of these eyes together" (p. 3). They separate Western science as seeing nature as something which is knowable, while Indigenous science wants to know what it is, not how it works (Hatcher, et. al, 2009). Brayboy and Castago (2008) support a "both/and" rather than an "either/or" approach, saying that it is the responsibility of the schools to help Indigenous students become comfortable with multiple ways of knowing. This can also be described as Indigenous and Western perspectives "circulating together in teaching and learning" (Wiseman, 2016, p. 110) in the science classroom.

Scholars caution against disconnecting the knowledge from the people it comes from (Nadasdy, 1999; Simpson, 2004), and from separating the language from the knowledge, as there is the risk of making the knowledge symbolic, an object, or an artefact (McKinley, 2005; Shizha, 2007). Although it can be common practice, teachers are warned against including Indigenous perspectives as an add-on to the curriculum as this risks "tokenizing" Indigenous knowledge, removing it from its context, and devaluing the insight it has to offer (Aikenhead, 2006; Cobern & Loving, 2001). This can reinforce a perception that Western science is superior to that of another way of knowing (Cobern & Loving, 2001). Nadasdy (1999) wrote that "integration" implies that traditional knowledge derived from cultural beliefs and practices are able to fit with a Western view of knowledge. He cautions against using the term "traditional" when describing Indigenous knowledge as it implies that Indigenous culture is static and therefore cannot grow and adapt with changing technology and society. These considerations are incorporated and explained when considering this study's methodology.

Challenges to incorporating Indigenous perspectives in the classroom.

Although scholars have suggested ways in which Indigenous perspectives might be incorporated, there has been considerable discussion around the challenges to such an action. A question posed by some scholars is whether it is possible to actually integrate or blend Indigenous knowledge with that of Western science without misappropriating Indigenous knowledge (Hermes, 2000; Lowan-Trudeau, 2014; Simpson, 2004). Similarly, there is the danger of using a single Indigenous worldview as representation of all Aboriginal philosophies, resulting in a “cultural misappropriation” (Lowan-Trudeau, 2014, p. 353; Hermes, 2000; Simpson, 2004). Snively and Corsiglia (2001) suggest that scientists may be reluctant to include Indigenous knowledge within a Western science definition as the knowledge is passed down through an oral tradition and has spiritual, fictional, and mythological elements.

Efforts have been made to incorporate Indigenous perspectives into the science curriculum. However, when looking at the inclusion of Aboriginal science in Canadian textbooks, Aikenhead (2006) found several issues. The authors of these texts decided what was authentically traditional “Aboriginal” and often stereotyped Aboriginal people (Aikenhead, 2006). Only a past tense verb was used to describe Aboriginal technologies, experiences, and knowledge, and a Western scientific epistemology was put over that of an Aboriginal epistemology (Aikenhead, 2006). Another researcher found that students did not see Indigenous knowledge as valid science and the textbooks used in the classroom focused more on the traditional and historical aspects of Indigenous knowledge, rather than any contemporary contributions (Kim, 2015). Inclusion of Aboriginal technologies was done as a way to compare and assess them based on Western science standards (Kim, 2015). Beyond simply classroom resources, Kim suggests that how Indigenous perspectives are represented in curricula matters as it reflects the value placed on it by policymakers, affecting how it is taught and presented in schools. Kim found that Indigenous perspectives were more likely to be found in the life sciences, rather than the physical sciences. Other Canadian curricula (i.e., Aikenhead, 2000, 2001) incorporate Indigenous perspectives more seamlessly and see Indigenous knowledge as a legitimate way of knowing, especially when developed with the expertise of Elders and community members (Aikenhead 2000, 2001; Kim, 2015).

Teachers have been reported to have an impact on the inclusion of Indigenous perspectives in the classroom. Shizha (2007) looked at teachers' attitudes towards Indigenous science in Zimbabwe and found that they dismissed and did not incorporate Indigenous knowledge in the classroom because they saw a dichotomy between the two. Teachers who were interviewed thought that there was no place for cultural knowledge in the science classroom and did not consider Indigenous science and the science they were teaching to be the same. Teachers in Shizha's (2007) study declared that Indigenous perspectives did not appear on standardized tests, so they did not feel the need to teach it. In British Columbia, Canada, a program implemented to challenge how knowledge is traditionally valued raised several concerns (Gaskell, 2003). These included concerns from universities in the shift in definition of science, issues of funding, the lack of standardized assessment for forms of practical knowledge, and parental concerns about student success in university (Gaskell, 2003).

Shizha (2007) contended that for teachers to successfully bring in a multicultural science program, they must first be aware of their preconceptions and biases regarding Indigenous science. This is echoed by Brayboy and Castagno (2008) who said that teachers need to have a particular set of attitudes, dispositions, knowledge, and values to successfully teach Indigenous students. Teachers need to have "an awareness and understanding of Indigenous cultures, histories, and political issues" (Brayboy & Castagno, 2008, p. 734). Most teachers have the perspective of what Dion (2007) termed as the "perfect stranger" when it comes to Aboriginal people and Aboriginal knowledge. This perspective is informed by "what teachers know, what they do not know, and what they refuse to know" (p. 331). Kilian-Schrum (1996) discovered that a teachers' self-image as a science teacher and loyalty to science as a discipline had to change before they were able to implement the more humanistic curriculum they used in their study.

Teachers may struggle with making connections to Indigenous perspectives in the science curriculum and may not understand what the cultural differences between an Indigenous and Western science view are (Bechtel, 2016). Aikenhead (2001) said that science teachers tend to have an allegiance to the values of scientism, seeing science as "non-humanistic, objective, purely rational and empirical, universal, impersonal, socially sterile, and unencumbered by the vulgarity of human bias, dogma, judgments, or cultural values" (p. 337). Teachers who view science in this way would find it difficult to understand and assume different positions on knowing (Gaskell, 2003). Beyond teachers' perception of themselves as a science teacher, Aikenhead (2006) suggested that teachers need to understand their own culture before engaging emotionally, cognitively, and metacognitively with their students' cultures to create a unique one within their classroom. Being an expert on Indigenous knowledge was not seen as a necessary requisite to teach Indigenous knowledge by Kim (2015). She considered herself to be an ally for Indigenous knowledge in the science classroom, having defined an expert as a "knowledge holder and a community member who has received teaching directly from Elders and is recognized by Aboriginal communities" (Kim, 2015, p. 3). She felt that the position of ally, rather than expert, could be applied to all non-Indigenous teachers.

Summary.

The importance of incorporating Indigenous perspectives in the science classroom, different teaching practices for integration, and the challenges of doing so are impacted by the beliefs, context, and goals that teachers have or experience in their classrooms. The research question for this study extends previous research on teacher pedagogical actions by exploring pedagogical actions around integrating Indigenous perspectives in the science classroom.

Chapter Summary

This research study was precipitated because of my personal inquiry into the practice of integrating Indigenous perspectives in the science classroom in Alberta. As a current, practicing, science teacher, this is particularly relevant to my own practice in how best to address the specific outcomes in curricular documents. With the introduction of the new TQS document in Alberta, this research is timely. The conversation of incorporation of Indigenous perspectives in classrooms is one that I have personally seen dominate professional development and professional conversations over the last two years. These informal conversations have generally been centered on what this might be or how it would look in classrooms across the province.

There has been significant study into the importance of incorporating Indigenous perspectives in the science classroom. These studies reveal that schools and the teaching of Western science as the most valid knowledge domain can contribute to the privileging of Western epistemologies over others (Aikenhead, 2001; Cobern & Loving, 2001; Gallagher, 1991; Siegal, 2002; Southerland, 2000). Scholars have suggested that Indigenous perspectives could be included in the classroom as Indigenous science (Aikenhead & Michell, 2011), through a multi-science perspective (Aikenhead & Michell, 2011; Ogawa, 1995; Snively & Corsiglia, 2001), or through an epistemological pluralist perspective (Cobern & Loving, 2001). Several challenges have been identified in incorporating Indigenous perspectives. There is the danger of misappropriating Indigenous knowledge and using one Indigenous worldview to represent many (Hermes, 2000, Lowan-Trudeau, 2014; Simpson, 2004). There are reported concerns with textbook resources (Aikenhead, 2006; Kim 2015), the lack of Indigenous perspectives on standardized assessments (Shizha, 2007), and teacher attitudes towards Indigenous perspectives in the science classroom (Brayboy & Castagno, 2008; Kiliam-Schum, 1996). A more detailed analysis of this is discussed previously in the literature review.

There is significant literature around the factors that impact teachers' pedagogical practices. Studies have examined individual factors impacting teachers such as beliefs that teachers have of teaching and learning (see Schraw & Olafsen, 2002), epistemic beliefs teachers have about science knowledge (see Brickhouse, 1990; Gallagher, 1991; Osbourne, 2007; Tsai, 2007), goals of teachers in the science classroom (see Bol & Strage, 1996; Kang & Wallace, 2004; Longbottom & Butler, 1999), and the context in which teachers teach in (see Kazempour & Amirshokoohi, 2014; Kim, 2015; Shizha, 2007; Tobin & McRobbie, 1996). As well, some scholars have looked at the interacting nature of beliefs, goals, and context on teacher behavior and action in the classroom (see Gess-Newsome et al., 2003; McRobbie & Tobin, 1995).

There is a lack of research, however, that *explores the factors that impact how teachers integrate Indigenous perspectives in the science classroom*. This is specifically seen in Alberta. In order for the mandates of curriculum and TQS to be actualized in the classroom, it is imperative that the factors that facilitate or hinder integrating Indigenous perspectives in the science classroom be explored. The research question for this study is: "What factors impact teachers' actual and preferred practice around incorporating Indigenous perspectives in their science classroom?" While there is research into how teachers might incorporate Indigenous perspectives and the concerns around current practices, there is a lack of studies which explore actual teacher practice around incorporating Indigenous perspectives. This is especially relevant and important for Alberta as integrating Indigenous perspectives is part of the mandated curriculum. As previously mentioned, I have personally experienced a shift in professional development and professional conversations to focus on Indigenous perspectives in our classrooms. However, it does not seem likely that any changes will be made about teacher practice if teachers' current practice and the factors that impact it are not explored.

The following chapters explore the methodology and analysis of the collected data. Teachers gave self-reports about what they thought their practice currently “looked like” and what they would have preferred it to be with regard to integrating Aboriginal perspectives in the classroom. While the initial development of instruments was focused on determining what teachers’ epistemic beliefs were and how these beliefs influenced their practice, the use of semi-structured interviews enabled me to build ideas about the complexity of the factors that influence teaching practice.

Chapter 3: Methodology

This chapter explains the methodology used in this study in three sections. The first, introductory section gives an overview of the study and information on the participants and research site. Following this is a section focused on the tools and processes used to collect data. Each of the three components of the study are explained in detail: how each component was constructed, why they were included, and the theoretical background for each. A short reflection on using each component is also presented. These reflections are expanded throughout the discussion, but are briefly included here as part of developing the narrative of how the research was conducted. The final section is a general overview of how the data were analyzed from each part of the study. Results are discussed in the next chapter, but tools that were used in the analysis are noted and their use explained here.

Introduction

Foreword.

This research study was initially focused on the impact of teachers' epistemic beliefs of science on the integration of Indigenous perspectives in the science classroom. It became evident however, following the first interview that I conducted with "Thomas" (note: pseudonyms are used for teachers who were interviewed), that there was more to teacher practice around Indigenous perspectives in the science classroom than just what they believed about science as knowledge. This first interview led me to shift some of the questions that I asked in the semi-structured interviews in order to gain a better understanding of the multiple factors that were impacting teacher practice. While this initially was done without completely comprehending what this would mean for my study and my research question, it became increasingly evident during the data analysis that I could not ignore what the emerging data were telling me. This led me to review and revise my research question, as I have described in the literature review.

While the methodology that is described below was developed with a focus of epistemic beliefs in mind, the mixed methods approach (Hesse-Biber, 2010) used in this study also provided information about teachers' teaching contexts and goals. It was the data collected from the multiple components of the study that necessitated a more reflexive consideration of what was emerging. Before collecting data, I did not consider that the methods chosen would reveal other insights than those I was searching for. While this is perhaps naïve, it is reflective of the change in how I perceived the process of research. My previous research background was in science disciplines such as biochemistry, molecular biology, and microbiology, where I developed and enacted a more positivist approach (Creswell, 2014) to research. The experience of this research study, however, has shifted what research is "supposed" to look like. It has been a challenging process to change my perception of the research process and has given me a renewed appreciation for the change that is required of teachers to teach in a way that may not be familiar to them (i.e., integrating Indigenous perspectives in their science classroom).

Selecting a mixed methods approach to this research was originally done to account for the multi-faceted nature of epistemic cognition (Barzilai & Zohar, 2014). While this is still relevant, it also provided more information about teachers' behaviors than one component of the methodology could have done. In this chapter, a detailed description of each component and how it was used is provided. Included with each description is a short reflection about what was learned from using the component in the study. This is more fully explained in the discussion chapter.

Overview of study.

A mixed methods approach (Hesse-Biber, 2010) was used in this study. The use of both quantitative and qualitative methods was in recognition of the multi-faceted nature of epistemic cognition that necessitates methods targeted to particular components (Barzilai & Zohar, 2014). The research contained three components: a survey, short scenarios looking at different ways to incorporate Indigenous perspectives in the classroom, and semi-structured interviews. By incorporating three different methods of data collection, the information obtained could be triangulated (Guba & Lincoln, 1989) as a way to increase the trustworthiness of the analysis and conclusions drawn (Maxwell, 1996). Data collection took place over the course of four weeks, which gave teachers an opportunity to reflect on their experience in the survey before the subsequent interview. As well, it provided more time for the researcher to schedule and travel to different interview locations (see Table 5 for timeline).

Participants and research site.

Luft (2001) reported that while more experienced teachers may evolve their teaching practices to better reflect administrative guidelines or governmental policy, their epistemic beliefs are much more stable than beginning teachers. Therefore, this study focused on science teachers with five or more years of teaching experience. To qualify as a “science” teacher within this study, a teacher had to have a teaching schedule that was primarily science courses, which was defined as a minimum of 75% of their teaching load. This was in consideration of the effect that a lack of background in science study and education could have on epistemic beliefs. It was thought that teachers with less background would not have sufficient exposure to science as a discipline to have developed a firm understanding of the subject. Further research in this field might consider looking at the differences between teachers whose background is science compared to those who are not in teaching science courses and their pedagogic actions around incorporation of Indigenous perspectives. This consideration, however, was beyond the scope of this study.

While it was hoped that at least 50 teachers would participate in the survey portion of the study, it quickly became apparent that this number of participants would not be reached. A total of 20 teachers from a Catholic school board in Alberta, Canada took part in the survey component, requiring some minor adjustments to be made in the first envisioned data collection process. Following an application process, permission was given by the school district to conduct research with teachers. An introductory electronic letter was constructed and sent out to the coordinating teachers of science departments in the Catholic school district, via the principal, and forwarded to teachers in their department. This letter contained an introduction to the researcher, the purpose and description of the research, an outline of informed consent, and a confidentiality agreement. Participation in a brief electronic survey was requested with the link to the survey as part of the letter; interested teachers were asked to provide their contact information within the online survey to indicate whether they wanted to also be part of subsequent qualitative aspect of the study. Upon confirmation, an email was sent to each interested teacher and an interview time was established. Consent forms (Appendix 2) were read and signed at the interview, with a copy given to the participating teacher.

Due to concerns around participation numbers, the way in which data for the constructed teaching scenarios were collected was altered from what was originally considered. Initially, it was thought that of the 50 surveyed teachers, 25 would be asked to complete the second part of the study, which was an audio recording of their responses to two questions surrounding constructed teaching scenarios. However, to ensure that as much data could be collected as possible, this was changed. Instead of teachers responding in a short interview format, the scenarios were included as a second part of the online survey. Teachers read through the descriptions and typed their responses into the online form (see Appendix 3 for scenario descriptions). Giving teachers the opportunity to read, think about, and then type responses, it was considered that it may have had the added benefit of gathering data that were more fully considered than if it had been solely asked verbally. Of the 20 surveys collected, 11 teachers agreed to meet for an interview. A semi-structured interview (average time: 30 minutes) was conducted with each teacher that also explored their responses to the teaching scenarios (see Appendix 4 for questions used in interviews). While all teachers willing to participate in this final portion of the study were interviewed, the decreasing numbers from the original grouping was in line with the proposal which had planned to decrease the number of participants in the qualitative part of the study in order to be cognizant of the depth of data that can be collected and the number of teachers willing to participate (Marshall & Rossman, 2011).

Data Collection

Introduction and considerations.

A mixed methods approach was chosen for this study as it has been shown in the literature to be an appropriate way to study epistemic beliefs (Barzilai & Zohar, 2014; Deniz, 2011; Hofer, 2004). Assessing epistemic beliefs is a challenge due to their multidimensional nature (DeBacker, et al., 2008). Surveys have been a popular form of exploring students' and teachers' epistemic beliefs (e.g., Conley, et al., 2004; Deniz, 2011; Tsai, Ho, Liang, & Lin, 2011). However, several scholars have warned against using quantitative methods as the sole data source (Barzilai & Zohar, 2014; Deniz, 2011; Hofer, 2000; Hofer & Sinatra, 2010). When examining personal epistemology (and by extension, epistemic beliefs; see Chapter 2), Hofer and

Sinatra (2010) describe several challenges. The reliability and validity of different assessments is called into question when a single method is used. They question whether a dichotomous scale such as a survey is sufficient in assessing a non-dichotomous construct such as a person's epistemology because most existing instruments do not take into account all four dimensions of epistemology as listed above (see Table 2 on p. 25) by Hofer (2000). There is also the challenge of response bias, as well as the potential that respondents may be reflecting on their views of knowledge for the first time while completing a survey, therefore affecting the results (Hofer & Sinatra, 2010).

When studying epistemology, it is important to identify which facet of epistemology is being assessed and match the method to it (Barzilai & Zohar, 2014; Duell & Schommer-Aikins, 2001). For example, it has been suggested that epistemic beliefs can be assessed with use of questionnaires while epistemic metacognition is better evaluated through interviews and observations (Barzilai & Zohar, 2014; Hofer, 2000; Hofer, 2004; Hofer & Sinatra, 2010). The common use of surveys to assess metacognition makes it difficult to evaluate both awareness and regulation components of epistemic metacogntion (Hofer & Sinatra, 2010). Studies specifically looking at the metacognitive component of epistemology and epistemic beliefs have used think-aloud protocols and interviews to achieve more valid results (Barzilai & Zohar, 2014; Hofer, 2004). Several scholars have promoted a mixed methods approach as an appropriate way to study personal epistemology (Barzilai & Zohar, 2014; Deniz, 2011; Hofer, 2004).

Hofer (2000) and DeBacker et al. (2008) have spoken to the difficulty in developing instruments to assess epistemic beliefs. Many of the instruments currently developed for assessing epistemic beliefs are domain-general in regards to knowledge, despite growing evidence that personal epistemology can be domain-specific (Buehl & Alexander, 2001;

DeBacker et al., 2008; Hofer & Sinatra, 2010). The instruments measuring epistemic beliefs necessarily assume that these beliefs are conscious and accessible to the participant (Hammer & Elby, 2012). It should be noted that any self-report instrument constructed is based on the researcher's underlying theoretical assumptions, which may or may not align with the respondent's interpretation of statements in a survey or questionnaire (Maclellan, 2015). The difference between these two may become more pronounced when participating individuals have not reflected on their beliefs of knowledge before (Maclellan, 2015). For transparency, the theoretical assumptions made by the researcher in the development of the data collecting tools are explained within the description of each tool below. Potential discrepancies between these and teacher responses are considered within the analysis and discussion.

This section is separated into four parts. Each component of the study is explained in detail about how the instrument was developed. To begin, modifications made to the original survey (Tsai et al., 2011), along with justifications for those changes, are presented in the paragraphs below and Table 5. The constructed teaching scenarios that were included in the online survey are explained first with a general overview and rationale, followed by a more detailed description of the theoretical underpinnings of each found in the literature. The initial questions used in the semi-structured interviews are described with some examples of how these questions evolved as more interviews were completed. Following the description of the three components of the study, a timeline of the data collection is given in Table 6. The ethical considerations of the study are presented, with reference to materials used in the data collection for informed consent from the participants.

Step 1 – Quantitative survey.

Using a survey as the first component of data collection was done to assess teachers' epistemic beliefs regarding science for the subsequent parts of the study. The survey also served as an intervention to trigger teachers' thinking about their beliefs about scientific knowledge to be cognizant that these beliefs may not have been consciously considered before (Hammer & Elby, 2012). By developing clear statements specifically targeting a potential variety of epistemic beliefs around the nature of scientific knowledge and knowing, a foundation was established from which to construct further questions and points of analysis.

Four dimensions of personal epistemology were mentioned (Hofer (2000): (a) certainty of knowledge, (b) simplicity of knowledge, (c) source of knowledge, and (d) justification of knowledge (see Table 2 in literature review). These dimensions were incorporated into the Scientific Epistemic Beliefs (SEB) survey (Tsai et al., 2011) as four science-specific factors: Source, Certainty, Development, and Justification (see Appendix 5). Table 4 shows the relationship between Hofer's (2000) and Tsai's (2011) categories of epistemic belief dimensions. Tsai (2011) changes the language for his categorization of dimensions of epistemic beliefs. Changes in language in Tsai's (2011) survey as compared to Hofer (2000) are bolded.

Table 4

The relationship between Hofer's (2000) and Tsai et al.'s (2011) categories of epistemic belief dimensions

Hofer	Tsai	Hofer	Tsai
Nature of knowledge	Nature of knowledge	Nature of knowing	**Process** of knowing
Certainty of knowledge	Certainty	Source of knowledge	Source
Simplicity of knowledge	**Development**	Justification of knowledge	Justification

Source items explore beliefs of external authority as a resource for scientific knowledge while Certainty items are concerned with the confidence in answers provided by science. Development items for Tsai's survey examine beliefs around the evolving and changing nature of scientific knowledge. Items in Justification focus on views of the role of experimentation in science and how one justifies scientific knowledge. The items within each of these dimensions are further explored in this chapter and within the analysis of the data.

Because the Scientific Epistemic Beliefs (SEB) survey is domain-specific, shown to have high construct reliability and validity (Tsai et al., 2011), and designed around the dimensions of personal epistemology, it was adapted in this study to assess teachers' epistemic beliefs about teaching science and about science as a discipline. This adaptation is unique in the field as most surveys that have been developed focus on students' knowledge rather than teachers'. The changes that were made to the survey were for three primary reasons. First, statements were changed to be more specific to teaching science, rather than learning it. Second, changes were made to survey statements to reflect development epistemic belief past a high school level understanding of knowledge. As outlined in the literature review, individuals move from being more absolutist in their beliefs to relativistic, finally culminating in an evaluativist perspective (Bendixen & Rule, 2004). Statements were shifted to reflect at minimum a relativistic view, as it was assumed that teachers with a university education would have developed beliefs at least past an absolutist view. The third major change to statements relates to the definition of science given in the literature review which uses the Standard Account of science, as outlined by Cobern and Loving (2001). Language and phrasing that reflect this understanding of science were used as the Standard Account is generally accepted by the scientific community and portrayed by scientists in their own writing (Cobern & Loving, 2001). I made the assumption that teachers would have been exposed to this definition and language of science in university level science classes taught by practicing scientists (Gallagher, 1991). Other small changes to the language were to reflect the higher level of education and more sophisticated vocabulary of an adult as opposed to a high school student, the target of the original survey. The modified survey is shown in Table 5 below, with the justifications for changes made to each statement. See Appendix 6 for the final version of the survey used in the study.

Table 5

Modified Scientific Epistemic Beliefs (SEB) survey for teachers

Dimension	Original Statement	Modified Statement	Reasoning for modification
Source	Everyone has to believe what scientists say.	Everyone should believe what scientists say and write.	A change was made from "has to" to "should" to account for more developed epistemic beliefs. Included 'write' to account for the written aspect of scientific explanations.
	In science, you have to believe what the science books say about stuff.	When teaching science, the information in the textbook should always be taken as true.	This statement was changed to make it more specific to teaching science.
	Whatever the teacher says in science class is true.	There is only one definition of science as determined by the scientific community.	Focus was shifted from teacher being the locus of scientific knowledge to a more general statement in light of this study being about teachers' understandings of science, rather than that of a high school student. Although I did consider that this change had the potential produce more variability in the survey data, I also thought that it would provide a point of discussion in the interviews.

	If you read something in a science book, you can be sure it is true.	Valid scientific knowledge comes from experimentation by scientists.	A more substantial change was made here. The statement was altered so that it focused on where science knowledge is generated based on the Standard Account of science versus simply focusing on the use of textbooks. This was meant to align with a university level of science education that would influence epistemic beliefs, as compared to that of a high school student.
Certainty	All questions in science have one right answer.	All scientific questions have one right answer	Language was changed to be more concise for an audience with a higher level of education.
	The most important part of doing science is coming up with the right answer.	The most important part of teaching science is helping students come up with the right answer.	Statement was made more specific to teaching science rather than learning science.
	Scientists pretty much know everything about science; there is not much more to know.	Scientists know nearly everything about natural phenomena.	Language was changed to be more concise and to better target those with a university level education.
	Scientific knowledge is always true.	Scientific knowledge is always true.	No change.
	Once scientists have a result from an experiment, that is the only answer.	Once scientists have an explanation from experimentation, it can be applied to all contexts.	This was shifted from saying that something is "the only answer" to where it can be applied which makes it more specific to this study while still including the sense of the explanation being the "only answer". The

			change to “explanations” versus “results from experimentation” was a choice made to account for more experience in science as a discipline through university education and life experience.
Development	Some ideas in science today are different than what scientists used to think.	Some scientific ideas today are different than what scientists used to think.	Changed to more concise language that is consistent with other parts of the survey.
	The ideas in science books sometimes change.	What is considered science is influenced by culture.	A major change was made here in order to coincide with definition of science statement seen in a previous section (i.e. “there is only one definition of science”) and to get teachers’ opinions on the fluidity of science. This was interpreted to have been the intent of the original statement; this change made it more specific to this study and to the inclusion of alternative perspectives in the science classroom.
	There are some questions that even scientists cannot answer.	There are some questions that science cannot answer.	Language was changed to be more concise. The word “even” was taken out as it was interpreted to create a particular tone or underlying sentiment that gives an overt opinion as to what knowledge is more valid. The omission gave a more neutral tone to the statement.

	Conclusions developed by scientists are always objective.		This statement was added to explore teachers' thoughts regarding scientific explanations and the people who develop them; is it possible to be completely objective? Although adding this statement was more of a risk as it has not been tested under the original survey's framework, it was included to question teachers on the extent to which they considered there was an element of the human experience in the development of knowledge, or if it is just "there."
Justification	Ideas about science experiments come from being curious and thinking about how things work.	Ideas about science come from being curious and thinking about how things work.	Made the language more concise and general to science rather than just simply about experimentation.
	In science, there can be more than one way for scientists to test their ideas.	There is more than one way to test a scientific theory.	Changed in order to make it more concise and use higher level vocabulary/understanding more appropriate to educated science teachers.
		One important part of science is doing experiments to come up with new ideas about how things work.	This statement was removed as it was felt to be redundant for this particular audience. This statement seems to be asked with statement 1 and 4 in this section.
	Good answers are based on evidence from many different experiments.	Good scientific explanations are based on evidence from many different experiments.	Here, changed from "answers" to "scientific explanations" to reflect language used in the Standard Account of science (Cobern & Loving, 2001).

	Ideas in science can come from your own questions and experiments.	Ideas in science can come from questions and observations made in many different settings.	This was made more specific to this particular study by looking at different settings for scientific inquiry versus “your own questions and experiments”.

Items were constructed based on the SEB survey into a 5-point Likert-style survey, revised from the 7-point Likert scale used in the original survey. Changing to a 5-point scale reflects other instruments in the field designed to measure epistemic beliefs (i.e., see Schommer (1990) and Schraw, Bendixen, and Dunkle (2002)). The revised survey was reviewed by the researcher's supervisor, and adjusted based on his comments. The electronic survey was tested by two individuals not participating in the study prior to opening access to participating teachers. This affirmed that the online survey collected the data that it was intended to.

Reflection.

Due to the low number of participants, analysis of the collected survey data was limited. A challenge of using a survey, as I found out, is that for it to valuable in providing information about the participants, more than 20 responses are required. I made the assumption when designing the methodology that I would receive at least 50 responses to the survey, considering the sample pool size that I was working with. In the original plan for the methodology, however, the survey was meant to serve a second function, as an intervention to have teachers begin to think about what they believed about science knowledge. Pairing the completion of the survey with the constructed teaching scenarios (see below) could have had an impact on how teachers responded to the scenarios. However, it was difficult to quantify how much of an impact reading through and completing the survey had on the thought processes of teachers as they chose and explained which scenarios best reflected their current and preferred teaching practice around incorporation of Indigenous perspectives.

Step 2 – Teaching scenarios.

Four scenarios looking at a spectrum of possible ways to incorporate Indigenous perspectives in the science classroom were developed for teachers to read and type a response to in the second part of the online survey. Hypothetical teaching scenarios have previously been used with teachers as a way to analyze epistemic beliefs around teaching science (e.g., Hashweh, 1996). Other researchers stated that the claims teachers made about how and what they think they should be teaching was not always in line with what they believed they should be teaching (Veal, Lloyd, Howell, & Peters, 2016). Having teachers choose teaching scenarios for both their current and preferred practice gives more insight into what is currently occurring in classrooms, as well as what teachers would prefer to do.

These scenarios were based on curricular outcomes from Science 10 as this has generally been taught by most science teachers and does not rely on teachers having a discipline specialty (i.e., chemistry, physics, or biology). Within the Science 10 Program of Studies, as developed and mandated by Alberta Education, the incorporation of Indigenous perspectives is: (a) acknowledging Indigenous contributions to our understanding of the natural world, (b) supporting thinking relationally through integration of different science disciplines, (c) developing a sense of connectivity to and responsibility for caring for the natural world, and (d) fostering positive attitudes with experiences that help develop confidence in ability to succeed (Alberta Education, 2014). Suggestions made to incorporate Indigenous perspectives within this curricular document reflect these principles and were used to inform the detailed scenarios. Teachers were asked to read through each scenario and respond to the following questions: (a) which of the following scenarios would best reflect your approach to incorporating Indigenous perspectives in the science classroom and why and (b) which scenario would be your preferred approach and why? Because of the nature of the online survey format, responses for those teachers who provided contact information for an interview were identifiable and as such, could be brought up in the interviews for teachers to elaborate on their responses. The general structure for each scenario is described below. See Appendix 3 for the scenarios that teachers read and responded to.

Scenario 1. The first scenario centers on zero inclusion of Indigenous perspectives. Here, the lesson described is of science taught according to a Western understanding, with focus on the prescribed outcomes of the Program of Studies and no mention of alternative ways of being in or understanding the world. This serves to represent an extreme universalist approach (Snively & Corsiglia, 2001) to the nature of science. The teacher in the scenario does not intend to recognize other contributions or ways of understanding the world, encompassing a more scientistic belief of the superiority, objectivity, and universality of scientific knowledge.

Scenario 2. In this scenario, Indigenous perspectives are incorporated as an add-on to the curricular outcomes to represent the common practice of "tokenizing" Indigenous knowledge and technology with an underlying universalist belief of the nature of science (Aikenhead, 2006; Cobern & Loving, 2001; Southerland, 2000). Within the described teaching scenario, the lesson focused on an analysis and interpretation curricular outcome by looking at trends in scientific data through discussion of the movement of traditional Indigenous use of willow bark to treat pain into more modern uses of aspirin (Alberta Education, 2014). The description of it as "traditional" and directing the application towards its contribution to Western medicine decontextualizes this knowledge from its particular epistemology and ontology (Aikenhead, 2006). The use of past tense language in the scenario to describe the Indigenous use of willow bark also acts to separate the Indigenous knowledge from a current understanding, focusing instead on the Western application of it (Aikenhead, 2006). While this scenario does not harbor the more explicit scientism seen in Scenario 1, it does reinforce universalist ideas of scientific explanations from Western science being applicable across cultures and maintaining the superiority of Western science over Indigenous knowledge in describing the latter's *contribution* to Western medicine.

Scenario 3. This scenario uses the idea of "epistemological pluralism" as conceptualized by Cobern and Loving (2001) as a way to consider Indigenous perspectives in the classroom. An epistemologically plural curriculum values many forms of knowledge from its own sources and centers on looking at the various ways in which different epistemologies can provide unique insights in answering questions (Cobern & Loving, 2001). In doing so, the scenario begins to move into the multicultural realm of epistemic beliefs around the nature of science in recognizing Western science as equal, although distinct, from other domains of knowledge. An important distinction of this scenario from the final one is that Indigenous perspectives of the natural world will not be labeled as "science," but rather as "Indigenous knowledge." Scenario 3 describes a lesson that examines the benefits and risks of human activity, and its impact on the environment (Alberta Learning, 2014). Pedagogically this is approached by comparing the Gaia hypothesis of Western science with local Indigenous perspectives of the natural world, exploring the insights that each viewpoint offers to inform students' understanding and potential action (Alberta Learning, 2014; Snively & Corsiglia, 2001). As background to this lesson, it is mentioned that students have been given a specific definition of science that makes explicit what science can contribute as knowledge and what its limitations are. Similarly, opportunities for students in the classroom to share their particular cultural beliefs and perspectives with their classmates, as a way to provide insight into Indigenous perspectives, is also part of the background information.

Scenario 4. This final scenario considered the full incorporation of what is termed "Indigenous science" into the classroom, representing the full expression of multicultural beliefs of science education (Aikenhead, 2006; Aikenhead & Michell, 2011; Ogawa, 1995; Snively & Corsiglia, 2001). By using "Indigenous science," these perspectives are considered to have greater equity with Western science (Aikenhead & Michell, 2011). This lesson is based on resources from the "Rekindling Traditions" project developed through the combined efforts of teachers, university affiliates, community members, and local Elders (Aikenhead, 2000, 2001). The resources selected in this scenario are structured around making snowshoes as part of learning about pressure and force in the physics unit of Science 10. As part of this lesson, there is an incorporation of a more holistic framework of learning, an understanding of Cree and Dene cultures, an examination of the differences between Indigenous science and Western science, and discussion of how knowledge is passed on in these different worldviews (Aikenhead, 2000). Western science does not replace Aboriginal science in the lesson, but rather, serves as enrichment (Aikenhead, 2001).

Reflection.

Inclusion of the constructed teaching scenarios, in light of the data that emerged from the interviews, was valuable in that it provided a comparable example of teachers' current and preferred teaching practice around inclusion of Indigenous perspectives in the classroom. By limiting the options to four, theory-based scenarios, the choices that teachers made with regard to the scenarios that reflected their current and preferred teaching practice could be compared along with survey responses. They also provided a launching point for conversation within the interviews. Part of the challenge of using the scenarios as a source of data was that teacher interpretation of each scenario, nor how they responded (i.e., to what depth did they explain themselves) could be controlled for with the short answer, typed format that was used. In the original design of the study, the responses to the scenarios were meant to be done in person and audio-recorded. It was later considered that this method of data collection would limit the number of responses, so it was changed to the typed response as part of the online survey.

Step 3 – Semi-structured interviews

Semi-structured interviews were done with teachers following the completion of the online component of the study, which had included both quantitative and qualitative elements. A semi-structured format was chosen to allow for flexibility in questioning that better reflected the responses received from the survey and teaching scenarios. An initial script was developed, but was modified through the process of interviewing teachers to discuss themes or ideas that emerged over the course of the interviews. For example, when asking teachers "How do we come to know what scientific knowledge is?", extra questions were added to have teachers elaborate on their response. These questions were "How did you develop this idea?", "Where did it come from in your experience?", and "How has it changed over time?". Another question that was modified was one about scenarios 3 and 4: "In scenarios 3 and 4, Indigenous perspectives are included within the classroom in different ways. What do you think is the difference between them?". This was altered to "Is there a distinction for you?". Another question was added, based on the constraints that teachers mentioned in their interview responses to including Indigenous perspectives in their classes. This question was, "Are there any constraints that prevent you from teaching/incorporating different ideas into your classroom?". The first questions asked in the interview were directed towards having teachers elaborate on their epistemic beliefs of the nature of science. Drawing on their response in the scenario portion of the study, interview questions explored the relationship between teachers' epistemic beliefs about scientific knowledge and the ways in which they might incorporate Indigenous perspectives in the classroom, with special attention paid to any disconnect between the beliefs and what pedagogical actions they report would be used or would prefer to be used (see Appendix 4 for the initial questions that were used). Final questions asked in the interview focused on awareness that the participants had around the influence of their beliefs on pedagogical actions and whether there was an aspect of control or monitoring of these beliefs.

Reflection.

The process of conducting and transcribing the interviews was the most illuminating with regards to the data that emerged from it. As previously mentioned, it was after the first interview that I realized that there was more to teacher practice around Indigenous perspectives than I had originally considered. The advantage of using semi-structured interviews was that the questions that were originally developed could shift based on the conversation with the individual teacher. While this was beneficial in that a better understanding could be gleaned from each teacher's description of their teaching practice, it also presented some challenges. Each interview had unique aspects that could not necessarily be repeated with each teacher. Should subsequent studies be based on this one, it would be interesting to focus in on and further explore some of these aspects.

Table 6

Timeline of planning and data collection

Date	Activity
August, 2016	Research proposal approved by University of Alberta Research Ethics Office
October, 2016	Application to conduct research in school district submitted for review and approved by committee
January 11, 2017	Sent initial introductory emails to high school principals, with a request for permission to contact science teachers in their schools (See Appendix 7 for initial email transcript).
January 17, 2017	First responses for the online survey received
January 25, 2017	Interview #1: Thomas
January 30, 2017	Interview #2: Bradley
February 1, 2017	Interview #3: Daniel
February 2, 2017	Interview #4: Eli
February 2, 2017	Interview #5: Rachel
February 7, 2017	Interview #6: Anne
February 8, 2017	Interview #7: Trevor
February 10, 2017	Interview #8: Sarah
February 12, 2017	Interview #9: Karla
February 14, 2017	Interview #10: Michael
February 14, 2017	Interview #11: Christina
February 15, 2017	Interviews completed; transcribing continues and data analysis begins

Ethical Considerations

Because this research was done with human participants, it was essential to obtain informed consent. The consent form created included the purpose of the research, what the participant would be contributing, and what the participant may receive by being part of the process (i.e., in what ways will he/she benefit) (see Appendix 2 and 7 for consent form and introduction letter, respectively). It was made clear in the introduction letter and consent form that participants could not be coerced to be part of the study by either the researcher or school administration. Participants were informed that they were welcome to leave the study at any point without prejudice. Reading through the consent form at the beginning of each interview, prior to the participating teacher signed it, reminded teachers of this as well as gave the researcher the opportunity to revisit the conditions of consent in order to keep them foremost as the research was conducted.

By going into a school, I was aware that my presence could and would most likely have an impact on the participants. This necessitated approaching the participant and research with respect and humility. The research being conducted, with pre-determined guidelines to maintain confidentiality and anonymity, was shared with the school district and school principals to establish a healthy relationship. Approval was sought from the school board through a formal application. Guidelines of the school district for research occurring within their schools were adhered to and modifications were made to the process of gathering participants. Potential participating teachers were not allowed to be contacted directly, but rather the principal of each high school was responsible for sending along information to each science department.

Data Analysis

The process of data analysis was guided in part by protocols developed by Bogdan and Biklen (2007) for analyzing qualitative data in education research, as well as through analysis processes that the researcher considered to be relevant to the emerging data. Qualitative and quantitative data were reviewed simultaneously, switching between the three sets. I thought that looking at the data more holistically may help me assess it with greater circumspection. In this section of the methodology, an explanation is given for the processes that were used to analyze the three different sets of data. A journal was kept throughout the data collection, data analysis, and writing process to document thoughts that emerged, as suggested by Marshall and Rossman (2011). These thoughts, as well as supporting literature, help to build a narrative of the thought process throughout the analysis. This informs the results in the next chapter.

Epistemic beliefs of teachers regarding science as knowledge were examined in terms of the Tsai et al. (2011) framework developed in the Scientific Epistemic Beliefs survey, which was modified and used in this study. As more thoroughly described in the literature review, Tsai separated dimensions of epistemic beliefs into four categories: source of knowledge, certainty of knowledge, development of knowledge, and justification of knowledge. The survey statements were broken up into these dimensions, which could then be analyzed. When reading and coding the interviews, comments about knowledge were distinguished using these four epistemic belief categories.

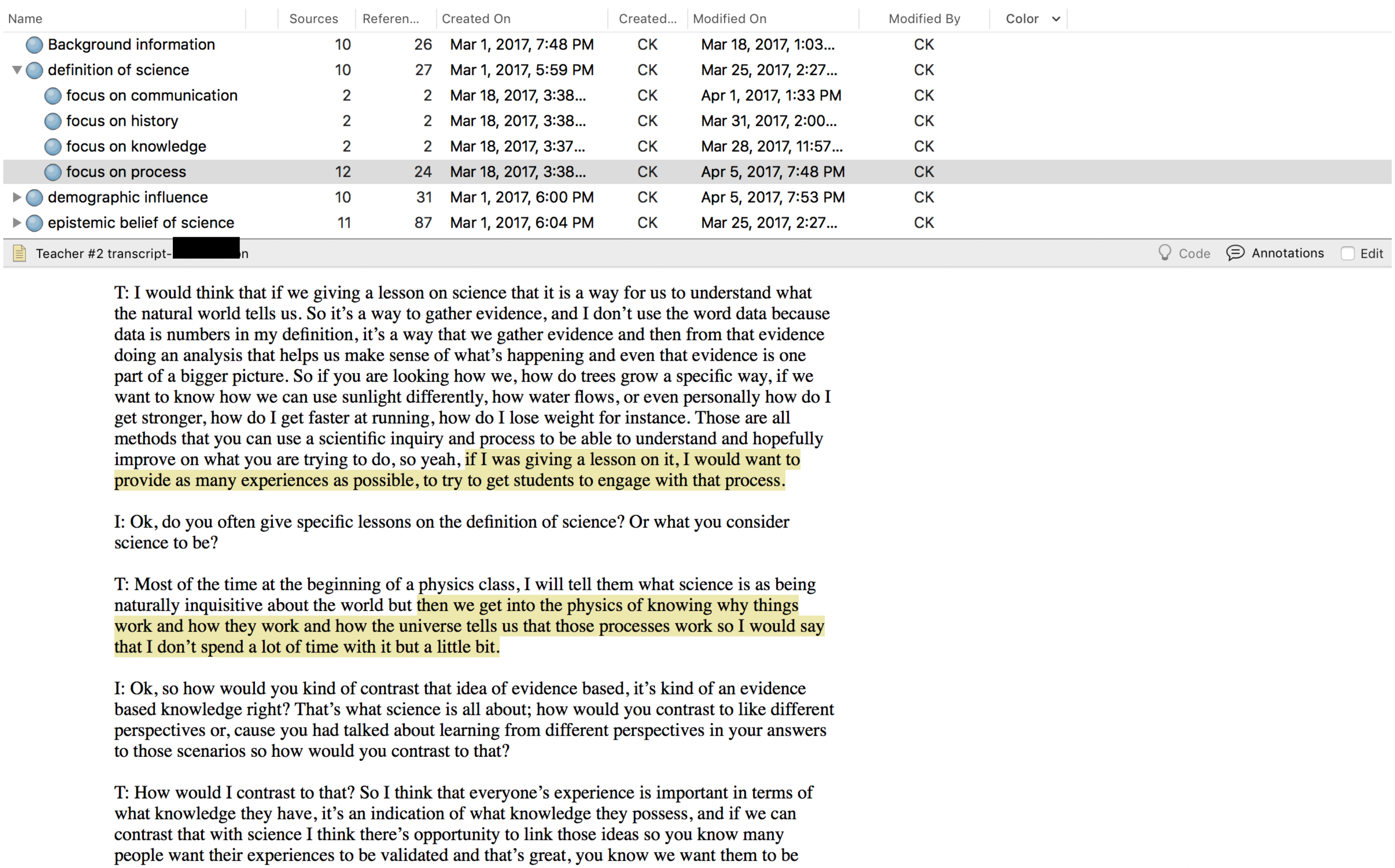
Interviews.

Interviews were audio-recorded and transcribed by me into a Word document. This transcript was uploaded into and coded using NVivo software. This software allowed the researcher to build codes that could be used on all 11 interview transcripts. Transcription followed the completion of the interview, generally the same day or, in a few cases where multiple interviews happened on one day, the next day. This was done to guide the chosen semi-structured interview format, where the experience of previous interviews and ideas that came out of them helped to inform what other types of questions might be valuable to ask in subsequent interviews (Guba & Lincoln, 1987). I had not had any previous experience in conducting semi-structured interviews, so this helped guide the process for me. While transcribing, notes about the first impressions of the interview were taken and initial codes were developed, reflecting the constructivist framework of this research in allowing the data to guide the analysis process (Creswell, 2014). Transcribed interviews were sent back to the teachers to member check for accuracy (Marshall & Rossman, 2011) and to allow teachers to clarify or add something they had thought about following the interview. This member-checking was done to ensure the trustworthiness of the data (Lincoln & Guba, 1985).

Codes that arose from transcribing the data as well as pre-determined codes that were considered within the research proposal were used to analyze the transcripts. These pre-determined codes included *strategy codes* (Bogdan & Biklen, 2007) such as "teaching strategy" and "integration of concepts" and *perspectives codes* (Bogdan & Biklen, 2007), which involved codes pointing to instances of a universalist or multicultural perspective of science knowledge. Codes that developed during the transcription of the data were built on the patterns and themes that were seen in the data (Patton, 2002). For example, two codes that arose from the data were "teaching constraint" and "perception of Aboriginal worldview." For a full list of codes used in this study, see Appendix 8. While coding the interviews, sub-codes were also developed. As seen in Appendix 8, the list of codes and sub-codes was quite extensive, but this allowed the researcher to develop a much clearer idea of the specific themes that were emerging from these conversations with teachers which informed later thinking and writing. Figures 2 and 3 below show a screen shot of a partially transcribed interview and how statements appear under particular codes. Figure 2 shows coded phrases in the transcribed interview within the code “focus on practice” highlighted in the partial list of codes at the top of the screen shot. Figure 3 shows quotes from different interviews that were coded as “perception of Aboriginal worldview.”

Figure 2

Screen shot of partially transcribed interview using NVivo



Name	Sources	Referen...	Created On	Created...	Modified On	Modified By	Color
Background information	10	26	Mar 1, 2017, 7:48 PM	CK	Mar 18, 2017, 1:03...	CK	
definition of science	10	27	Mar 1, 2017, 5:59 PM	CK	Mar 25, 2017, 2:27...	CK	
focus on communication	2	2	Mar 18, 2017, 3:38...	CK	Apr 1, 2017, 1:33 PM	CK	
focus on history	2	2	Mar 18, 2017, 3:38...	CK	Mar 31, 2017, 2:00...	CK	
focus on knowledge	2	2	Mar 18, 2017, 3:37...	CK	Mar 28, 2017, 11:57...	CK	
focus on process	12	24	Mar 18, 2017, 3:38...	CK	Apr 5, 2017, 7:48 PM	CK	
demographic influence	10	31	Mar 1, 2017, 6:00 PM	CK	Apr 5, 2017, 7:53 PM	CK	
epistemic belief of science	11	87	Mar 1, 2017, 6:04 PM	CK	Mar 25, 2017, 2:27...	CK	

Teacher #2 transcript-[redacted]n Code Annotations Edit

T: I would think that if we giving a lesson on science that it is a way for us to understand what the natural world tells us. So it's a way to gather evidence, and I don't use the word data because data is numbers in my definition, it's a way that we gather evidence and then from that evidence doing an analysis that helps us make sense of what's happening and even that evidence is one part of a bigger picture. So if you are looking how we, how do trees grow a specific way, if we want to know how we can use sunlight differently, how water flows, or even personally how do I get stronger, how do I get faster at running, how do I lose weight for instance. Those are all methods that you can use a scientific inquiry and process to be able to understand and hopefully improve on what you are trying to do, so yeah, if I was giving a lesson on it, I would want to provide as many experiences as possible, to try to get students to engage with that process.

I: Ok, do you often give specific lessons on the definition of science? Or what you consider science to be?

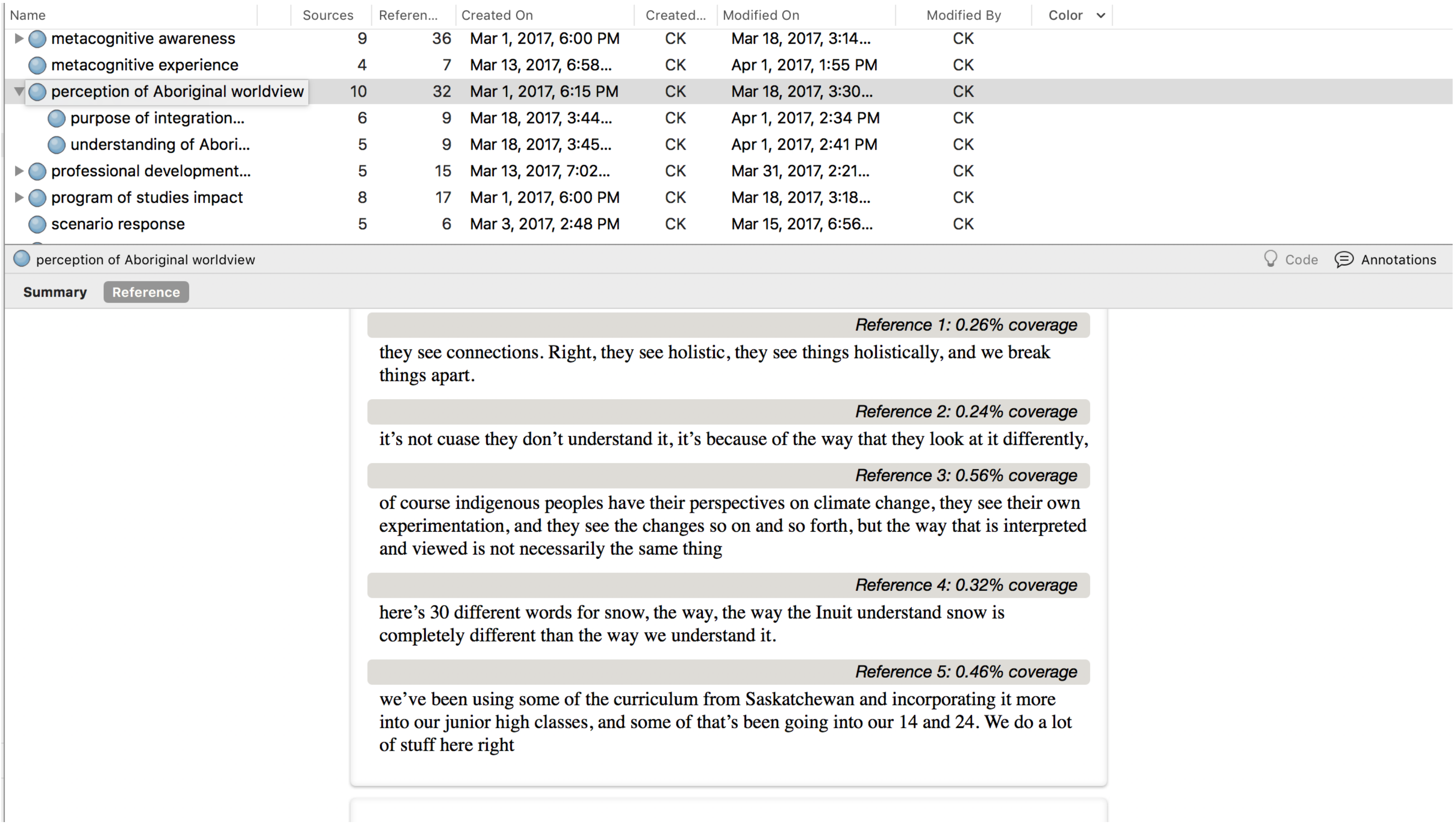
T: Most of the time at the beginning of a physics class, I will tell them what science is as being naturally inquisitive about the world but then we get into the physics of knowing why things work and how they work and how the universe tells us that those processes work so I would say that I don't spend a lot of time with it but a little bit.

I: Ok, so how would you kind of contrast that idea of evidence based, it's kind of an evidence based knowledge right? That's what science is all about; how would you contrast to like different perspectives or, cause you had talked about learning from different perspectives in your answers to those scenarios so how would you contrast to that?

T: How would I contrast to that? So I think that everyone's experience is important in terms of what knowledge they have, it's an indication of what knowledge they possess, and if we can contrast that with science I think there's opportunity to link those ideas so you know many people want their experiences to be validated and that's great, you know we want them to be

Figure 3

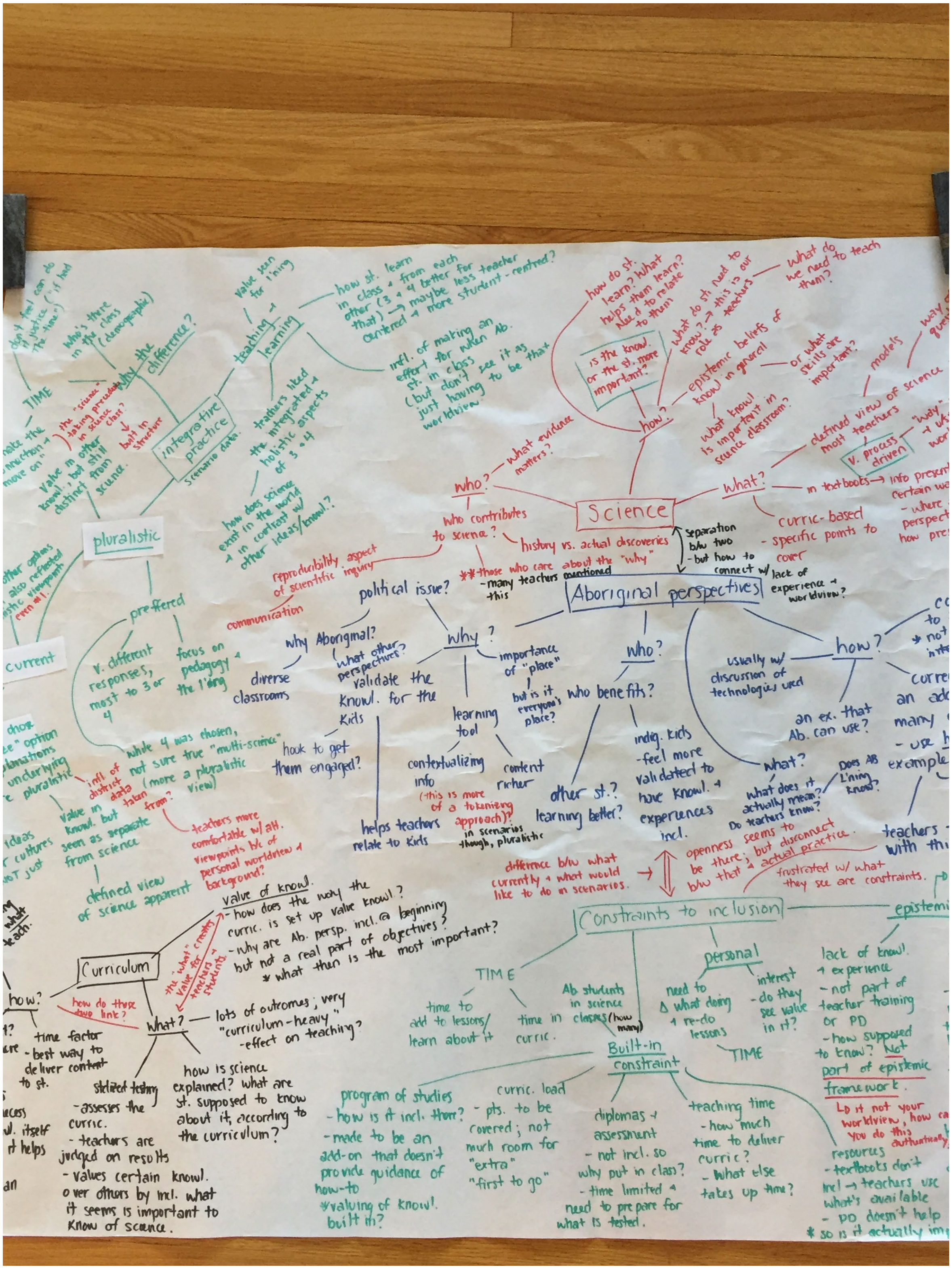
Screen shot of statements coded as "perception of Aboriginal worldview"



Following the initial coding of the interviews, a summary was written about each teacher about major perspectives that they seemed to be presenting. This summary also helped me to assemble my ideas surrounding these conversations that were to guide further analysis and thought. The interviews were then sub-coded, intentionally in a different order than the one they were transcribed and initially coded in, in order to look at each interview less based on the progression with which they were conducted. From here, a concept web was constructed to organize the major themes and ideas that were developing from the interviews (Marshall & Rossman, 2011) (see Figure 4, below). This was summarized into an initial document.

Figure 4

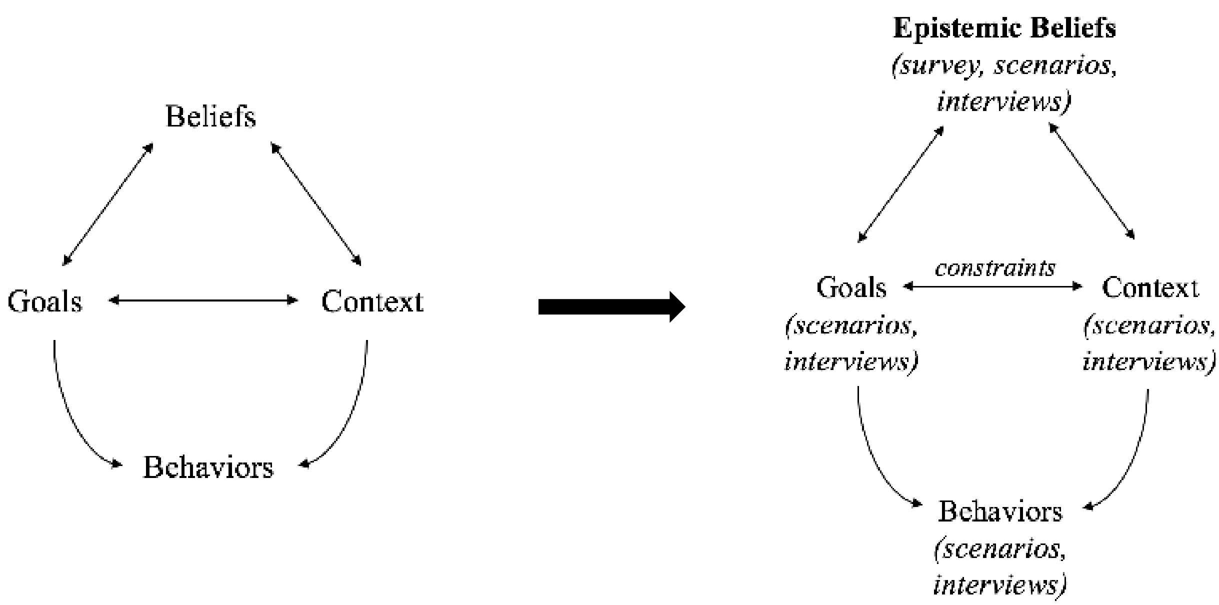
Initial concept web to organize major themes and ideas emerging from the data



Once well-described categories that reflected the data collected were established (see "theoretical sufficiency" (Dey, 1999)), with my supervisor's guidance, a theoretical framework was developed based on the research questions and the patterns that emerged from the data (seen in Figure 5 below). Since 1995, research into beliefs has intensified and become much more diverse. Therefore, there is a need to recast the McRobbie and Tobin (1995) model (see Figure 1 in previous chapter). This revised model provided the theoretical framework in which the data were considered and explained.

Figure 5

McRobbie and Tobin's (1995, p. 381) model and the revised model based on emerging data



The revised model seen in Figure 5 bolds "epistemic beliefs" as epistemic beliefs were the original focus of the study and for what the methodology was initially constructed to provide data. The words italicized in brackets in the model represents the components of the study that provided data for the particular factor impacting teacher behavior. "Constraints" appears above the line connecting goals and context as these two factors were often related to what teachers felt limited their practice in the classroom. The components of the theoretical framework are interrelated and often will be within the analysis. Where appropriate, they will be separated in the analysis, although this was difficult to do as epistemic beliefs, context, and goals were shown to impact one another and teacher behavior.

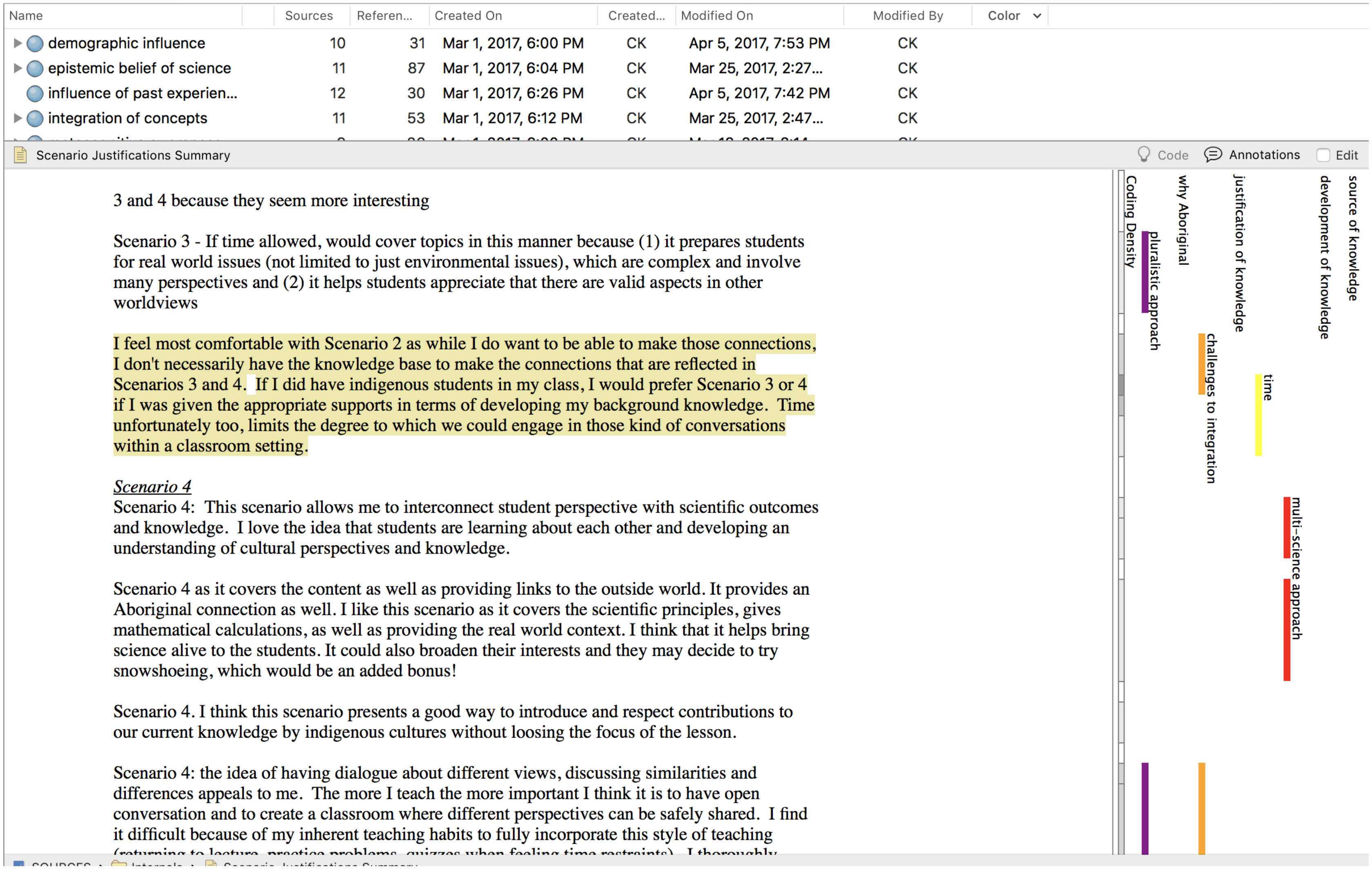
Following development of a theoretical framework, the audio recordings of each interview were listened to again along with the written transcripts. While listening to the recording, each interview was annotated a third time. A summary based on the theoretical framework that guided this study was then written for each teacher. It was decided after initial drafts of the analysis that the interview data would be best represented through a series of case studies that incorporated other pieces of data to create a more holistic view of a teacher and his/her beliefs and teaching practice. Case studies are not used in this study as a methodology, but as a way to represent data. Marshall and Rossman (2011) describe case studies as a tool to explore phenomena in depth and detail. This was thought to be an appropriate way to integrate qualitative and quantitative data in this study. Six teachers were selected for the case studies. Teachers were selected for two reasons. First, the epistemic beliefs of the teacher clearly connected to their practice for inclusion of Indigenous perspectives in the science classroom. The second reason a teacher could have been included was that he/she represented a major finding in the data.

Scenarios.

The anonymous typed responses to the constructed teaching scenarios that were obtained from the second part of the online survey were amalgamated into a single document and separated in two ways. First, responses were grouped by the question they were responding to in the survey (i.e., "what best reflects your current teaching practice and why?" and "which teaching scenario would you prefer to use and why?"). Following this separation, responses were grouped by the scenario teachers had chosen for the question they were answering (i.e., Scenario 1, Scenario 2, Scenario 3, or Scenario 4). This aided the researcher in examining the teachers' responses for commonalities, as well as any differences for teacher choice. These responses were coded in NVivo using the codes developed from the interviews to maintain consistency and to see if there were any links between these responses and the themes that were emerging from the interviews. Figure 6 shows a screenshot of the partially coded document. This screenshot also includes a side bar feature of NVivo which enables the researcher to see the frequency of particular codes in a document.

Figure 6

Screenshot of partially coded scenario response document



Survey.

The data collected were analyzed with some descriptive statistics, including mean, median, frequency, and variance, although with the limited data, ideas constructed from trends in the data will be less general and cannot be applied to any population outside this sample of teachers. Due to limited participation in the survey, only basic descriptive statistics were done as more advanced analysis would not have been appropriate or valid (Peers, 1996). Of these, mean and frequency were chosen to represent the general findings of the data, as seen in Chapter 4. The mean was chosen to represent findings in the survey data as all values on the Likert scale had equal importance and the mean represents the average value that teachers responded to (Peers, 1996). The frequency of responses on the Likert scale was measured, clumping together responses on either "end" of the scale (i.e., the agree versus disagree ends) to help determine if there were any general trends that could be seen (Peers, 1996). It would have been interesting to analyze responses in the survey based on the scenarios that were chosen by teachers for their self-reported and preferred practice, but again, there was not enough data to make this statistically valid and so more simple trends were examined.

Summary

This chapter has explained the mixed methods approach that was used in this study and how the emerging data from this approach necessitated the change to the original research question and conception of the study. A mixed methods approach has been shown in the literature to be appropriate for assessing epistemic beliefs. A survey, constructed teaching scenarios, and semi-structured interviews provided quantitative and qualitative data that were analyzed. The modified Scientific Epistemic Beliefs survey, originally developed by Tsai et. al (2011), was used to target teachers' beliefs about science. The constructed teaching scenarios, and in particular, the semi-structured interviews, were included to explore the relationship of epistemic beliefs to actual teaching practice around integration of Indigenous perspectives in the science classroom. The emerging data from the constructed scenarios and interviews also provided insight into the impact of teaching contexts and goals on epistemic beliefs, and the relationship of these three on teaching behavior. Data from the interviews, in particular, contributed to the change in focus of the study from being primarily about epistemic beliefs to a broader understanding of what impacts teacher practice. The next chapter presents the analysis of the data and what could be suggested from it in relation to the research question.

Chapter 4: Analysis and Results

Introduction

Data obtained from the quantitative and qualitative portions of this study were initially analyzed and presented based on a theoretical framework. This framework explored three components that arose from the data: epistemic beliefs of teachers, the impact of epistemic beliefs on current teaching practice, and the disconnect between current practice and preferred practice, that were identified as constraints to teaching practice. The theoretical framework was developed partially through the initial question that was posed for the study and on data that emerged during data collection. This was in line with the original intention to use a constructivist methodology in analyzing the data, being careful to build it based on the content of the data. The data that emerged from this analysis, however, prompted a broadening of the original research question to explore factors that impact teaching practice other than only epistemic beliefs. As epistemic beliefs were the original focus for the development of methodology and data analysis, and because they were not specifically part of the McRobbie and Tobin (1995) framework for teacher behavior (as previously described), epistemic beliefs are more prominent within the analysis than other factors that impact teaching practice.

The analysis and results from the data are separated into three sections. Section 1 examines the epistemic beliefs of teachers as inferred from results from the modified Scientific Epistemic Beliefs survey, scenario responses, and the interviews. Included in this section are a variety of tables and figures which serve to represent the data. Section 2, “Classroom Practice and Indigenous Perspectives,” focuses on the responses teachers gave around their current and preferred teaching practice, as represented by the constructed teaching scenarios. This section also includes a series of six case studies which build a more holistic picture of teachers’ epistemic beliefs, teaching context, and instructional goals, and the impact on their practice, incorporating all the data collected in the study. The final section, "Identified Constraints to Inclusion of Indigenous Perspectives in the Classroom," provides evidence of internal and external contextual factors that teachers reported as influencing to their practice regarding inclusion of Indigenous perspectives in their classrooms. Sections 2 and 3 provide more insight into other factors influencing teacher behavior, as suggested by McRobbie and Tobin (1995).

Each section begins with an introduction, giving a brief layout of the section and, where appropriate, concludes with a summary of the information presented. All names have been changed to a pseudonym for anonymity.

Section 1: Epistemic Beliefs

Survey.

In this section, epistemic beliefs of teachers are reported based on the data collected from the survey portion of the study. A total of 20 teachers completed the survey, with 11 of these teachers also participating in the interview portion of the study. As was outlined in Chapter 3, the survey was modified from the Scientific Epistemic Beliefs survey, as developed by Tsai et. al (2011) for high school students (refer to Table 1 in Chapter 3 for modifications made to the original survey, as well as the justification for each change). The survey statements were categorized through the four dimensions of epistemic beliefs: source of knowledge, certainty of knowledge, development of knowledge, and justification of knowledge (Tsai et al., 2011). These statements were responded to using a five-point Likert scale with 5 being "strongly agree," 4 "agree," 3 "not sure," 2 "disagree," and 1 being "strongly disagree." The use of the survey in this study was in part to collect quantitative data of teachers' epistemic beliefs in an attempt to triangulate the information gathered in the study (Guba & Lincoln, 1989), as well as a way to *trigger* teachers' thinking around their epistemic beliefs of science as they continued through the study, after the survey administration.

The data are presented in several ways, beginning with an overview of the teachers' responses, becoming more specific as the data are examined in different ways. Each figure or graph with survey data will be elaborated upon, explaining why it was included within the analysis and discussing what information it suggests. The progression of data from general to more specific will lead into subsequent sections that examine the epistemic beliefs that emerged from responses given in the scenario and interview portions of the study.

Survey dimensions.

Table 2 in the literature review (p. 26) described the dimensions of epistemic beliefs as developed by Hofer (2000). Tsai et al. (2011) changes the language slightly for his categorization of dimensions of epistemic beliefs. This is represented in Table 4 (p. 57). The Scientific Epistemic Belief survey (Tsai et al., 2011) was modified for this study and included statements to look at these two dimensions. For nature of knowledge, teachers responded to statements around the certainty that one has of the answers for what is considered scientific knowledge (Certainty) and the continuous evolving and changing nature of scientific knowledge (Development) (Tsai et al., 2011). Statements around the process of knowing focused on scientific knowledge originating from an external authority (Source) and the role of experiments in how scientific knowledge is justified (Justification) (Tsai et al., 2011).

Analysis based on epistemic belief category.

In Table 7, survey statements are separated into the two epistemic belief categories: nature of knowledge and process of knowing. This table shows the statistical mode of each response on the Likert scale by individual survey statement. The mode of responses corresponding to “strongly disagree” and “disagree” (1 and 2 on the Likert scale), and those of “strongly agree” and “agree” (5 and 4 on the Likert scale) have been combined for clarity throughout the analysis, due to the small sample size.

Table 7

Mode of responses in survey data for all participants

Survey Statement	Disagree (1-2)	Neither agree or disagree (3)	Agree (4-5)
Nature of Knowledge			
All scientific questions have one right answer	15	5	0
The most important part of teaching science is helping students come up with the right answer	14	4	2
Scientists know nearly everything about natural phenomenon	18	1	1
Scientific knowledge is always true	11	6	3
Once scientists have an explanation from experimentation, it can be applied to all contexts	16	2	2
Some scientific ideas today are different from what scientists used to think	0	1	19
What is considered science is influenced by culture	5	7	8
There are some questions that science cannot answer	0	1	18
Conclusions made by scientists are always objective	11	3	6

Survey Statement	Disagree (1-2)	Neither agree or disagree (3)	Agree (4-5)
Process of Knowing			
Everyone should believe what scientists say and write	4	14	2
When teaching science, the information in the textbook should always be taken as true	5	5	10
There is only one definition of science as determined by the scientific community	8	6	6
Valid scientific knowledge comes from experimentation by scientists	1	4	15
Ideas about science come from being curious and thinking about how things work	1	0	18
There is more than one way to test a scientific theory	0	0	20
Good scientific explanations are based on evidence from many different experiments	1	2	16
Ideas in science can come from questions and observations made in many different settings	0	0	20

To interpret Table 7, trends are examined in terms of the two epistemic belief categories as a way to provide points of discussion in later sections. It is valuable to report on trends based on these two categories as epistemic beliefs in both the scenario responses and interview responses will be documented based on nature of knowledge and process of knowing (see Table 6). This part of the analysis combines the dimension statements within the two categories to examine trends seen in the data around teachers' beliefs.

Nature of knowledge.

For the category of nature of knowledge epistemic beliefs, several interpretations emerge from the table based on teachers responding similarly to particular items. One interpretation that emerges from Table 7 is that teachers see science as a dynamic discipline and evolving body of knowledge. This is supported by the majority of teachers responding similarly to statements such as "some scientific ideas are different than what scientists used to think" (19/20 in support) and "scientists know nearly everything about natural phenomenon" (18/20 not in support). The certainty of science having the "right answer" was something that teachers did not support or were unsure about in the survey. For example, teachers were not supportive of ideas such as "all scientific questions have one right answer" (15/20) and "the most important part of teaching science is getting the right answer" (14/20). Similarly, teachers did not see scientific explanations as being completely universal as evident in their response to "once scientists have an explanation, it can be applied to all contexts," with 16 of the 20 teachers responding as "disagree." Not seeing science as having universal explanatory power could be further supported with 16 teachers responding "agree" to the statement, "there are some questions science cannot answer," suggesting that teachers may see limitations in the areas that science might be appropriately used as a process to explain.

There was a lack of consensus in teacher response to three items within the nature of knowledge category. In responding to the influence of culture on what is considered science, 7 of the teachers responded with “not sure,” 5 were not supportive of this statement and 8 were supportive. The statement regarding the influence of culture on what is considered science was a statement added to the survey to assess teachers’ ideas around the relationship between culture and science and as a starting point for conversations around integrating Aboriginal perspectives into the science classroom. The objectivity of scientists also had a range of responses with 11 teachers not in support of “conclusions made by scientists are always objective,” 3 being unsure and 6 supporting that statement. In response to “scientific knowledge is always true,” 11 teachers said that they were not in support of that idea, 6 were unsure, and 3 were supportive. The lack of consensus for these statements suggests that the teachers had differing views of the influence of culture on science, the objectivity of scientists, and the truthfulness of scientific knowledge.

Process of knowing.

From the statements centered around the process of knowing, there was general consensus around the idea that the process of science is what makes something scientific. This was evident with the majority of statements being “agree” for statements such as “good scientific explanations are based on evidence from many different experiments” (16/20 responses), “valid scientific knowledge comes from experimentation by scientists” (15/20 responses), and “ideas in science can come from questions and observations made in many different settings” (18/20 responses). These statements suggested that these teachers supported the idea that “science” is about questioning and looking to a deeper explanation of how things work. The positive responses to the statements above also suggest that teachers consider valid scientific explanations and theories to come from multiple routes and through extensive and varied observations and experimentation. Teachers were also supportive of the idea that science was concerned with deeper explanations into natural phenomena with all teachers answering with a 4 or 5 on the Likert scale to “ideas about science come from being curious and thinking about how things work.”

There was a lack of consensus in the process of knowing category in survey statements around the “truthfulness” of resources that teachers use, and whether there is one definition of science. In their response regarding resources used in the classroom, 10 teachers were in support of the information in textbooks being truthful, while 5 were unsure, and 5 did not support that statement. The response to “there is only one definition of science, as determined by the scientific community” was more diverse with 8 teachers not being supportive, 6 teachers in support, and 6 teachers being unsure.

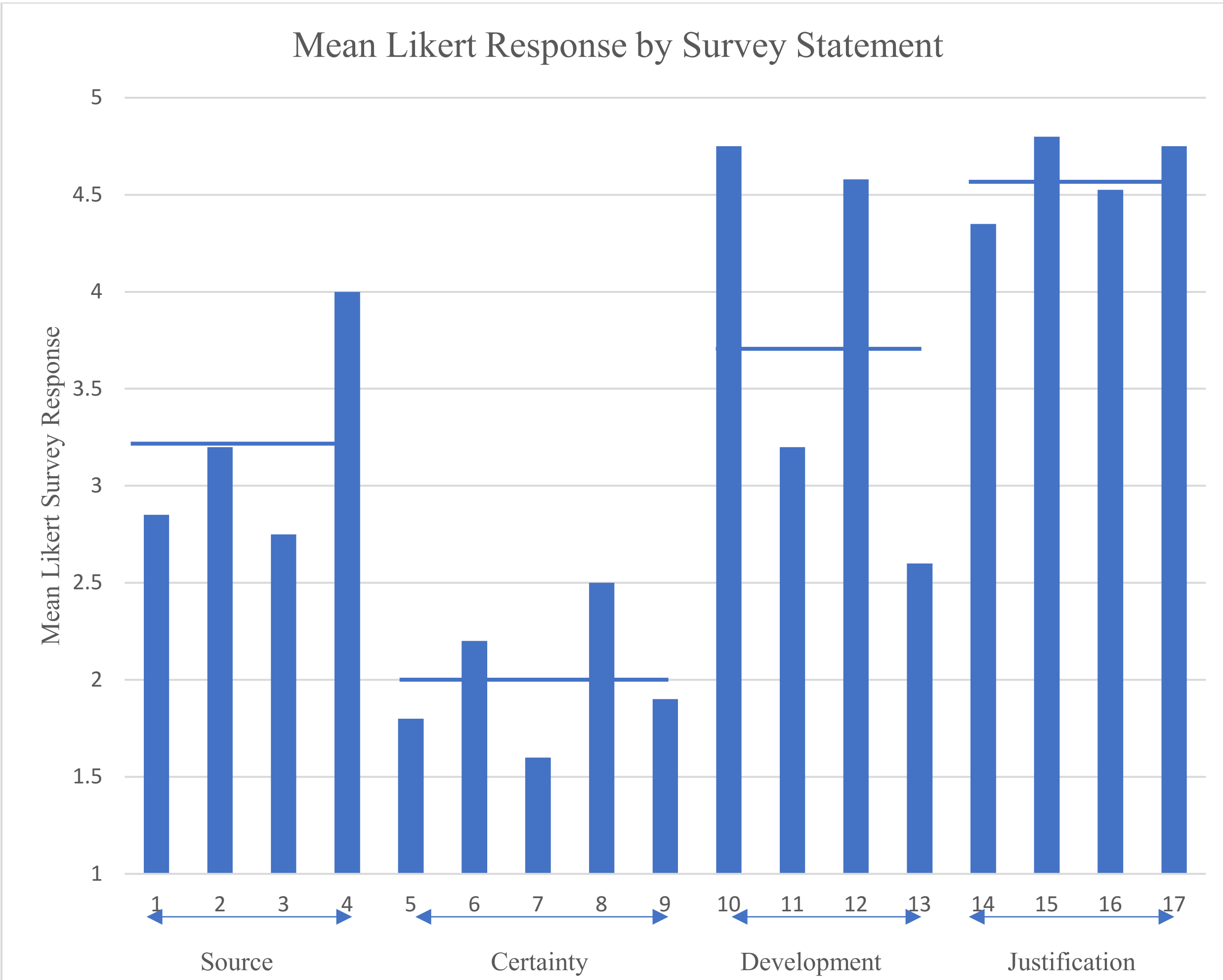
Responses to the statement “everyone should believe what scientists say and write,” were unique in the survey as it was the only item where the majority of teachers selected 3 or unsure (14/20 teachers). This could suggest that while teachers were supportive of experimentation by scientists being the source of valid scientific knowledge (as seen above), they were unsure about how scientists interpret and then communicate that interpretation. As will be described in the following section in discussing teachers’ epistemic beliefs that were evident in the interviews, teachers as a group may be supportive of the process of asking questions and seeking answers in science, but are not in agreement around the nature of interpretation of the data. In particular, there seem to be differing opinions on whether the interpretation of scientific evidence can always be done in a manner that should be completely trusted or whether the presented data could be challenged, as seen with the range of responses within the two categories of epistemic beliefs.

Analysis based on dimension.

Moving from the two categories of epistemic beliefs to the dimensions that compose them (see Table 6 above), Figure 7 (shown below) shows the mean Likert responses given in the survey by individual statement in each dimension (out of a possible score of 5). The mean response for each dimension is shown as a line above the statement bars that they correspond to. The dimensions are not ordered based on which category of epistemic beliefs they relate to, but in the order that teachers responded to in the survey. See Appendix 6 for the specific survey statements in each dimension.

Figure 7

Mean Likert Response from Survey by Statement



From Figure 7, it can be seen that, on average, teachers were supportive of the statements in the Justification dimension in the survey (mean for each response above 4), and were not supportive of statements in the Certainty dimension (mean below 2.5 for each response). As can be seen in Figure 7, there was more variability in the responses to statements in both the Source and Development dimensions, with mean Likert responses being above and below "unsure" (3 on the scale). This observation is discussed further in conjunction with the next table.

Table 8 (see below) expands on Figure 7 by comparing responses in dimensions based on the individual teacher to aid in building an epistemic profile for each. This is done by displaying the mean response that each participating teacher had to each dimension. Included in this table are the pseudonyms for the interviewed teachers and the overall mean for each dimension. This table is used to reference the survey data within the case studies in Section 2 of this analysis. Looking at the overall mean for each dimension, the data suggest that teachers were generally unsure about scientific knowledge originating with an external source, as evident with the Source mean of 3.2. Teachers were, overall, not supportive that there can be certainty in answers of science (Certainty mean of 2). A mean response for Development of 3.77 suggests that teachers were somewhat supportive of the notion that scientific knowledge is changing and evolving. Teachers more strongly supported the role of experiments in justifying scientific knowledge, with a Justification mean of 4.61. The mean responses for each dimension indicate that teachers were more sure of their beliefs around the Certainty and Justification of scientific knowledge with mean values definitively in the “disagree” or “agree” ends of the Likert scale. Conversely, the means for Source and Development, when taken with the trends seen in Figure 7, imply that teachers were either unsure or more diverse in their beliefs with calculated means closer to the middle of the Likert scale.

Table 8

Mean Response for Each Dimension by Teacher

Teacher	Sources Statements	Certainty Statements	Development Statements	Justification Statements
Overall Mean	**3.2**	**2**	**3.77**	**4.61**
1 (Karla)	3.75	2.8	4	4.67
2	3.5	1.4	4.5	4.75
3	3.5	2.2	3.75	5
4 (Michael)	2	1.6	3.5	3.5
5 (Thomas)	2.75	1.4	4.25	5
6	3.5	2.2	4.25	5
7	2.5	2	4	4.75
8	3	1.2	4	5
9 (Eli)	3.75	1.6	3	3.75
10 (Daniel)	3.5	1.6	4	4.75
11 (Bradley)	3.5	1.4	2.75	4.75
12 (Sarah)	3.25	1.4	4	5
13	2.75	2.4	3.75	5
14 (Anne)	2.5	1.8	3.5	3.75
15 (Rachel)	3.75	2.4	3.75	4.25
16	4.5	2	3	5
17	3.5	3.8	3.75	4
18	2.5	2.2	3.5	5
19 (Christina)	2.75	2	4.25	4.75
20	3.25	2.6	4	4.5

Note: Was not able to identify survey data for Trevor.

The mean values for Source were not definitively in the “agree” or “disagree” parts of the scale (3.2) and so these data could not give a clear indication of the responses given to statements within this dimension. It is evident from the individual teacher means for this dimension, however, that they are not necessarily neutral about Source beliefs. The data in Figure 7 show a split response for Source statements, suggesting a variety of opinions on the source of scientific knowledge from the scientific community and resources used in the science classroom. Similarly, individual teacher mean values in Table 8 range from 2 to 4.5, supporting the assertion that there was a lack of consensus in the group.

The mean values for Certainty indicate more of a consensus between individual teachers than the Source mean values do. In the Certainty dimension, 19 of the 20 teachers surveyed had a mean lower than 3, suggesting that teachers overwhelmingly did not support the statements being made about scientific knowledge as being definite, unchanging, and applicable to all contexts. In contrast, the Development dimension indicated diversity in individual teacher response in comparison to the collective mean. As evident in Figure 7, the mean Likert response for Development epistemic belief statements ranged from 2.6 to 4.75, and individual teachers means from 2.75 to 4.5.

In the Justification dimension, the importance that teachers place on the role of experimentation as part of the process of knowing scientific knowledge was evident with the majority of teacher responses giving means of 4 or above. As was later reported in the interview responses, experimentation was understood primarily as a key element of the Western definition of the scientific method, although this was not a term used in the survey. This trend was also supported in Figure 7 which reported that Justification statements referencing gathering evidence, making observations, and experimentation were strongly supported with Likert mean responses all above 4. This suggests that the teachers considered the process of science or how science is done as being important to what distinguishes knowledge as being scientific.

The trends seen in both Figure 7 and Table 8 between the different dimensions of epistemic beliefs cautions against any definitive statement being made about the overall beliefs teachers have in either category. The data suggest that teachers are more in agreement that there is *A* way to do science, but there is less agreement around the impact and influence that individuals and culture does or should have on what it considered scientific knowledge, as evidenced by the lack of consensus in Source and Development. The notion that there is a particular way in which science is done was also evident in the scenario and interview responses, and is elaborated on in those sections of analysis.

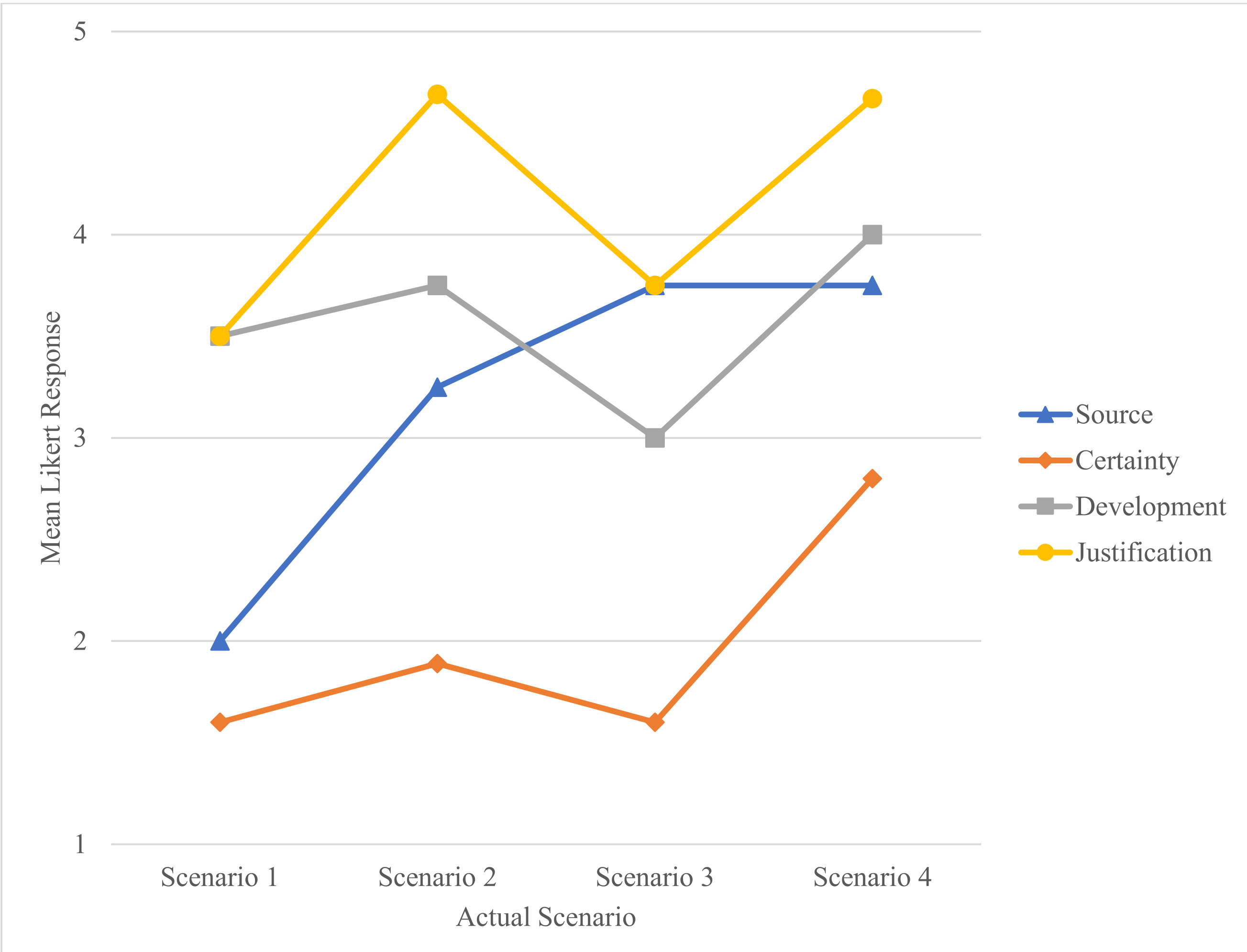
Survey and scenarios.

This section examines the possible connect and/or disconnect between epistemic beliefs of teachers inferred from analysis of survey responses and the teaching scenario chosen as their actual and preferred method of incorporating Indigenous perspectives in the science classroom. Figure 8 and 9 below shows a graphical representation of the mean response for Likert-based epistemic belief dimensions for all teachers surveyed, based on scenarios identified as actual and preferred teaching practice (respectively). It should be noted that one teacher chose more than one scenario as their actual practice and five teachers selected two scenarios as what they would prefer to use in the classroom. Their responses to each statement were included for both scenarios selected when calculating mean as it could not be determined which scenario best reflected their actual or preferred practice most. Three teachers did not make a choice as to their preferred practice. An analysis and discussion of responses given by teachers as to their reasoning for choosing more than one scenario is provided later. The points on each line represents the mean Likert response for each epistemic belief dimension on the survey (y-axis), based on the scenario chosen as preferred practice (x-axis).

As previously explained, Scenario 1 depicted a scientistic approach to the inclusion of Indigenous perspectives in that it was not included at all because it was not seen as being valuable to a science classroom. Scenario 2 integrated Indigenous perspectives in a tokenistic style, while Scenario 3 included these perspectives in an epistemological plural way that acknowledged the value and merit of an Indigenous worldview in a discussion about the Gaia hypothesis. Scenario 4 represented the most integrative approach with a multi-science view of Indigenous experiences and knowledge.

Figure 8

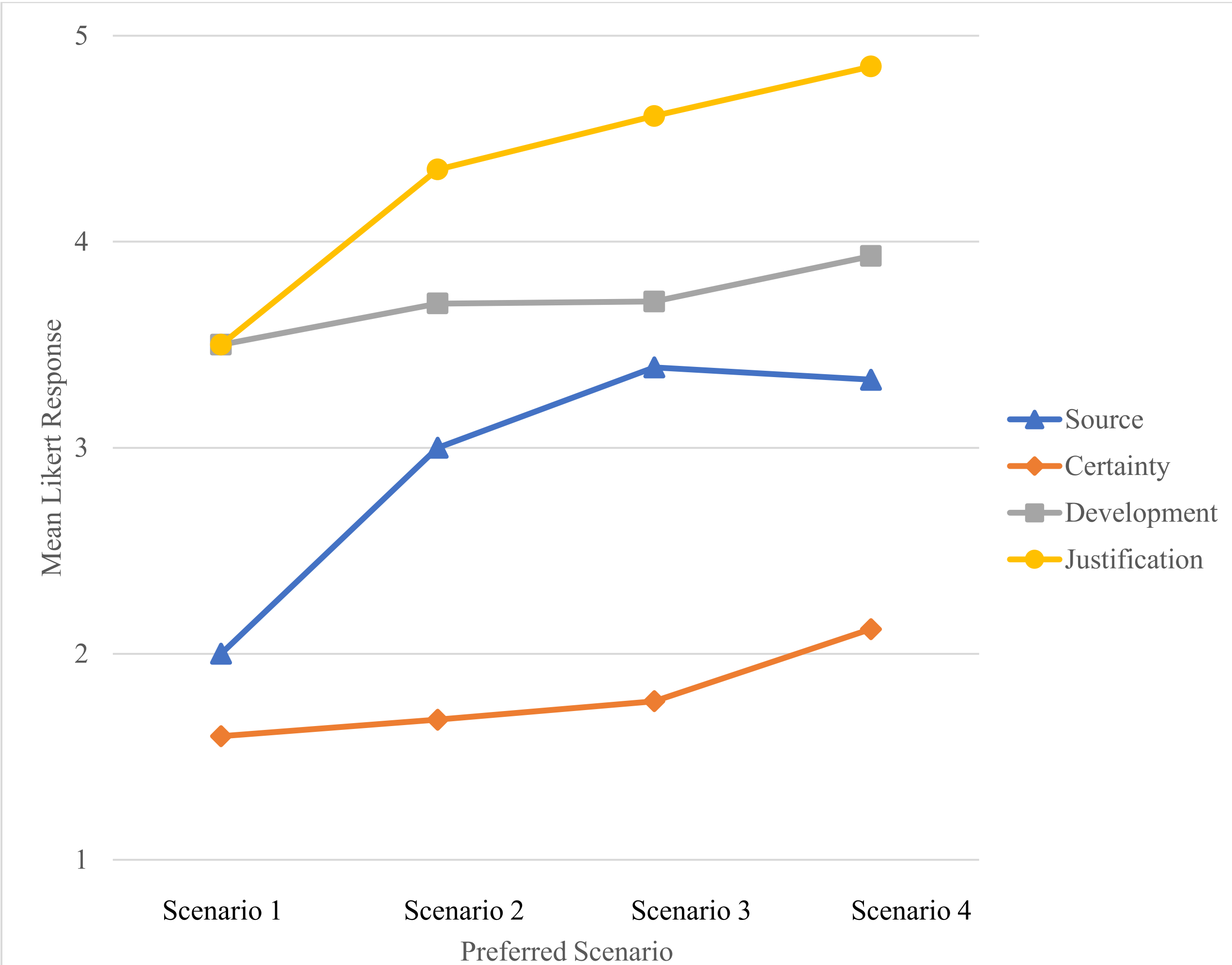
Mean Likert Response for Survey Dimensions Based on Scenario Chosen as Actual Practice



Note: Means for the scenarios were calculated based on the following number of teachers: Scenario 1, 1 teacher, Scenario 2, 16 teachers, Scenario 3, 1 teacher, and Scenario 4, 1 teacher.

Figure 9

Mean Likert Response for Survey Dimensions Based on Scenario Chosen as Preferred Practice



Note: Means for the scenarios were calculated based on the following number of teachers: Scenario 1, 1 teacher, Scenario 2, 5 teachers, Scenario 3, 7 teachers, and Scenario 4, 10 teachers.

Figure 8 shows a general increase in teacher mean responses, except with Scenario 3, where a decrease in response is depicted for Certainty, Development, and Justification dimensions. As this value is based on the responses of one teacher, it is imprudent to suggest any trend. The general upward trend (with the exception of Scenario 3) is also depicted in Figure 9. Figure 9 suggests that teacher mean responses to items generally increased in agreement with more purposeful incorporation of Indigenous perspectives. The graph shows that there is a general upward trend in mean Likert response in each dimension from Scenario 1 to 4, with the exception of Source, where there is a small decrease in mean for Scenario 4 as compared to 3. This suggests a relationship between epistemic beliefs and preferred scenario of incorporating Indigenous perspectives in the science classroom.

Information about the epistemic beliefs of teachers grouped based on preferred scenario choice can be inferred from the increase in dimensional mean. These inferences are based on the theoretical understanding of what each dimension represents of beliefs about scientific knowledge, as previously discussed. For instance, an increase in mean in Justification suggests a rise in support for the importance of experimentation in justifying scientific knowledge. A rise in mean from 3.5/5 in Scenario 1 to 3.93/5 for Scenario 4 in Development can be inferred as an increase in support of a dynamic and evolving nature of scientific knowledge. A similar trend is shown in Certainty, where Scenarios 3 and 4 show an increase in mean from 1.6 and 1.68 in Scenarios 1 and 2 (respectively), to 1.77 and 2.12 (respectively). This suggests increase in support for a definite and unchanging understanding of science that is applicable to all situations. Based on the theoretical underpinning of the scenarios, where Scenario 3 and 4 are more purposeful integration of Indigenous perspectives in the classroom, these results suggest that there could be a relationship between how a teacher understands science and how he/she chooses to incorporate Indigenous perspectives in the science classroom.

Due to the small sample size, however, it is imprudent to suggest more about the data other than that there is a general upward trend in responses in the Likert-based dimensions as teachers selected Scenario 4. When this information is merged with other data collected in the qualitative scenario response and interview portions of the study, it becomes evident that there are several influences other than epistemic beliefs that impact teachers' choice of preferred scenario. This is analyzed and discussed in more detail in the upcoming sections.

Interviews.

Data reflecting teachers' epistemic beliefs of science from the interviews are found in Table 9, where teachers' responses to two questions in the interview are presented: (a) in your opinion, how do we come to know what scientific knowledge is; and (b) if you were to give a lesson on the definition of science to your students, what would you tell them? The first question yielded responses that reflected epistemic beliefs related to the process of knowing scientific knowledge. Responses to the second question reflected epistemic beliefs related to the nature of scientific knowledge. This was not the intention of the questions when they were first developed, although upon reviewing them based on the responses given by the interviewed teachers as part of this analysis, I noted a relation of the questions to those aspects of epistemic beliefs as is explained below. As teachers who were interviewed are examined in more depth in the next section as case studies, only general results of the epistemic beliefs of teachers are reported here. Words or phrases are highlighted in the table for emphasis and further discussion. Table 9 shows responses that teachers gave to two interview questions, using quotes from the interview (seen in quotation marks) and in some cases, a summary of their response (no quotation marks). Trevor is included in this table, as he did participate in an interview. Teachers' beliefs are separated into two categories of epistemic beliefs, based on the dimensions discussed earlier in this section: process of knowing (Source and Justification) and nature of knowledge (Certainty and Development) (Tsai et al., 2011)

Table 9

Teacher Responses to Two Interview Questions

Teacher Pseudonym	In your opinion, how do we come to know what scientific knowledge is?	If you were to give a lesson on the definition of science to your students, what would you tell them?
Karla	"from reading and prior conversation with colleagues" "…if it's knowledge, it would have to be something that was in some way **proven** or currently **believed to be true** [through experimentation]"	Would not tell them initially; use a brainstorm session, then "kind of make-up a webby kind of thing where all the ideas come together and I think it would become apparent."
Michael	"I think it's a, mostly it's going to come from the, I guess like, the **scientific institution.**"	Would not tell them initially, but use an activity for them to come up with the ideas themselves; focus on ideas that "science isn't just a body of facts, that science is about models and finding ways to explain the world that's useful for us to be able to **make predictions**."
Thomas	"I think you come to know by **experimentation** and by **interacting** with your world, and by being **curious**. I think science is the avenue to do that…it's not about the answers you are trying to find, it's about the questions." "I think you need to engulf yourself in the dialects of the language of science."	"It has to be **testable**, it has to be **repeatable**, it has to be **observable**, and you have to be able to make **predictions**. If it meets those four parameters, then it's science...that's actually one of the first things I teach."

Eli	"Scientific knowledge is, I would say, any knowledge or understanding that has come from someone **thinking about something**." "It could be anything where someone has thought about why something is the, sort of **causative factors** and reasons that that thinking came to be."	"I would ask them to come up with some sort of question that they're interested in, for them to **investigate**."
Daniel	"So scientific knowledge, how we come to know what it is; often based on **experimentation**, and or **evidence** that's out there that's just looking at nature and seeing it again and again, understanding that's just the way it is and trying to figure it out from there."	"I would probably say it's a **way of knowing**, because the **scientific method** would be involved in the lesson." "I think that science is a **way of problem solving** and **way of discovering** about nature and everything, so it's a means to an end."
Bradley	"When we look at the way that science is conducted, research, observation, anecdotal records, we start to collect patterns." "from those themes and patterns, we can then run statistical processes to be able to understand if there is a significance from them [leading to a correlation or causation]"	"that it is a way for us to understand what the natural world tells us. So, it's a **way to gather evidence** and then from that evidence doing an analysis that helps us make sense of what's happening." Would provide students with as many experiences as possible to engage with the process of scientific inquiry.
Sarah	"I have certainly broadened my view on how we acquire scientific knowledge and what it is and separating scientific information from, separating out the fact that something has a science background versus that it is **fact**." "What we consider data is also something that I think we need to look at critically."	"I usually focus on the idea that it's a **discovery** and **explanation** of the world." "I always approach with just trying to discover the world around, trying to see it through a lens of **how does it work**." Focus on the scientific method, as she considers it important that there "be properly gathered data."

Anne	"well, the physics person tells me, you know, you need to, **experimental**, reading, something that you can **know what it is**." "there are **truths**, I guess, we can put towards science, truths, like veritable, something you can **observe** or at least **quantify**."	"…it's like a life science or it's a natural science. If it's something that's breathing, or pulse, or you know, alive, then it's considered a life science. If it's something that's a little bit more law and abstract, "kind of gotta take my word on that whole mole things," then that's more of a natural science." "science can actually explain, you know, why does this pencil drop, why does that fire burn, why is that plant useful to us? Everything else is not really science."
Rachel	"I really think the only way you're going to know what scientific knowledge, not the only way, the best way, is the way scientists discover scientific knowledge, through **experimentation and inquiry**."	"science is a process of discovering about our world around us, our universe, through experimenting. And science is about knowledge that is **constantly changing** as we discover new things with our experiments and our new ideas that come about." Would teach the scientific method with an older audience of students.
Christina	"I think it's a combination of initially what we were taught and then I think a lot of it comes from experience too. So, the lab component for the kids."	"I think I would tell them that science is how humans make sense of the world, so again, where science comes from is people noticing and making, like noticing things in the world around them and then asking, "well, **why is that**?"
Trevor	"I guess mostly through **experimentation** and **duplication** of others experimentation to verify what others have found testing, and making hypotheses and testing them and basing them off of data."	"I guess I would have to include objectivity, I would have to include controlled experimentation, and **objective analysis** of data collected."

In relation to the process of knowing, the interviewed teachers mentioned the importance of experimentation and science being a process of coming to understand the natural world, more specifically related to the Justification dimension of process of knowing. This was evident in statements such as, “science is a way of problem solving and way of discovering about nature” (Daniel) and “science is a process of discovering about the world around us, our universe, through experimenting” (Rachel). Six of the eleven teachers specifically mention elements of experimentation as being an important aspect of science, while other teachers refer to a process in science with phrases such as, “it’s a way to gather evidence” (Bradley), “way to explain the world” (Michael), and [discovering the world] through a lens of how does it work” (Sarah). Discovery of the natural world and seeking the “why” behind observations was a key component of science for many teachers, using terms like “explain,” “predictions,” “why does…,” and “causative factors.”

The Source of Knowledge as a dimension of process of knowing provided more varied responses than that of the Justification, as seen above. This reflects the data obtained in the survey, where there was more variation in response to statements in the Source dimension than within the Justification dimension. While experimentation and inquiry are clearly important sources of scientific knowledge for the interviewed teachers, as seen in the responses, other sources were also proposed. Karla said scientific knowledge came from “reading and prior conversation with colleagues,” while Michael thought that it originated from “the scientific institution.” Rachel, Daniel, Thomas, and Trevor all mentioned experimentation specifically as being the origin of scientific knowledge. Other teachers, like Eli and Sarah, were broader in where they thought scientific knowledge came from, Eli saying that “it could be anything where someone has thought about why something is, sort of causative factors and reasons that that thinking came to be." Christina mentioned the effect of "initially what we were taught" on where scientific knowledge originates, but also reports the importance of "experience" in science, using the example of the use of lab activities in the classroom for students. What could be suggested from the above responses is that the interviewed teachers seem to have consensus on how scientific knowledge is justified, through experimentation, being curious, and making observations, however they have diverse views regarding where that knowledge originates.

It is more difficult to summarize teachers' beliefs regarding the nature of knowledge, specifically in relation to the understanding of the Certainty and Development dimensions, as previously described. As seen in the language teachers used to describe what they considered science to be and how one comes to know what science is, the focus in the responses to the two interview questions was primarily on the <u>process</u> of science as a way to know or understand something. This observation does reflect the results obtained from the survey, with there being a strong support for the process of experimentation as justifying science. While I do not want to speculate as to what teacher beliefs are within these interview statements regarding the nature of scientific knowledge, perhaps one interpretation is that teachers see science as a process as compared to a specific body of knowledge. The nature of scientific knowledge is that it is a method of looking at and interpreting the world. Throughout the responses given by teachers about science, there is no mention of science being only one way of looking at the natural world or that the knowledge gathered through a scientific process is impacted by human interpretation. The responses instead suggest that teachers give weight and value to a scientific explanation because of its nature when they used phrases such as, "science is how humans make sense of the world," "science can actually explain…" (Anne), and "[scientific knowledge is] something that was in some way proven or currently believed to be true" (Karla).

Summary.

The data from the survey, scenario responses, and interviews suggest that participating teachers have a tightly defined and limited understanding of science. The importance of process and experimentation to what makes something scientific was evident throughout the data. This process of science seems to create a benchmark for what knowledge is considered valid and valuable in the science classroom for teachers, and this claim will be explored in the following sections.

Section 2: Classroom Practice and Indigenous Perspectives

This section moves from focus on the epistemic beliefs of teachers to explore their reported practice within the constructed teaching scenarios and the semi-structured interviews. Emerging from this exploration are other factors that impact teaching practice, primarily teaching context and instructional goals. The first part examines the responses teachers gave to four written scenarios constructed around different approaches to integrating Indigenous perspectives in the classroom. They were asked to choose the scenario that best reflected their current practice, followed with the scenario that they would prefer to use and to elaborate on both responses (see Appendix 3). All teachers who participated in the survey portion of the study also responded to the scenarios as part of the online component. Only teachers who participated in interviews could be identified in the otherwise anonymous responses, and so are the only ones mentioned with a pseudonym.

Following analysis of the scenario responses, a series of case studies is presented. For each case study, four pieces of data are combined to develop a more comprehensive view of factors that impact the teachers reported pedagogical choices. These case studies include survey data, scenario responses to both current and preferred practice, and responses in the interview.

Six teachers are selected from the eleven who participated in interviews. As their scenario responses are examined in detail within the case study, they will not be the focus of the next section (although they may be mentioned as part of the analysis).

Scenarios.

Table 10 below shows a summary of the scenario choices made by all participating teachers when asked to choose a scenario which best reflects their current practice, and one that they would prefer to use in their science classrooms. Pseudonyms for interviewed teachers are given. Within the study, these scenarios were used to introduce teachers to the idea of inclusion of Indigenous perspectives in the classroom and begin to try to link epistemic beliefs of science with teaching practice around this particular topic. See the Appendix 3 for the scenarios that teachers read.

Table 10

Scenario choices of all participating teachers for current and preferred practice

Teacher	Scenario chosen representing current practice	Scenario chosen representing preferred practice	Difference
1 (Karla)	4	4	0
2	2	2	0
3	2	4	+2
4 (Michael)	1	1/2	+1
5 (Thomas)	Did not choose a scenario	Did not choose a scenario	N/A
6	2	2/3/4	+1/2
7	2	4	+2
8	2	3	+1
9 (Eli)	2/3	3	+1
10 (Daniel)	2	3/4	+1/2
11 (Bradley)	1	2/3	+1/2
12 (Sarah)	2	4	+2
13	2	4	+2
14 (Anne)	2	2	0
15 (Rachel)	2	3	+1
16	2	4	+2
17	Did not choose a scenario	Did not choose a scenario	N/A
18	2	Did not choose a scenario	N/A
19 (Christina)	2	3/4	+1/2
20	2	4	+2

Note: Scenario choices for Trevor could not be identified from the online data.

Self-reported practice.

As is reported in the table above, of the 20 participating teachers, 15, or 75%, chose Scenario 2 as best reflecting their current practice. As has been previously described, Scenario 2 depicts a lesson in which Indigenous perspectives are included in a tokenistic way as a historical example for the science concept being taught. Of the remaining five teachers, two teachers selected Scenario 1, one teacher Scenario 4, and two teachers did not choose a scenario. Two groupings of teacher responses will be analyzed in this section: those who chose Scenario 2 and those who did not.

Choice of Scenario 2.

Teachers gave various reasons for choosing Scenario 2 that included: (a) specific ideas around what science is; (b) the use of cultural references or stories as a teaching tool or connection piece; (c) systemic restraints such as curricular outcomes, standardized assessments, and the time necessary for both; and (d) issues with classroom enrichment being specifically Indigenous.

A) Specific ideas around what science is.

Ideas around what science is could be understood as part of teachers' epistemic beliefs of science. A teacher's specific understanding of what science is and the place of it within the science classroom was evident when one teacher wrote,

> I believe that objective scientific principles are not cultural. Though science cannot explain everything, they are based on tested experimentation. I would never discount someone's religious or cultural beliefs, but I do not believe that they should be presented as an alternative to science in a science classroom as there is no way of testing or supporting these ideas. (Teacher 2)

Another teacher echoed this sentiment by saying "I focus on the development of scientific knowledge through experimentation, understanding of facts, and application to current processes" (Teacher 16). Both of these responses support a particular view of science that emphasizes experimentation and process, as was also evident in the previous section, looking at the epistemic beliefs of teachers in the interviews and survey.

B) Using cultural references or stories as a teaching tool.

Responses teachers made also reflected that they differentiated between what they considered to be science curriculum and Aboriginal experiences and contribute to teachers' goals for teaching science and Aboriginal perspectives. Scenario 2 was intended to exemplify a more tokenistic approach to integration of alternative experiences to a Western view of science. This was reflected in these two responses, in that they both include Aboriginal perspectives as something in which to reference for background information, but not part of the curriculum they teach. Teachers made statements such as "I do try to include cultural references (whether they be from Indigenous or other cultures) to help students make the connection that scientific principles are the result of humans trying to adapt to their environment" (Teacher 19) and "I try to approach each new concept with some historic anecdote to give a background "story" and show different views and realistic nature of science" (Sarah).

C) Systemic restraints: curriculum, assessment, and time.

Systemic restraints identified in the scenario statements contribute to an understanding of the context that teachers think they teach within. Some teachers referenced Indigenous perspectives as outcomes within the Program of Studies document and related how they approached these in the science classroom. One teacher said,

> I tend to focus more on delivering the knowledge and skills outcomes of the curriculum. I do address the attitude outcomes where I can, as well. I would not have time to cover the traditional and current ways that snowshoes are made, for example. I really have to focus my time in covering content and giving students time to practice that content (i.e. calculations, labs, etc.). (Teacher 3)

In this comment, the relationship of time and what is deemed "important" in the written curriculum becomes evident. Although other teachers did not specifically describe the inclusion of Aboriginal perspectives as being an “attitude outcome,” the idea that it is extra to the teachable and testable curriculum is apparent in other responses. One teacher thought Scenario 2 “represents a situation that would be quick and to the point. We could then move on to the next objective” (Teacher 8). In another response, the teacher saw value in “mak[ing] a connection to other influences that might not typically be noted in the curriculum and credit to non-western scientific practices,” but that eventually he would have to “move on due to curriculum constraints” (Eli). There was a sense that teachers felt limited by what they could do within the classroom, due to their interpretation of the Program of Studies, as well as time available to work through the material they considered to be important to building students’ knowledge of science.

D) Issues with classroom enrichment being Indigenous.

Finally, teachers mentioned their view that alternative experiences and perspectives to a more Western understanding of science did not necessarily have to be Indigenous. Some teachers approached this from the standpoint that other cultural perspectives should also be included, evident when one teacher said that the background “stories” he/she includes are to “show different views and realistic nature of science…are from all over the world; not specific to Indigenous people of Canada” (Sarah). Other teachers perceived integration of Indigenous perspectives as not being necessary because of their classroom demographic. One teacher said, “my classroom contains a largely immigrant community. I generally will have only one or two students with an Aboriginal background. Tying my lessons so strongly to the Aboriginal culture is not meaningful to the majority of my students” (Teacher 7). Another teacher had a similar response by saying that he/she did not usually have “many, if any, Indigenous students enrolled and as a result, I don’t feel the impetus to focus specifically on Indigenous connections in class” (Christina). Rejecting more integrative scenarios, such as Scenarios 3 and 4 (see Appendix 3) based on a class demographics, and conversely, choosing to include alternative perspectives because of Aboriginal students being present, represents a tokenistic approach to integration, as well as a lack of understanding of the written science curriculum. This was also seen within the interviews, as will be elaborated upon in subsequent sections.

Other choices of scenarios.

As seen in Table 10, five teachers did not select Scenario 2. Michael and Bradley's response for current practice will be explored in greater detail in the case studies (next section), as well as Thomas' response as to why he did not select a scenario. Karla chose Scenario 4 as reflective of her current practice. She wrote that she thought it was "important that all students have a voice and are allowed to share their perspective and knowledge on various concepts. This assists all students in their learning and provides an opportunity for students to develop and appreciate various cultures and perspectives." Karla's response suggests that she interpreted Scenario 4 as being a pedagogical strategy that allows students to share perspectives and knowledge, rather than as the intended view that science is not restricted to a Western understanding, but rather has multiple definitions. This suggests that Karla did not understand the intention of the scenario, an issue that was evident in teachers' responses for scenarios reflecting their preferred practice.

Preferred practice.

The response to the scenarios became much more varied when teachers were asked which scenario they would prefer to use and why. Teacher responses can be separated into two groupings: those whose choice for preferred and current teaching practice were the same, and those whose preferred teaching practice differed from their actual practice.

Current and preferred practice stayed the same.

Three teachers' choice of preferred practice were the same as their choice for current practice. Two selected Scenario 2 again, one teacher saying that Scenario 2 "highlights the contributions to medical knowledge by Aboriginal peoples, but does not stray from scientific principles" (Teacher 2). This response suggests a tokenistic approach to integration and suggests that the teacher perceived Aboriginal experiences and discoveries to be separate from scientific knowledge, which was in line with the intended theoretical perspective of the scenario. Another teacher who chose Scenario 2, however, also seemed to consider the teaching practices of Aboriginal peoples as being useful in his/her class. This response indicates that this teacher sees the potential for an influence on his/her pedagogical practice, rather than simply the content of the classroom. He/she wrote,

> I'm not particularly comfortable with either Scenario 1 or 3, although I've thought at times about how effective story-telling has been in many cultures, particularly in holding the attention of the audience. It's not an area that I feel very practiced in, but I wouldn't mind using story-telling more in my classroom. (Teacher 18)

Karla kept her choice for preferred practice as Scenario 4. She wrote, "this scenario allows me to interconnect student perspective with scientific outcomes and knowledge. I love that students are learning from each other and developing an understanding of cultural perspectives and knowledge." The context of how Karla would interconnect student perspectives with scientific outcomes in the classroom could be extrapolated from her response to her current teaching practice where she wrote that she thought it was "important that all students have a voice and are allowed to share their perspective and knowledge on various concepts." It is unclear from these two statements whether or not Karla would integrate Indigenous perspectives in a teacher-directed manner or by simply providing opportunities in which students could share their cultural perspectives if they chose to.

Current and preferred practice were different.

Fourteen teachers changed their scenario choice for their preferred practice, as compared to their current practice. Teachers either chose Scenario 3 or 4 as preferred or chose multiple scenarios to reflect what they would like to do in the classroom. For the nine teachers who chose either Scenario 3 or 4, responses indicated that teachers liked the holistic and integrative approach of Scenarios 3 and 4. One teacher wrote that Scenario 4 had “more explanation and tying together all of the concepts” (Teacher 20) and another said that he/she liked Scenario 4 because, “not all concepts (such as the development of Aspirin) are linear and I like the interconnected curricular outcomes” (Teacher 16). Eli wrote that he would like to have “more planned Scenario 3,” in order to “integrate [Aboriginal perspectives] better as opposed to bringing it in as a sideline and moving on might allow a deeper learning process to occur.” There seemed to be an interest in the more student-focused nature of the two scenarios, where students interact with each other and the teacher as learners, as compared to the teacher-centred focus of Scenarios 1 and 2. This was evident in one teacher’s explanation for why he/she chose Scenario 3 in saying that it would “allow students to be more involved in the class” (Teacher 8). Sarah’s response, supporting her choice of Scenario 4, also reflected this interest when she wrote,

> the idea of having dialogue about different views, discussing similarities, and differences appeals to me. The more I teach, the more important I think it is to have open conversation and to create a classroom where different perspectives can be safely shared.

While this statement does not specifically mention students learning from each other, it does suggest a less teacher-focused classroom in encouraging open conversation with students where they would have more input in the content of the classroom. Providing this type of classroom environment as a way to address integration of Indigenous perspectives was used by an interviewed teacher and is explored in more detail in his case study.

As seen in Table 10, five teachers selected multiple scenarios for their preferred choice. One teacher chose Scenarios 2, 3, and 4 as being his/her preferred method of teaching, saying that "Scenarios 2-4 all have desirable aspects that may apply to certain situations" (Teacher 6). Unfortunately, this teacher did not elaborate on what those particular situations might be. Michael chose Scenario 1 as his current practice and Scenarios 1 and 2 as his preferred choices, although he only chose scenario 2 because, as he said, "there [was] nothing about it specifically being an Aboriginal source of experimentation versus any other race throughout history." He thought that Scenario 3 was too narrow-minded in framing the lesson only from an Aboriginal perspective and that Scenario 4 was the same as Scenario 2. Bradley chose both 2 and 3 as his preferred practices. He wrote that,

> it would be nice to incorporate more experiences from Scenario 3 into my lessons. There are stories from many cultures and theologies that science have proven to be misleading. These stories provide points of discussion or ethical dilemmas, rather than an explanation of how the universe works.

This response clearly supports Scenario 2's underlying idea, particularly in acknowledging how science has "proven" stories from various cultures to be "misleading," a more hegemonic Western view of science. Bradley's response indicates that his interpretation of Scenario 3 was not in line with the underlying ideas it meant to represent. Christina and Daniel thought that Scenarios 3 and 4 had various aspects that they would like to apply to their teaching. Daniel chose these scenarios as he thought that "they seem[ed] more interesting." Christina said that, "if

I did have Indigenous students in my class, I would prefer Scenario 3 or 4, if I were given the appropriate supports in terms of developing my background knowledge." The influence of classroom demographics and the perceived lack of resources on integration of Aboriginal perspectives in the science classroom were issues that other teachers also reported and are elaborated upon in the next section of this chapter on Identified Constraints to Inclusion of Indigenous Perspectives.

While several teachers changed from Scenario 2, the tokenism scenario, as their current practice to Scenarios 3 and 4, which were intended to represent a pluralistic and multi-science perspective for inclusion of Indigenous perspectives, respectively, the explanation they provided of why they chose that scenario suggested that their interpretation of the scenario did not align with the intention of the researcher. This was evident, for example, when Sarah wrote,

> Scenario 4: the idea of having dialogue about different views, discussing similarities and differences appeals to me. The more I teach the more important I think it is to have open conversation and to create a classroom where different perspectives can be safely shared. I find it difficult because of my inherent teaching habits to fully incorporate this style of teaching (returning to lecture, practice problems, quizzes when feeling time restraints). I thoroughly enjoy time to discuss ideas from students that question the fundamentals of science and try to show historic examples where scientific "truths" were debunked. I believe this allows students to feel more free to question things that don't feel right.

This response suggests a more pluralistic viewpoint in that there is evidence of a distinction between science and another perspective. Another teacher's explanation of his/her choice of Scenario 4 suggested that the choice was not specifically for Aboriginal knowledge itself, but rather how it might enhance teaching practices and learning of the students. This was evident when he/she said,

> Scenario 4 as it covers the content as well as provides links to the outside world. It provides an Aboriginal connection as well. I like this scenario as it covers the scientific principles, gives mathematical calculations, as well as providing the real-world context. I think that it helps bring science alive to the students. It could also broaden their interests. (Teacher 3)

The "real world context" that the teacher likes about Scenario 4 removes Indigenous knowledge from its context and makes it into a tool for teaching scientific principles. This explanation suggests a tokenistic viewpoint, compared to the multi-science perspective that was intended. Tokenism was also evident in another teacher's response when he/she wrote, "I think [Scenario 4] presents a good way to introduce and respect contributions to our current knowledge by Indigenous cultures without losing the focus of the lesson" (Teacher 7). This teacher's framing of Indigenous knowledge around its contribution to "our current knowledge" strongly indicates tokenizing Indigenous knowledge as something historical. As seen earlier, Bradley's use of Scenario 3 in order to "provide points of discussion or ethical dilemmas, rather than an explanation of the way the universe works," looking at stories that science has "proven to be misleading" suggest a scientistic perspective where science has authority over another domain of knowledge.

Two teachers did indicate a closer alignment with the intent of the scenario chosen. For instance, about his/her choice of Scenario 3, one teacher wrote,

> This scenario would display to the students a number of important factors: 1) the importance of providing valid information for both sides of a topic (benefits and risks of

> human activity); bias-balanced approach, 2) discussion on the limitations of science; science is an ongoing process that is constantly evolving, 3) students would be discussing with each other, having input, and expressing their ideas. (Teacher 8)

The teacher went on to write that one of the important skills students would learn from this would be “the importance of understanding or at least hearing the insights and being made more aware of Indigenous perspectives.” This response strongly reflects the epistemological plural approach to integration intended by Scenario 3 in its separation and validation of areas of knowledge. Rachel had a similar explanation of why she selected Scenario 3 as her preferred teaching practice in saying that the situation in Scenario 3 would “prepare students for real world issues” and help “students appreciate that there are valid aspects in other worldviews.” This response will be analyzed in greater detail in Rachel’s case study. In both responses, time or the lack thereof, was brought up as potential barrier to structuring a class this way, Rachel saying, “if time allowed…” and the other teacher, “it would be nice to have time for this.”

Summary.

Responses from the scenario portion of the study introduce common themes that were evident in the interviews. These were the perception that Aboriginal perspectives were not an important part or absent from the mandated science curriculum and that what teachers were currently doing in their classroom is not what they would prefer to be doing. The perception that the majority of teachers who participated in this study consider Aboriginal perspectives to be outside of the written science curriculum and as such, extra to what is deemed important to teach, was a theme that also emerged in the interviews. It is important to consider this view when exploring the relationship between teachers’ epistemic beliefs of science and their impact of inclusion of Indigenous perspectives. It was also evident throughout the scenario responses that the majority of teachers are currently doing in the classroom is not what they say they would prefer to do, as seen by the difference in scenario choices for current and preferred practices. However, in their preferred responses, there was evidence of some lack of alignment between some teachers' underlying beliefs and the intention of the scenarios. This is explored further in the case studies in the following section as well as in the discussion chapter. In the scenario responses, barriers that teachers perceive to impede their preferred teaching practice were introduced. These included both intrinsic and systemic barriers and will be explored in greater detail in the final section of this analysis.

Case studies.

Case studies are used as a means of looking at data collected from the interview portion of the study in conjunction with the survey and scenario data for selected teachers. In doing so, a closer examination can be made of the connects and disconnects of teachers' epistemic beliefs of science and their reported classroom practice of inclusion of Indigenous perspectives. The case studies are also a way to represent the interaction between the three factors impacting teaching behavior: epistemic beliefs, goals, and context. Four pieces of data are employed: survey dimension responses, scenario responses regarding actual and preferred practice in incorporating Indigenous perspectives, and the supplementary information from the interview. Epistemic beliefs of science that became evident during the interview are distinguished in the case studies using the two categories that the epistemic belief dimensions fall under: nature of knowledge (Certainty and Development) and process of knowing (Source and Justification) (see the previous section focused on survey results for an explanation of these dimensions). This was done as it was difficult to identify statements that teachers made as being specifically one epistemic belief dimension or another. Each interview was also unique in how teachers spoke to their actual and preferred practice, where some teachers focused on one practice more than another.

Each case study is unique in regard to the level of influence that each of the three factors on a teacher's practice. For example, one teacher's teaching practice may be more influenced by his/her epistemic beliefs, while another teacher's teaching context impacts his/her pedagogical choices more. In some case studies, it appears that the three different factors can be at odds with each other and create a disconnect between what the literature indicates about the connection between teaching practice and particular beliefs of scientific knowledge. This was the realization, identified earlier, that induced the shift in the original research question.

Six of the eleven teachers interviewed were selected for case studies. Teachers were chosen for two reasons. First, the epistemic beliefs of each teacher clearly connected to their practice for inclusion of Indigenous perspectives in the science classroom. The second reason a teacher could have been included was that he/she represented a major finding for the study. Background information is provided for each teacher to help introduce him/her to the reader. Each case study is unique to each teacher as his/her teaching practices are particular to the beliefs, context, and goals, of each individual teacher.

Case study: Bradley.

Introduction.

Bradley is a physics teacher who has been teaching for nine years. He has a Bachelor of Science in General Mathematics and a Bachelor of Education degree in Secondary Mathematics. Bradley demonstrated a clear connection between his epistemic beliefs of science and practice within his interview and was the most obvious example of scientism in the group of interviewed teachers. He was included as a case study for these reasons.

Case study.

In relation to his beliefs around the nature of knowledge, Bradley's responses indicated that he considered scientific knowledge to be "truth" and to be universal in its explanatory power. He used the term "truth" to describe scientific knowledge in the interview, saying, "we can rely on scientific truths because of the way we have gathered evidence." When discussing the example lessons in the scenarios, he said that when using an example from another culture, it was necessary to "maintain that there is a truthfulness that needs to be upheld with what we are talking about." In the interview, Bradley was asked about his views on the contrast between different perspectives to Western science and that of a Western science perspective. In response to that question, he said

> I think that everyone's experience is important in terms of what knowledge they have. It's an indication of what knowledge they possess, and if we can contrast that with science, I think there's opportunity to link those ideas so, you know, many people want their experiences to be validated, and that's great, we want your upbringing and your culture and your stories to be validated. When we start probing deeper into "is there any evidence to that," this is where it gets difficult between people's experiences and scientific truth.

By applying "truth" to his understanding of the nature of scientific knowledge, this type of response supports a scientistic perspective. Describing knowledge as "truth" inherently attaches value to it, above other forms of knowledge. A scientistic view is further supported in the continuation of the above quote, when Bradley says, "I like the idea of taking multiple perspectives and then providing a scientific explanation for maybe parts of that, sifting through some of those things that are *only* anecdotal story based" (my emphasis). "Only anecdotal story based" suggests less merit given to knowledge originating in personal experiences and an oral tradition and the value that Western science can give to multiple perspectives in its explanation. This is further supported in his explanation of his choice of Scenario 2 with elements of Scenario 3 as his preferred choice in the scenario portion of the study. Bradley wrote, "there are stories from many cultures and theologies that science has proven to be misleading. These stories provide points of discussion or ethical dilemmas, rather than an explanation of the way the universe works." Using the phrase "proven to be *misleading,*" again places value on the explanations of Western science, rather than another cultural perspective. However, he goes on to write,

> Science too, though, is faulted with being too prescribed with its way of seeing the world. Having more opportunity to unify students' thinking and perspectives of the world speaks very closely to my pedagogical beliefs of learning. The more opportunities or experiences that we can provide students to work through, challenge, and learn from others is a worthwhile feat in my opinion.

This statement reflects some of the ideas underlying the epistemological pluralism of Scenario 3 in recognizing the limitation of a scientific worldview and providing opportunities for students to challenge and learn from other perspectives. However, it is in contrast to the inherent value he places on science in other parts of his responses.

A scientistic perspective was also evident in Bradley's belief in the universality of scientific knowledge that emerged from the interview. For example, he said,

> When you look at the example of the willow bark, for example, that's experiential evidence, right, so someone's saying "look, we found if we chew or we brew this, our pain goes away." That's using experiential evidence, and the science would take hold of that

> and say "and this is why, because what's in the willow bark is the acetylsalicylic acid," and make sense of it and does that multiple times, multiple trials, and send out multiple samples that the different willow barks in different regions would have different concentration of that chemical. So, it's a way that we take these stories, these experiences, and we can make even more sense of them and apply them outwards.

From this statement, not only is it evident that Bradley sees science knowledge as being universal, but also that Western scientific inquiry can make cultural experiences *more* universal in saying that Western science can "apply them outwards." This perspective is supported later on when he describes science as being a way to unify different cultural beliefs, saying "it would be interesting to know what there were of those cultures that we could incorporate more scientific knowledge or belief into" and that "if there's a way to link [different cultural beliefs] through scientific evidence, then that just helps to unify people a little more." In these statements, there is authority given to Western science because of its perceived universal nature and application. Applying universality to the explanatory power of science suggests that Bradley considers science to be outside of human influence. This was supported in his survey responses to the Development dimension when he indicated that he did not support the notion that culture had an influence on what was considered science (2/5).

Epistemic beliefs around the process of knowing also indicated Bradley's scientistic perspective. He described science as "a way that we gather evidence and then from that evidence, doing an analysis that helps us make sense of what's happening." When comparing an Indigenous way of knowing with that of a Western scientific understanding, he did not think that the two were the same because, "we look at process, we look at evidence, we look at how we gather and make sense of it." According to these two statements made by Bradley, scientific knowledge originates in a particular way of looking at the world. The use of "we," suggests a gap between an Indigenous way of knowing and a scientific one. This was in contrast to some of his responses to Source dimension statements in the survey. His mean score for the Source dimension was 3.5/5, but this close to neutral score is misleading as Bradley was polarized in his response to individual statements within the dimension. While his score of 5/5 suggested that he strongly supported the idea that there is only one definition of science as determined by scientists, his other responses in the Source dimension indicated that he was not supportive of the idea that everyone should believe what scientists say and write and that valid scientific knowledge comes from experimentation by scientists (2/5 and 2/5 respectively). The discrepancy between the response to the latter two survey statements and his evident beliefs around the authority of Western science was also evidenced in his choice and explanation of Scenario 2 as best reflecting his current practice. In his response, he said he "like[d] the idea of experiential learning along with observational, theoretical, and practical application to how we understand the universe." With the example of Scenario 2, he wrote that,

> we can attribute the Aboriginal discovery of chewing and brewing willow bark to their experiential discoveries. We can add to this idea by sharing that scientists have further discovered that the chemical responsible for relieving pain was done using a scientific process. There is a connection here between experience and scientific inquiry.

In this response, Bradley again separates himself and content in the science classroom from that of an Indigenous perspective in the use of "we" and "their." There are clear indications that he has a defined personal definition of science that allows him to separate an Aboriginal "experience" from "scientific inquiry."

As seen in previous statements, this teacher separates experiential evidence from scientific knowledge. In response to the question of how we come to know what scientific knowledge is, Bradley replied,

> When we look at the way that science is conducted, research, observation, anecdotal records, we start to collect patterns. Those patterns can be in the form of data collection, they can in forms of themes and patterns from your records. From those themes and patterns, we can then run statistical processes to be able to understand if there is significance from them, is there is a correlation, is there a causation we can lead to, a test to go to. How we come about that is from our observations, our experiences, from our general inquisitive sense of learning and trying to understand what those things are.

The importance of data collection and analysis is evident in this statement, but what is interesting is that he mentions anecdotal records as being part how science is collected, while later on, he distinguishes experiential evidence from what he considers to be valid scientific information. In this statement, he seems to be speaking to anecdotal records in the realm of Western science, while experiential evidence is discussed when looking at various cultural perspectives. This reinforces his inferred scientistic view; anecdotes from those categorized as "we" have more validity in what is scientific knowledge than do the experiences of those classified as "they."

Summary.

While there seemed to be some discrepancy within the survey and scenario responses in regards to Bradley's epistemic beliefs and subsequent practice of inclusion of Indigenous perspectives, the interview data provided evidence of a much clearer connection. The truthfulness and universalism that was given by this teacher to the nature of scientific knowledge influenced his pedagogy, as demonstrated in his vision of a science lesson showing how science has built on different cultural ideas from the past and in the ability of Western science to prove and disprove various traditional notions. Choosing Scenario 2, the "tokenism" option, as his preferred practice, correlated with how he views scientific knowledge as compared to an Indigenous perspective. He considered science as being a way to "validate" the culture and beliefs of students and provide a bridging point between different cultures within the classroom. These considerations suggest a connection between Bradley's beliefs and his goals for the classroom in what and how students should learn science. By using the scenarios as examples throughout his responses, Bradley was able to provide a much clearer connection between his epistemic beliefs and pedagogical choices.

Case study: Thomas.

Introduction.

Thomas had been teaching for eight years. While primarily he has taught biology, he has more recently taught general science and chemistry at the grade 11 and 12 levels. He has a Bachelor's degree in science and an Education degree. He works in a small school with a higher Aboriginal student population, as compared to most schools within his school district, due to the close proximity of a First Nation reserve. Thomas was included as a case study because while he has specific parameters of what can be considered "science," he does not limit it to one, more Western perspective. Rather, he values multiple perspectives to help build understanding and make decisions in society and represents a more multiscience perspective within the group of interviewed teachers. There is a difference for Thomas between the process of collecting data and interpretation, the latter being affected by one's language and worldview. His beliefs about knowledge do have an impact on his pedagogical choices in the science classroom, although not in the ways that were suggested in the constructed teaching scenarios.

Case study.

In his interview, Thomas repeatedly cited the definition of science that he gives to his students: “it has to be testable, it has to be repeatable, it has to be observable, and you have to be able to make predictions.” Thomas reported that if a question was not able to satisfy those four parameters, “then it’s not science; not to say that it’s not a valid thing to research, but in and of itself, it probably wouldn’t be scientific.” These four characteristics describe a process in which scientific knowledge can come about, contributing to his beliefs around the process in which one comes to know scientific knowledge. The emphasis on being able to “do” one of the parameters listed above suggests that he identifies a way that is valid for building scientific knowledge. This was supported in the interview when he said,

> I think you come to know by experimentation and by interacting with your world and by being curious. I think science is the avenue to do that; it’s really not about the answers you are trying to find, it’s about the questions.

The importance that Thomas places on experimentation in the process of coming to know scientific knowledge was supported by his mean Justification survey response of 5/5, suggesting that he strongly supported the position that experimentation is important for justifying scientific knowledge. Thomas also supported the notion that scientific knowledge was a dynamic field of knowledge, as evidenced by a Development mean of 4.25/5.

A belief that Thomas had around the process of knowing was the importance of perspective in understanding and interpreting science. He said that “science is science, no matter if it’s chemistry, physics, or biology; they’re all dialects of the same language.” Although

Thomas says “science is science,” he limits it to modern divisions of chemistry, physics, and biology fields. He goes on to say that “you have to understand the subtleties of the language, and everyone interprets those differently.” Thomas returned to the importance of interpretation when he discussed his views on scientific data. He distinguished between the data, which fit into his parameters of what can be considered science (“testable, repeatable, observable, and you can make predictions”), and the interpretation of that information. In the interview, he said that “the interpretation of the data is going to have multiple perspectives,” going further to say that “when we are talking about scientific research, we need multiple voices, and we need multiple perspectives.” He used the example of Aboriginal worldviews and science, saying,

> If I’m looking at how snow packs and how it separates and then how it changes over time, I am going to see only one viewpoint, if I’ve studied it in only one class in university. But if I’ve lived around it my whole life, have a living history with it, my culture has seen it and experimented and seen it in multiple ways, then I’m going to have a broader understanding. I’d want to have that voice when I’m trying to understand how glaciers work in the Rockies.

The value that Thomas places on multiple perspectives in these statements was consistent with his mean response to the Source dimension of 2.75/5. Thomas’ more negative response to this dimension as compared to the group mean of 3.2, suggests that he is less supportive of the position that scientific knowledge comes from an external authority. The importance of Thomas’ understanding of multiple ways of knowing and interpretations is more evident when analyzing the connect and disconnect of his epistemic beliefs of science with how he integrates Aboriginal perspectives in his classroom. For now, the value that he places on other perspectives and the partial multi-science view (where science is not limited to a Western definition) he has should be noted with his epistemic beliefs of scientific knowledge.

In both his scenario and interview responses, Thomas reported that it was important to give voice to different cultural perspectives in his classroom. Thomas did not choose a scenario for his current or preferred practice. In response to his preferred practice, he wrote that he thought that there was not an ideal teaching style for every classroom situation. He thought that an important question to be asked was “how do we not only give Indigenous Peoples a voice, but *everyone* a voice in a modern, culturally diverse classroom?” (emphasis added). In the interview, he described how he tried to make many of his courses project-based in order to give students the opportunity to share their perspectives and experiences in relation to particular topics being taught. For example, Indigenous students in a Science 24 class completed a project on brain tanning (a process used by Aboriginal people that uses animal brain matter to preserve animal hide (Boren, Baker, Hurd, Mason, & Knight, 2004)) in conjunction with learning about environmental chemistry. Thomas described this project, saying,

> I got a PowerPoint from them about brain tanning; so, they talked about, they connected, cause a big thing is environmental toxins, dioxins, furrans, and all sorts of stuff. I’ve actually used it a bit in Science 30; so, they looked at organic pollutants, you know POPs (Persistent Organic Pollutants) and stuff like that, and they looked at brain tanning and compared to sort of an industrial process. They took the concept from our curriculum and brought some of their own experiences with tanning hides into that.

There is a separation here of the knowledge that the Aboriginal students have from the curriculum when he says “our curriculum.” This suggests some ownership over the curriculum being presented in the science class. Thomas continued by saying that he incorporates these types of projects into his instruction “when I have time and when I have the clientele, that have the right interests. I try to tailor my classes to what my clientele is, I try to bring as much other stuff in as I can.” This statement suggests that Thomas does not perceive Indigenous perspectives to be part of the science curriculum, but rather as “other stuff.” Allowing students to explore what are considered curricular topics through projects that can incorporate their own perspective also seems to be for the sake of the student. It does not support that these projects are for the incorporation of Indigenous and other cultural perspectives as a “normal” priority in the classroom. Thomas indicated that this was a way to be culturally sensitive, allowing students to “talk about their culture and stuff like that,” and “give them a voice from time to time.” This coincided with factors impacting how he currently taught, as identified in his response to the scenario portion of the study. He wrote,

> The reality is that your approach changes dependent on the situation. There are things you need to consider: time (usually being the utmost importance), demographics, general interests of the students, content (not all content is as suited for offering an Indigenous voice), and a host of other things that come up organically throughout the semester.

Thomas’s response is reflective of issues that were repeatedly expressed by teachers, both in the responses to the scenarios and within the interviews, such as time, classroom demographic, student interest, and curricular outcomes.

The practice of giving opportunities for students to share different perspectives than that of a Western science one is disconnected with what it seems are Thomas’ epistemic beliefs of science. Earlier, statements he had made around the influence of interpretation on knowledge and the importance of differing perspectives on how data are understood are in direct contrast with his reported pedagogical orientation. In statements he made about the importance of different perspectives to understanding data, there were clear indications that he valued Indigenous knowledge for its own merit. This was further supported in the interview, when he said that “when we are talking about scientific research, we need multiple voices and we need multiple perspectives.” This position was not reflected in the more “tokenistic” practice of incorporating projects that give voice to students’ cultures only when a particular demographic is present. Thomas wrote in his scenario responses that “one must also consider other ethnic groups to be culturally sensitive in a Canadian classroom.” The incorporation of Indigenous perspectives (and other cultural perspectives), as opined by Thomas in his responses, suggests that it is a tool in which to give a voice to other viewpoints to be culturally sensitive, and perhaps, ethical, rather than as an important and necessary part of the science curriculum. This theme was evident in other teacher responses and will be further identified and discussed.

Summary.

Giving students opportunities to include their personal experiences and knowledge with their growing understanding of Western scientific knowledge partially demonstrates a multicultural approach to science education. However, the presence of Indigenous perspectives and experiences alongside more Western science perspectives in Thomas’ classroom was because of student input rather than viewed as directives of the written curriculum by the teacher. While the data presented suggest that Thomas does value an Aboriginal perspective in science to some extent, it translates into his own interpretation of the science curriculum in a limited way in that he tailors various courses with more project-based learning dependent on the demographic present. This, however, was a more intentional approach to including alternative perspectives in the science classroom than any of the other teachers who were interviewed. What is striking about Thomas’ practice is that there seems to be a disconnect between the value that

Thomas places on Aboriginal perspectives and how he structures his science classes to allow for this, and other cultural, perspectives. It would seem that the context (demographic of the classroom, interpretation of curricular outcomes, and time) may be in contrast with his beliefs and goals in regards to knowledge, creating a partial multicultural approach to science education.

Case study: Michael.

Introduction.

Michael is a physics teacher who has been teaching science for ten years. He has a degree in Mathematics as well as an Education degree with a double major in mathematics and physics. Through his teaching experience and collaboration with colleagues, he has built on the idea of science being a system of models which can make predictions about "why" various natural phenomenon work. Michael limits scientific explanations to that which is related to the natural world and brings this perspective into his classroom teaching and conversations with students about science. For Michael, scientific knowledge comes from the science community, in what scientists say and write. Michael is included as a case study as he clearly demonstrated an understanding between different forms of knowledge that translated into his teacher practice. His beliefs about knowledge influenced his teaching goals and subsequent behavior in the science classroom.

Case study.

Throughout his survey responses and within the interview, Michael made clear statements regarding his epistemic beliefs regarding scientific knowledge. When considering the nature of scientific knowledge, Michael described science as "[not] just a body of facts; science is about models and finding ways to explain the world that's useful for us being able to make predictions." In his science classrooms, he tried to "make it more focused on the kids realizing that, it's not a collection of facts or truths, that they can't prove things." This view was supported by his mean Certainty survey response of 1.6/5, suggesting that he did not think that there can be certainty in the answers that science can give. Scientific knowledge, as inferred from Michael's interview responses, is limited by its explanatory power, evident when he said that "science gives us explanations to make a specific type of prediction about the world." He reported that he did not believe that science "necessarily need[s] to conflict with other ideas or beliefs" and thought that, "belief systems don't really matter in the scientific community, because they're not really relevant to what the scientist is saying." It is evident in these responses that Michael has developed a clear distinction between what he considers to be science and beliefs or "other ideas." In speaking to the predictions that science can make, he clarified, saying that "science isn't talking about things outside of the natural world; they are constricted to the natural world." It was evident that he also considered science to be a dynamic knowledge domain, saying that he wanted his students to recognize science as "more of a process and something that builds and changes over time." This specific statement was supported by his individual survey responses to statements in the Development dimension focusing on the dynamic and evolving nature of scientific knowledge, where he either responded to most items with a 4 or 5 out of 5 (agree or strongly agree, respectively). His response to the Development survey statement, "conclusions made by scientists are always objective," however, was dissimilar to other statements in this dimension with a response of 1/5 or strongly disagree. Michael did not include the objectivity of scientists as part of his interview responses, so this survey response provides the only information of Michael's perception of this aspect of scientific knowledge.

Within the epistemic realm of process of knowing, there were inconsistencies between interview responses and his mean response to both Source and Justification dimensions. Michael expressed that he thought scientific knowledge primarily came from the scientific institution, which was in contrast to responses to two survey statements in the Source dimension. Michael responded with 3/5 or "unsure" for the statements "valid scientific knowledge comes from experimentation by scientists" and "there is only one definition of science as determined by the scientific community." This suggests that he was unsure of the role that the scientific community had on what is considered science and what is considered valid science. However, when asked in the interview how we come to know what scientific knowledge is, he replied: "from scientists in the field, either directly from them in things like classes or discussions with them or through reading papers, or then, farther removed from that, in journal articles or in pop science type magazines." He said that it was "easy to find that kind of [science] information, from good sources." As a source of scientific knowledge, Michael reported that he was interested in the history of science and the progression of scientific thought and liked to incorporate this into his classrooms. He said that,

> I actually like the history of science stuff, so I do a lot of incorporating of where scientific progressions came from. Most of our scientific progressions came from Europe, because when you look at worldview, for whatever reason, European culture tends to be the most interested in trying to figure those things out.

Michael's limited view of science seems to impact his perception of scientific progression, making it Eurocentric and dismissive of other contributions to modern science. This was further supported when he expressed that he did not consider a trial and error approach to developing technologies as contributing to scientific progressions. He said,

> a lot of cultures were more around trial and error side of developing technologies. You look, some of the best metals ever developed came out of China. But they didn't

> do it because they were studying chemical reactions, they did it by trial and error. They tried something, then they tested it, and were like, “oh? That worked better,” so they tried something else, “oh, that worked better and, oh, that didn’t work.”

This statement separates what Michael considers to be a “trial and error” way of developing technologies from a valid source of scientific knowledge. The focus of finding out “why” was important to Michael in classifying something as scientific, evident when he said that scientific progression began in Europe because they were interested in “not just going, “oh, this is how you can make this technology work,” to why does this work?” and building a systemic approach to finding these answers. Again, the emphasis is put on the European or Western contribution to scientific knowledge with no consideration of the value of other culture’s contributions or if they also had a perspective of trying to find “why” something worked. The importance that Michael placed on the work of scientists and the pursuit of finding the underlying causes of natural phenomenon in the interview was, again, in contrast to responses made in the survey within the Justification dimension. In this dimension, Michael had a more neutral response of 3.5/5 as compared to the average of 4.61 from the other participants. While most teachers agreed that experimentation was an important factor in justifying scientific knowledge, Michael’s response suggested that he was more unsure with a mean close to 3.

There were clear indications of a connection between Michael’s epistemic beliefs of science and how he described incorporating Aboriginal perspectives in the classroom. Michael was the only teacher who participated in the study who chose Scenario 1 as reflecting his current and preferred practice. The theoretical construct behind Scenario 1 was scientism, in that the teacher in the scenario disregarded any alternative perspective regarding Aboriginal perspectives as worthy of consideration or discussion in a science classroom. Although Michael chose this scenario, he did clarify, saying that the last part of the scenario was not like his teaching style because he thought it said that "science was right and your little beliefs are not useful," which he was not in agreement with. He wrote that he chose Scenario 1 as being reflective of his current teaching practice because he "believe[ed] that science education should be focused on scientific knowledge and its interconnections to our society, not from a narrow view of a specific culture, but a holistic view of the limits of scientific knowledge." When speaking of his preferred practice in the scenario portion of the study, Michael gave similar reasoning for his choice of Scenario 1. He described scientific knowledge as "our present understanding of natural phenomena; it is a series of models that are used to make predictions about outcomes to experiments" and said that "science only gives us outcomes to experiments, and so there are questions it cannot answer." This response suggests that Michael sees science as being a defined domain of knowledge that has its limitations. In the interview, Michael expanded on these views, saying, "when we're talking about scientific knowledge, which might be the point of the scientific classroom, that knowledge should be based around those ideas, not on other ideas." "Those ideas" that Michael is referring to in this statement reflect his belief that science is specific to predictions about the natural world. He expressed that he thought it was important to understand that "the science classroom is for scientific models." The science classroom, as expressed by Michael, should reflect this understanding.

Michael took issue with the other scenarios, particularly in their focus on an Aboriginal perspective and its relationship to science. He wrote,

> [Science] has no ability to tell you how the world actually is, but it can help you make predictions as to the outcomes of an experiment or event. So, it doesn't matter if you have a North American Aboriginal worldview, a different Aboriginal worldview, or a Jewish

> worldview, or a Buddhist worldview; science does the same thing for you, and can only provide you with a specific type of knowledge. This whole idea to frame things in an Aboriginal worldview is silly and a waste. Many races have contributed to our understanding of science. Give them credit where credit is due. We shouldn't be limited to this narrow, Canadian, nationalistic view.

This statement proposes to me that Michael considers a "worldview" to be separate from his understanding of science. It should also be noted that he uses the term "race" rather than "culture" when looking at contributions to Western science. Throughout his responses, there is the sense that Michael sees science as existing outside of, and potentially above, a human worldview. There were clear indications that Michael's view on the place of alternative perspectives to Western science in the science classroom was focused on the culture's contributions to what he considers to be scientific knowledge. He wrote,

> we have not been using science to design technologies until the last 50ish years and so you can use any example of any technology made in the past by any culture and you will find similar examples of technology leading science.

In saying that science has not been used to "design technologies until the last 50ish years," Michael further articulates the position that he holds an understanding of science that severely limits where (and when) scientific knowledge can originate and be used. "Cultural contributions" are considered outdated and historical to the more modern Western science advances in this statement.

When asked in the interview why he thought Aboriginal perspectives were part of our curriculum, he said that it was an "attempt to placate a political issue. The fact that we did horrible things to the Aboriginal people, it's trying to recognize some of the contributions they made." If these "recognitions" fit within a particular curriculum, he supported the inclusion of the perspectives, but he considered forcing in Aboriginal perspectives did a "disservice to both sides." He said that "it does fit in, especially in lower levels, there are lots of things, and there are some areas in biology where it fits in, but there's other curriculums where it doesn't." Michael's responses suggested that he did not think that incorporating non-Western science perspectives in the classroom necessarily had to or should be Aboriginal. He said, "I think we should be using ideas from cultures around the world that contributed to science, and give them their, I guess, acknowledge those perspectives from everybody." He went on to say:

> If there's something that came from [Aboriginal] culture, great, stick it in the curriculum. If there's something that came from China, stick it in the curriculum. Something came from the Middle East, put it in the curriculum. Something came from Europe, put it in the curriculum. If it fits [with the other science content].

This idea of "fit" with what Michael considers to be scientific knowledge as criteria for inclusion in the science classroom supports the earlier distinction that he makes between scientific knowledge and other perspectives and beliefs. While he did not mention any time that he spent in class discussing with students the differences he saw between science and Aboriginal perspectives, he did describe a lesson in which he spoke to students about integrating religious belief with scientific knowledge, to impress upon students that being a scientist does not have to translate into being an atheist, using examples of a scientist who used his Nobel address to speak to this issue, saying that "that's not the way the scientific community works."

Summary.

It is difficult to classify Michael as having one coherent theoretical approach to integration. While his focus on science compared to other forms of knowledge may indicate a scientistic understanding of science, Michael appears to be tokenistic in his approach to integration in including technologies or contributions that any culture outside Western/European has made to the study of science. As well, with his intentional separation of scientific knowledge and other beliefs through discussion with his students, he could also appear to be pluralistic in his understanding of the relationship between Western science and other perspectives. What makes Michael the most distinct though, is his clarity and honesty around his well-articulated thoughts on the difference between various ways of knowing. He seems to recognize that he is at odds with the prescribed curriculum around Aboriginal perspectives, although he does not appear to understand the purpose of incorporating Aboriginal perspectives in the curriculum, other than as a way to placate a particular group of people. While other teachers questioned the inclusion of Aboriginal perspectives, Michael was articulate about his opinions around the issue.

Case study: Anne.

Introduction.

Anne is a science teacher who teaches primarily physics and general science. She has been teaching within a high school setting for three years and previous to that was employed as a Teacher Advisor at a university for two years while working on her Master’s degree in physics. Anne’s first degree was a Bachelor’s in physics and mathematics and following her master’s, obtained an Education degree with a mathematics major. Anne was included in these case studies for the beliefs she has about science and teaching and because she exemplified the impact that both her personal teaching goals and teaching context have on integration of Indigenous perspectives in the science classroom. Goals and context have a significant impact on her teaching practice and create internal and external constraints to what she feels she can do in her classroom. These constraints are explored more fully in the next section of this chapter.

Case study.

Anne described scientific knowledge as “something that you can know what it is.” She went on to say, “there are truths, I guess, we can put towards science, truths, like verifiable, something you can observe or at least quantify.” When describing what she thought knowledge was, she said, “it’s just something you know or can guess to be true or think, usually through some sort of experiment or even, through some sort of thought experiment.” The use of the word “truths” suggests that Anne gives value to scientific knowledge, as far as it can be observed or quantified through actual experiments or thought experiments. This was not consistent with her mean response to the Justification dimension in the survey of 3.75/5 as compared to the group average of 4.61/5. Her interview responses suggest that she places considerable value on experimentation and “finding out why” on her notion of what science is, but this mean value, particularly being more negative than the group mean, implies that she was not as supportive as the group of the role of experimentation in justifying scientific knowledge. Anne separated science into two categories: life science and natural science. She described the difference, saying,

> if it’s something breathing, or pulse, or you know, alive, then it’s considered a life science. If it’s something that’s a little bit more laws and abstract, kind of gotta take my word on it on that mole, then that’s more of a natural science. Isn’t science like knowledge in Latin? *Sciencia*? But it’s really something that’s just, it’s how to explain the world around us, that’s what science is.

It is evident in this statement that Anne considers science to have explanatory power when looking at the natural world, when she said “it’s *how* to explain the world around us” (emphasis added). Her reliance on a scientific explanation is evident in other comments made throughout the interview, as identified below.

Anne reported the knowing “why” of something as being essential to classifying it as science. With reference to traditional Aboriginal practices, she said that “if you don’t know why that happens, then that’s not necessarily science and [Indigenous peoples] had no interest in finding out why it happens, they just tell you, “do this”.” She continued, saying “why does it work? They don’t care. Like, the whole aspirin thing [in reference to Scenario 2], we don’t care. To me, the fact that you don’t care and you’re not seeking answers, that is not science.” Anne reported that she considered Aboriginal perspectives and traditional practices to be closer to religion than to science, when she said, “why it falls into religion? Cause it’s the closest thing to a religion.” This response was consistent with her responses to her choice of scenario for current and preferred practice. Anne chose Scenario 2 as best reflecting both, saying, “science is very much about the facts; in Religion, they do not learn about Science and so I don’t crossover.” The “Religion” that she refers to in this quote is a class taught at school. The separation that Anne makes in these statements between science and religion (and consequently, Aboriginal perspectives) suggests a defined and limited understanding of what can be considered science that impacts what she includes as part of her science classroom (i.e. “I don’t crossover”).

Although Anne did not speak specifically to the source of scientific knowledge in regards to her personal understanding of process of knowing, she did refer to the sources which provide the science content for her teaching. The process of coming to know what scientific knowledge is in the classroom, according to Anne, was from the testable curriculum and the textbooks used in the classroom. When asked if the curriculum dictates what she does in the classroom, Anne replied, “yes, ‘cause at the end, that’s what they get tested on, right?” She went on to say,

> the curriculum dictates what you have to cover, right? My Science 10s, I have to make sure that they have all the information otherwise, when they go into Bio 20, they’ll fail. If they,

> whatever, chem, physics, and then Bio20 needs to be there so they can be successful in Bio 30 and write the diploma. Where's that diploma coming from and where did those questions have to be answerable to? The curriculum.

This statement is indicative of the external issues that were reported in several interviews, where the curriculum and classroom resources as teachers interpret and use them establish hegemonic authority in the science class. Anne reported textbooks used in the science classroom as being influential on what teachers present in their classrooms. She said,

> I can trust people who wrote this textbook are going to give me all the information that I need to make kids successful. Like, unless I had that interest to go beyond, no. Right, so the dictators of how teachers teach really are the textbook creators. If the textbook creators deem it important, I'll include it. Like, if they don't deem it important, then I won't include it.

Anne's perception that if the textbook writers "don't deem it important" she will not include it in her teaching capitulates an external authority to the content of a science classroom. In the survey, Anne's mean response for the Source dimension was 2.5/5. This mean suggests that she was not supportive of the idea that an external authority has influence on what is considered scientific knowledge. While this comment focuses on the influence that the textbook has on Anne's teaching practice, emphasis is placed on an external authority deciding what knowledge is appropriate to include within a science classroom. Anne's comment of "unless I had that interest to go beyond" is returned to in the paragraphs below regarding internal and external factors impacting integration of Indigenous perspectives.

Anne described the integration of Aboriginal perspectives into her classroom as "something that I have to actively work towards" and that if she is "pressed for time, then that's what goes." Integration of Indigenous perspectives was influenced by several external and internal factors for Anne. These include: (a) student interest in Indigenous perspectives; (b) curriculum, time, and assessment; (c) classroom demographic; and (d) teacher interest and knowledge base.

Student interest was reported to affect how and if she included Indigenous perspectives. For example, in the Science 24 curriculum that she teaches, there is a section on communicable diseases and an example given within the curriculum is smallpox, in reference to Indigenous peoples in Canada. She said that,

> what we found was that [the students] really don't care when they don't understand what smallpox is, because they don't know anyone near them that has smallpox. So, although yes, got great Aboriginal, you can be like, "this is how we screwed them over," they learnt about it in Social, and yeah, they don't care.

This statement suggests that Anne does not consider the inclusion of an Aboriginal experience to be helpful to teach this particular concept in science. As well, it seems that she considers the reference in the curriculum to the experience of Indigenous peoples to have another, potentially political, purpose. She continued to say that "little by little, [Aboriginal perspectives] outdates itself. I'll mention it, but it's hard to actually dedicate as much time as Alberta Ed wants us to." When asked to elaborate on what Alberta Education would like teachers to do in regards to Indigenous perspectives, she responded, saying,

> I think Alberta Ed is essentially trying to appease the Aboriginals (sic). It's true, frankly, I think more or less they don't care. They feel, I guess, some obligation to include it and they would like you to spend more time on it. I mean, it is one of your objectives in the Program of Studies.

While Anne recognizes Indigenous perspectives as being an objective in the program of studies, it is evident from these statements that Anne does not consider it as important as other objectives. The perception that Anne has about the attitude of the curriculum writers to Indigenous perspectives was also the one held by Michael, as already discussed. This is returned to in the discussion chapter.

Anne makes reference to the influence of assessment on her teaching in relation to Aboriginal perspectives and the objectives mentioned above. She said, “if we don’t cover it, again, it never gets tested. We’ve had a district final, what like three years? It’s never there so why are you going to spend time on it when it’s already this condensed.” The “district final” mentioned is a standardized assessment created by the school district in which Anne works for grade 10 level science course. A relationship is created between standardized assessment and time in this statement when Anne wonders “why are you going to spend time on [Indigenous perspectives]” when they do not appear on a standardized assessment. The issue of time to teach curriculum and the impact they have on one another was also evident when Anne said,

> One of those [Aboriginal perspectives], you need to make a point that kind of exists outside the normal class…it’s something that I have to actively work towards, but the same time, if I know I am pressed for time, then that’s what goes.

Time denotes particular value for Anne, in that giving a particular topic time, whether because of a standardized assessment or teacher perception of what is important (as is seen in the paragraphs below), makes the topic more important than another. Assessment and time as external factors that impact including Indigenous perspectives are discussed in more detail in the next section on Constraints to Inclusion, as many other teachers reported these as issues.

Anne reported in the interview that the external factor of the demographic of her classroom influenced how she taught. She said, “your kid population kind of dictates how you decide to tailor the curriculum.” In university, she had a professor who took students out to the local Aboriginal community to see the school there. Of this experience, she said “it’s kind of cool cause the education system is completely in Cree. Like, so you know, again, cause that’s your target demographic.” This suggests that, although Anne does not see a place for Aboriginal perspectives in her current classroom, she might if there were more Indigenous students in her classroom. It also indicates that she perceives the demographic to be influential on how a teacher decides to tailor her curriculum to make it meaningful to her students.

Teacher interest and knowledge base are internal factors identified in the interview as impacting the inclusion of Indigenous perspectives in the science classroom. It is evident throughout the interview that Anne perceives teachers to have an influence on what is considered important in the classroom by what is added to the prescribed curriculum and the time given to it. For example, in regards to Science 10, Anne said, “ecology, we’re done in two weeks, we don’t need four weeks for this cause we’re going to be spending time doing something actually useful.” “Spending time doing something actually useful” supports the notion that Anne influences the time spent of particular topics in her science classroom. Anne said, for her, “you could totally see in planning wise, the stuff that I care about, like energy, we’ll go crazy, like you know, we’ll build a roller coaster or something. It’s the things I care about.” She also related a teacher’s knowledge base to these decisions by saying,

> I’m more comfortable being in a chemistry, physics, you know, “I will teach you chemistry and physics” roles than “I will teach you” biology role. So, the less time that I have to spend on, outside of my comfort zone, the less I would want to.

These statements suggest that, through a combination of personal interest and comfort level with different knowledge, Anne may build an implicit perception in her class about what is important and not important by what she decides to enrich the science content with and spend time on. The impact of teacher interest and knowledge on integration of Indigenous perspectives is analyzed further in the final section of this analysis and in the discussion, but this comment suggests an influence of a teacher's knowledge background on how a topic is enriched in the classroom.

Summary.

Anne spoke mostly about the teaching of science, rather than of science as knowledge. The way she described her practice in the interview and the underlying epistemic beliefs of those practices did support her choice of Scenario 2 for both current and preferred practice. Anne's responses suggest that she saw value in Indigenous perspectives in the classroom when the demographic, or her context, supported it. However, she reported that these examples were not as useful in her classroom as she did not think that they were meaningful to her current demographic of students. Teacher interest and knowledge were both discussed in the interview in relation to how a course is enriched and planned; Anne's choices and goals in regards to planning clearly indicated her knowledge base and interest in physics. While it was not evident that Anne considered that science was superior to that of Indigenous perspectives (scientism), the data collected suggest that she does not see value in including Indigenous perspectives in the science classroom. If Anne were to mention Aboriginal perspectives in the science classroom, it would be in a tokenistic manner and included primarily because of the specific objectives in the curriculum.

Case study: Rachel.

Introduction.

Rachel is a biology and general science teacher and has been teaching for 23 years. She has two separate Bachelor degrees, one in science and one in education. For Rachel, scientific knowledge comes through experimentation and inquiry and is constantly changing as a result. She considers science to be limited in its scope and to be a particular worldview that can be applied to “big ideas.” Rachel was an unique case among the interviewed teachers and included as a case study as her epistemic beliefs of science better aligned themselves with her preferred way of teaching, rather than her self-reported current practice. Her self-reported current practice seemed to be more influenced by her interpretation of her teaching context. In Rachel’s choice and discussion around her preferred practice, there was a clear connection between the beliefs she held about scientific knowledge and how she would envision that she would incorporate Indigenous perspectives in the classroom.

Case study.

Rachel was articulate about her beliefs around science as knowledge, providing a clear picture of what she considered it to be. With respect to the nature of scientific knowledge, Rachel indicated that she considered science to be a dynamic discipline when she said that “science is about knowledge that is constantly changing as we discover new things with our experiments and our new ideas that come about. It’s an ever-changing, it’s a dynamic area of knowledge.” This was consistent with her Development mean survey score of 3.75/5, suggesting that she was more supportive of the dynamic and evolving nature of science. She also verbalized the idea that science is a particular worldview which impacts how one thinks about ideas about nature. For example, in reference to what is considered alive or not in biology, she said that “it’s a very narrow view in science and not necessarily so in other worldviews," indicating limits to a scientific view in its ability to understand something. Her Certainty mean of 2.4/5 from the survey also supports this assertion as it suggests that she was not supportive of there being absolute certainty in answers in science.

Regarding the process of knowing scientific knowledge, Rachel reported experimentation and inquiry as being the best way to know what scientific knowledge is. She described science as "the process of discovering about our world around us, our universe, through experimenting." This was consistent with her mean response in the Justification dimension in the survey, where her score of 4.25/5 suggested that she was very supportive of the role of experiments in justifying scientific knowledge. When responding in the interview to how she would present the idea of what science is to her classes, she said,

> we have to appreciate the fact that when we, when we experiment and discover new ideas it has to be, it has to be in a manner that can be replicated, that others can do what you did, that can be communicated to others.

The ability of experiments to be replicated and communicated were important tenets of scientific knowledge that were also mentioned by other teachers, such as Thomas and Eli. Rachel's responses suggested that she did not confine this process to an external authority, such as the scientific community, but considered there to be many ways in which knowledge could be obtained. This was supported when she said,

> For instance, our understanding of, I don't know, acids and bases and indicators, we know that Indigenous peoples discovered those properties but they discovered them in a different way. So, what, so to me that is science. It's a discovery and an application of that knowledge, but in a different way.

Her mean response to the Source dimension of 3.75/5, however, suggests that Rachel had a more positive opinion about the impact of an external authority on scientific knowledge, which is not consistent with her interview statement above.

The beliefs that Rachel held about scientific knowledge, particularly in it being limited in its scope and not restricted to a Western understanding, were in contrast with the scenario she reported as best reflecting what she was currently doing in the classroom. Her beliefs more clearly lined up with her description of what she would prefer to do in the classroom when integrating alternative perspectives to a Western science one. Rachel reported her current practice in the survey to most likely reflect Scenario 2, the "tokenism" scenario. In her scenario response, she wrote that, "whenever possible, I try to include additional contributions/perspectives by those other than the traditional Western view presented." Rachel was the only teacher in the scenario responses to specifically recognize a distinction between a Western view and other perspectives. Continuing in her scenario response, she described constraints to integration of other perspectives in saying that, "because of time constraints, often this is done more superficially or briefly than I would prefer." At one point in the interview, Rachel did suggest that the demographic of her classroom had an effect on how she taught. Within the constraints that she reported of the curriculum and time to deliver it, she said that,

> I try my best to kind of adjust what I do and how I do it, you know, to my audience. Who am I teaching here? How can I best serve the needs of the students who I'm working with, so I can cover the curriculum in my time constraints, but do it in the, in a way that is respectful to my audience?

Rachel, like other teachers, perceived the integration of other perspectives as being in addition to the science curriculum. The inclusion of Indigenous perspectives for a particular demographic would be considered a tokenistic practice, however, it does contrast with other indications of a more pluralistic position that Rachel indicated with her reported preferred practice.

It was evident in Rachel's responses that she had underlying pluralistic ideas in regards to knowledge, as indicated by her choice of Scenario 3 as her preferred practice and her specific and limited definition of science, as outlined above. To explain her choice of Scenario 3, she wrote:

> If time allowed, I would cover topics in this manner because (1) it prepares students for real world issues (not limited to just environmental issues), which are complex and involve many perspectives, and (2) it helps students appreciate that there are valid aspects in other worldviews.

This response reflects more of an epistemological pluralist viewpoint than responses from other teachers. It recognizes the value that many perspectives can give to particular issues and the desire for students to appreciate this. It also supports the idea that Rachel considers science to be a separate perspective from that of an Aboriginal worldview. This was further evidenced in the interview, when she said that she "always want[s] to respect knowledge that has been acquired by people before we had a formal scientific process; I feel like they were doing exactly the same thing." When describing her vision of how Indigenous perspectives would be integrated into a science classroom, she said,

> I would love to see us having just a course on that, where we can explore different topics in science and explore the idea that there is more than one way of looking at things and there's validity in both, in all of those.

In the interview, Rachel reported a distinction between facts and "big ideas" within the science classroom and a distinction of how that might be approached. She said, "if I am going to talk about something that's more fact based, one can discuss how we came to the same conclusion about things in different ways" (this was in relation to a previous quote about the discovery of acid, base, and indicator properties by Indigenous peoples). This was distinguished from other "big" ideas, when she said,

> But whereas you talk about big scale ideas, you know, how does everything all fit in when there's ideas that are big and there's many interconnected aspects of it? How, when you talk about the biosphere, and again, the universe, that kind of thing lends itself more to the theory, the, philosophy is not the right word, the view, that led us to those ideas, then you're not necessarily talking about Indigenous science. You're talking about a worldview that influenced how you went about understanding that big idea. So, I could see doing both but in different contexts.

The distinction that Rachel makes between Indigenous science and an Indigenous worldview in this statement can be extended to a separation that Rachel makes between a scientific worldview and Western science. This distinction is supported by previous quotes, where Rachel remarks that the definition of being alive or not is "a very narrow *view* in science," as well as describing science as "the process of discovering the world around us…through experimenting." These statements together provide additional support for the epistemological pluralist position interpreted for Rachel. Her responses suggest that she sees Indigenous perspectives having a particular place to "fit in" to the curriculum. Integration of these perspectives would be holistic and not simply based on the technologies or discoveries of Indigenous peoples. Rather, it would distinguish between what Rachel considers to be an Indigenous science and an Indigenous worldview.

When discussing the disjoint between her current and preferred practice, Rachel was the only teacher interviewed to describe the experience of her realizing that she had not thought about her beliefs of science as "uncomfortable." She said,

> This is the first time I've been ever asked in a pointed way to think about [her beliefs of science]. I suppose kind of intrinsically, I've always had my view about how we get scientific knowledge. I suppose that's always governed the way I present things and how I interpret ideas in the classroom, but to be pointedly asked, what is my view of science and to think about it in a very specific way, I've never done that.

She went on to say that teachers should have more reflection and thought on "what are we doing here?" as it "surely must affect how I teach things, and how I interact with the students, and how I present ideas that are connected to each other, but I've never really thought about it." More discussion on Rachel's ideas of how these concerns should be addressed is in the following section on constraints to inclusion, but it is mentioned here as Rachel's interview suggests that she recognizes an impact of her view of science on her teaching practices.

Summary.

Rachel's epistemic beliefs of science more closely align with her preferred practice in integrating Indigenous perspectives into the science classroom than with her current practice. The disconnect between her current and preferred practice was different than other teachers whose narratives were presented in that she felt uncomfortable with the realization that the two were different. Rachel reported that she saw value in thinking about what one's beliefs were about science as knowledge as she thought that it would impact what was done in the classroom. She did provide evidence of tokenism in her report of shifting her classroom practice based on who she was teaching. However, her description of how she envisioned integrating Indigenous perspectives strongly supports an epistemological plural view as she distinctly separated Indigenous science from a formalized Western science in how she would discuss facts in the science classroom, and also in the description of how she would approach "big ideas" in the natural world by comparing different worldviews.

Case study: Christina.

Introduction.

Christina has been teaching for 25 years, primarily in the area of chemistry. She has a Bachelor of Science degree in Biochemistry and a Bachelor of Education. For Christina, science knowledge comes from what she was taught and from experience in the laboratory. Science, in a more general sense, comes from observing and asking the question of "why." Christina is included as a case study as she echoes and expands on identified constraints to inclusion of Indigenous perspectives as first identified by Anne. Christina's teaching context and goals influenced her practice more significantly than her epistemic beliefs about science knowledge. She found it difficult to more seamlessly and authentically integrate Indigenous perspectives in her teaching because of these factors.

Case study.

Christina's definition of science centered around the use of science for explanations of the world through observations and exploration of underlying causes. This was evident when asked what she would tell students about the definition of science. She said,

> I think I would tell them that science is how humans make sense of the world, so again, where science comes from is people noticing and making, like noticing things in the world around them and then asking, "well, why is that?" I mean that's where the study and the research comes from.

The importance of understanding "why" to Christina's definition of science was supported when she described an Indigenous perspective as "knowing how something works before knowing why it works." This suggests that she thought a more scientific, theoretical perspective was not present for early cultures. The process of knowing from Christina's perceptive is that one comes to know what scientific knowledge is as "a combination of initially what we are taught and then I think a lot of it comes from experience too…the lab component for kids." She also said that when she considered the early origins of science, "it was humans looking at the world around them and trying to make sense of it. So, I think the observation part always comes first initially, and then the "why" part of it comes afterward." When asked if there was a particular method with which to make observations, she reported that "everybody probably approaches it differently." Christina seems uncertain in this statement of her perspective on the specifics of how scientific knowledge is built. She did, however, indicate support for the idea of science having a dynamic nature with her Development mean score in the survey of 4.25/5, which was higher than the group mean of 3.77/5.

In the scenario portion of the study, Christina wrote that Scenario 2 best reflected her current teaching practice. She wrote that her practice "focus[es] on the development of scientific knowledge through experimentation, understanding of facts, and application to current processes." Her focus on the development of scientific knowledge through experimentation was in line with her survey responses within the Justification dimension (4.75/5) which emphasizes the role of experiments in justifying knowledge in science. The relationship between understanding facts and the application to current processes suggests that Christina sees science as something which can be known, where "facts" have a direct application to a tangible process. In regards to the influence of an external authority on scientific knowledge, Christina's mean score of 2.75/5 as compared to the group mean of 3.2/5 suggests less agreement with an external authority as the source of scientific knowledge.

With respect to her classroom practice, Christina's responses suggested that her practice and any potential integration was more based on external factors than any clear connection to her epistemic beliefs of science. In her scenario response, Christina said that she would prefer to use Scenario 3 or 4 if the supports were in place. She explained, saying, "if I did have Indigenous students in my class, I would prefer Science 3 or 4, if I was given the appropriate supports in terms of developing my background knowledge." This statement supports the notion that Christina finds the presence of Indigenous students in her class as a factor influencing her decision to include Aboriginal perspectives in the science classroom. The lack of personal knowledge of Indigenous perspectives was reported in the interview as a barrier for inclusion. This was evident when she said that more integration would take place if "there was something that could be provided to us, cause us trying to go and search for it, it is too hard cause we don't even know what we are looking for." She reported value in using professional development to help teachers learn more about Aboriginal perspectives, suggesting,

> If there was an educator in the province, that was, you know, from an Indigenous culture, if they were able to make those links for us. If [the school district] were able to put together that resource or if we were able, you know, to find a PD day to go out with one of the Elders and they could show us some of the technologies.

Christina did not think that the curriculum provided enough of a plan of how to include Indigenous perspectives, saying "it's too vague. They need to give us resources, like concrete examples or if there's field trips, we could take the classes out." Throughout her discussion of constraints and solutions, Christina's responses suggest that she considers both to be external to herself, an observation that is discussed further in the next section of this chapter.

It was evident that Christina conflated teaching Indigenous perspectives from the curriculum with the presence of Aboriginal students in her classroom. When discussing the inclusion of Indigenous perspectives in the science classroom, Christina indicated that she considered these perspectives to be outside of the teachable curriculum and more valid to particular students when she said,

> you're just trying to get through the day and get through the content as is, and if it's not something that maybe's not going to be particularly relevant to the students in the class, I think it's just something that falls by the wayside.

She communicated that Aboriginal students often do not take the more academic science courses that she teaches, saying that "because they're not taking the courses, my teaching doesn't kind of lean that way." Christina said that when she teaches Science 14 or 24, where she often has Aboriginal students, she tried to make it more personal, thinking, "ok, they want to have this included, they want to have their culture recognized." In saying this, Christina has created a separation between Aboriginal students and the other students in the classroom, seeing this content as something which appeals to a particular group of students, rather than the entire class; the knowledge matters to someone, although not everyone. This statement also suggests a distinction between cultural knowledge and scientific knowledge in considering the inclusion of Indigenous perspectives as being more interesting to Aboriginal students.

Although Christina identified the lack of resources and direction given for integrating Indigenous perspectives in the science classroom, her responses indicate that she does see value in including Aboriginal perspectives. She references the recent Truth and Reconciliation Council in Canada (2015), saying

> I think the reconciliation part has to be us becoming more accepting and inclusive and respectful of their traditions. So, I think if there were some way we could incorporate it more seamlessly into the curriculum, even in the sciences, that might help encourage some of those kids to take those [higher level] courses.

While the intention of Christina seems to be around creating an inclusive environment for her students, this response suggests tokenism in the separation of Aboriginal perspectives from the sciences and it becoming a tool in which to appeal to Aboriginal students, rather than valuing the knowledge as it is. Christina demonstrates a desire in this statement to use these ideas as a way to build connection and care for students who were Aboriginal. In regards to caring for her students, she said that,

> When I really kind of step back and look at the job, it's not about the science, it's about the kids and it's about the relationships. So, I think I'm more likely in certain circumstances to let the curriculum fall to develop the relationship.

Christina does not necessarily see her preferred practice as disrespectful to Indigenous perspectives or students, but rather, sees it as a way to better connect with and build relationships with students and engage them in the science classroom.

Summary.

While Christina's responses do not provide a clear connection of her epistemic beliefs of science with her classroom practice, her responses are indicative of sentiments brought up by other teachers throughout the study and of the impact of context and goals on pedagogical choices. The influence of a particular demographic on what is added into the content in the science classroom and what is seen as valuable as enrichment to students is evident. One significant finding from Christina's interview was in her use or ideal use of Indigenous perspectives to create a more inclusive environment for Aboriginal students. This was a finding similar to Thomas' interview where the inclusion of other perspectives in the classroom was seen as a way to be "ethical." Christina's thoughts on barriers to integration and the external supports that should be in place to better facilitate integration is discussed in the next section in conjunction with other teachers. It was important to include Christina's comments with these case studies, even though there was not a clear connect or disconnect between her epistemic beliefs and practice. A lack of an articulated understanding of science was also seen with other teachers who were interviewed. It would not be prudent to suggest that these teachers do not have a clear understanding of science, but rather it is interesting that some teachers were able to verbalize it more clearly than others.

Section 3: Identified Constraints to Inclusion of Indigenous Perspectives in the Classroom

Throughout the interviews, teachers were asked to elaborate on any differences between their choices of self-report and preferred practice. As mentioned in the previous section, most of the teachers suggested they would have preferred to have a different practice than what they were currently doing and discussed the constraints they felt were impeding their teaching. Although this study was originally specifically looking at the impact of epistemic beliefs on inclusion of Indigenous perspectives, it became evident that there were several other factors that influenced teachers' practices, preferred and actual. These other factors created a disconnect between the practice that was expected of teachers based on their epistemic beliefs of science knowledge and what their reported teaching practices were. The goals and contexts of teachers that influenced their teaching behavior and beliefs were primarily reported as constraints to teaching practice. These constraints are separated into two categories for analysis: internal constraints and external constraints. It is difficult, however, to definitively label a constraint as being a belief, goal, or context factor. This is because there were often aspects of more than one factor within an identified constraint.

Internal constraints.

Internal constraints to inclusion of Indigenous perspectives in the science classroom are those which were part of a teacher's understanding or knowledge base. These included personal epistemic beliefs of science, lack of knowledge and personal experience with Indigenous ways of knowing, and personal interest or beliefs of teaching as impetus for classroom enrichment.

The data presented throughout this chapter suggest that epistemic beliefs had an influence on teachers' inclusion of Indigenous perspectives in the classroom and may be a roadblock to envisioning how this might be achieved. All teachers interviewed viewed Indigenous perspectives as an enrichment piece, rather than an essential part of the curriculum, suggesting a lack of understanding of curricular outcomes as well as their intent (see below for discussion around the impact of curriculum). Drawing on the teachers' responses, it seems that their interpretation and perceived focus of the curriculum on particular scientific principles developed a defined understanding and presentation of science as one form of knowledge. It was evident that teachers did have a defined and sometimes limited and limiting understanding of what could be considered "scientific." Teachers' definitions of science were varied, but for all teachers the focus of scientific inquiry (and this could potentially be limited to a Western view of science) was on determining the "why" of natural phenomenon. With this understanding, the data suggest that teachers found it difficult to frame Aboriginal perspectives, technologies, and experiences that do not fall within this limited definition of science as anything other than an add-on.

Lack of knowledge and experience with Aboriginal epistemology were reported to be significant constraints to integrating Indigenous perspectives in the science classroom. Teachers said that learning how to integrate Indigenous perspectives was not part of their teacher training or professional development, where the focus was primarily on the mechanics of teaching. Trevor said, “I know in my teacher training I was never given any instruction or information on [Indigenous perspectives] and in my 15 years of teaching, various textbooks and curricula, it’s only been mentioned sporadically and very briefly.” Christina supported this view when she described curriculum around Indigenous perspectives in science as being “too vague” and that “[the curriculum writers] need to give us resources, like concrete examples” and that if “there was something that could be provided for us, cause us trying to go and search for it, it is too hard, cause we don’t even know what we are looking for.” Trevor described the challenge presented by a lack of experience and knowledge, saying,

> I do know that an Indigenous point of view is probably significantly different from how I was brought up and what I think. I don’t want to discredit anyone’s point of view, but I wouldn’t feel comfortable talking about it if I didn’t understand it. I don’t know how science-y it is. Not saying it’s not, just saying that I don’t know.

The impact of not understanding an Indigenous perspective was also acknowledged by Sarah when she said,

> I think I have a hard time, because for me, [an Indigenous worldview] becomes more of a spiritual conversation and I can’t take it as scientifically serious as when I look at a textbook full of formulas. So, I would have to change my own way of thinking in order to then teach that way.

In this statement, Sarah reports having to "change [her] own way of thinking" in order to bring Indigenous perspectives in the classroom. This suggests that she recognizes a disconnect between her own epistemic framework and that of another perspective. Rachel mentioned something similar in her interview when she said that "we make assumptions about [Indigenous peoples] knowledge because of our limited view." The "limited view" acknowledged by Rachel in this statement may include many aspects, including a view built on experience with Western science as well as personal experiences.

Christina reported lack of experience with Aboriginal perspectives as being partly due to her personal experience, saying that when she grew up,

> we didn't have a person of other ethnic origin in my grade until I was in grade six. In junior high, again, a very homogeneous population and when I got to [high school] as a student, there were students from [local reservation community] attending, but they tended not to be in the traditional science classes. So, as a result, my experience with Aboriginal culture is very limited.

As a result, within her own teaching, she said that "although I try to bring [Aboriginal perspectives] in, I just don't have the personal knowledge or background to integrate maybe as much of it as I could." An Indigenous worldview did not seem to be part of these teachers' personal worldview, perhaps making that an obstacle to including Indigenous perspectives in an authentic way in their classrooms. In Anne's interview, she asked, "shouldn't someone who teaches Aboriginal education be Aboriginal?" She said, "if we had an Aboriginal teacher in the department, maybe I'd be a little bit more inclined to teach that way." Anne cites Aboriginal people here as being potentially valuable resources for inclusion of Indigenous perspectives, as they would be the "expert" and authority on Aboriginal knowledge. While this statement could seem like Anne is open to incorporation of Indigenous perspectives with the appropriate supports, the focus is on an “expert” who will provide the necessary components, rather than non-Aboriginal teachers expanding their personal understanding to better comprehend an Indigenous worldview.

Apart from a lack of knowledge and experience, it was evident that personal interest in Indigenous perspectives or personal beliefs of what should enrich students’ knowledge also had an impact on incorporation in the science classroom. What teachers were passionate about impacted the discussions and activities that deviated from what they saw as the prescribed curriculum and enriched students’ classroom experience. Anne said that “it all comes down to whatever you’re passionate about is what you know” and that when she plans and teaches Science 10, “it’s that stuff I care about, like energy, we’ll go crazy, like you know, we’ll build a roller coaster. It’s the things I care about. Biology, ‘guys this is the plant. Admire the plant, alright moving on.’” While the majority of teachers indicated that they were interested in Aboriginal perspectives and so would probably include them given the resources, other teachers implied interests outside of that and so would explore these within the classroom. Eli and Daniel, for example, identified teaching students to challenge ideas as being an integral part of their teaching. Daniel said,

> my real goal for [students] is that you question things and use the science or the skills you’ve picked up in the course to question what you hear on the radio, see on TV, read on the internet…you don’t have to believe everything you see.

Eli encouraged his students to “challenge everything. Why am I saying this? Why are these bullets the way they are in the curriculum?” Because Indigenous perspectives were seen as an opportunity for enrichment, rather than an actual mandatory outcome, the personal interests of the teacher had an effect on their inclusion.

Another aspect to personal interest or beliefs of what is important to include in the science classroom was the perception that inclusion of non-Western cultural perspectives did not necessarily have to be Indigenous. Several teachers stated that they thought that incorporation of other cultures' experiences and contributions to science should reflect the cultural diversity in their classroom. Michael said, "I think we should be using ideas from cultures around the world that contributed to science and give them their, acknowledge those perspectives from everybody." Sarah said that she "feels sometimes that if we choose science and we choose Indigenous ways of thinking, why Indigenous?" Along the line of "why Indigenous," Karla asked if "by being inclusive [of Indigenous perspectives in the curriculum], are we being exclusive?" She clarified by saying, "we're focusing on the FNMI and francophone, in doing that, are we excluding out Filipino kids?" These concerns were raised in the scenario responses, as seen in Section 2 of this chapter. It further supports the assertion that the integration or lack thereof of specifically Indigenous perspectives in the science classroom was not simply impacted by epistemic beliefs of science, but rather a host of other factors.

External constraints.

External constraints are considered to be those which have been integrated into the role of the teacher and are generally perceived by teachers to be outside their sphere of influence. These include curriculum and curricular constraints, and teaching resources.

Curriculum.

Two aspects of curriculum were evident as external constraints to integration of Indigenous perspectives in the science classroom. The first was teachers' perception of curriculum, which includes what teachers considered to be present in curricular documents and what they considered to be absent. The second aspect of curriculum was how teachers approached teaching the curriculum. Here, teachers reported being influenced by standardized assessments and time.

Regarding teachers' perception of the curriculum, teachers had an opinion on what was present in the written curriculum or Program of Studies, as well as what was not there in terms of Indigenous perspectives. Rachel described the curriculum as the framework in which teachers need to work from, saying, "sadly, a lot of what drives what I do is making sure I do service to the curriculum, make sure students have learned that curriculum, to the best of my ability." It is evident from this statement (with reference to Rachel's case study in Section 2) that the curriculum that Rachel is ensuring students are learning does not include Indigenous perspectives. This supports the observation made with all interviewed teachers that Indigenous perspectives are considered "extra" to the mandated curriculum. Eli said that with regard to the Program of Studies, he found that "there are very well-defined bullets that you have to cover and do and that makes it awkward to come up with alternates [ways to present information] because they're very defined." This was echoed in Sarah's interview when she said,

> If I were to spend time on [Indigenous perspectives], I feel like I'm taking time away from the prescribed curriculum. Even though I find it important, I would feel afraid that I'm losing time on what they need, to get to that final point.

The above statements indicate that teachers do not consider Indigenous perspectives to be part of what students "need" to be successful in the science classroom. Trevor said,

> When I think of the program of studies of a course, I'm thinking about specific things that I have to teach to get them ready for the diploma exam. I couldn't tell where [Aboriginal

> perspectives are] in that program of studies, I believe that it is, but I couldn't tell you where. And when you have to prepare the students for a diploma exam, we like to focus on things that they likely to see as opposed to not [see].

Like Trevor in the above statement, other teachers mentioned the difficulty of finding any mention of Aboriginal perspectives in the science curriculum. Karla described the presence of Indigenous perspectives to be a "splash of water in a swimming pool" and that she did not think "it [was] hardly there at all." Trevor said that "in teacher training I was never given any instruction or information on that and in my 15 years of teaching, various textbooks and curricula, it's only been mentioned sporadically and very briefly. So, there's not a lot there, I found". These statements suggest that teachers perceive a lack of depth and presence of these perspectives in the curricula they are to use in the classroom, making it difficult to know how to incorporate it well. Trevor elaborated on this perception by saying,

> I don't think there's a lot of information for teachers out there about Aboriginal perspectives. So, I mean, it's in the Program of Studies, but I bet more teachers couldn't tell you where and I am wondering how many of my colleagues actually bring it up?

Rachel considered the curricular documents to be an important way to ensure that Indigenous perspectives were included in the science classroom. She said that "if [Indigenous perspectives are] not embedded in the curriculum, it's not going to translate to the classroom." This is in contrast to Trevor who recognized the presence of Indigenous perspectives in the current science curriculum. However, these statements suggest that both teachers see ways that these perspectives may be integrated to be more obvious to teachers.

When teaching the curriculum as they understood it, teachers identified two challenges affecting how they teach: standardized assessments and time to deliver content. How teachers approached the curriculum was heavily affected by diploma exams and other standardized assessments, particularly in the priority of information given in class. In Alberta, diploma exams are a government-issued standardized assessment that students write in grade 12 level courses. Several teachers who were interviewed taught diploma level courses felt that the inclusion of Aboriginal perspectives were not important as these never appeared on any diploma exams. Trevor said, “I’ve never seen a question on Aboriginal ideas on the diploma exam, so I don’t think that is something I would spend a lot of time on from that point of view.” Eli said that “I try and integrate what I can but ultimately I am preparing them to write a particular exam and to meet the outcomes of the curriculum.” This supports the idea that Indigenous perspectives were considered to be outside of the testable curriculum. Christina reiterated this notion when she said, “the ‘what’ I teach is totally driven by the curriculum. Like, that can’t change, because we always have that diploma exam at the end.” Teachers felt pressure to prepare students for these exams and seemed reluctant to deviate too far from what they considered to be the prescribed curricular points with the pressure that they felt for time. Anne supported this idea when she said, “if we don’t cover [Aboriginal perspectives], again, it never gets tested. We’ve had a district final, like three years? It’s never there so why are you going to spend time on it when [the course] is already this condensed.” These statements suggest that preparing students for a standardized assessment established an implicit hierarchy of information that needed to be covered and assessed in the classroom.

Time was a factor that impacted how teachers approached teaching the perceived outcomes within the science curriculum. Eli said,

> typically, what ends up happening because I guess time restraints due to curriculum is you need to cover this material and although over the years, I’ve changed and

> modified and tried to improve and integrate all sorts of perspectives on science and things, I also look for the most expedient way to get from point A to point B quickly because of time constraints.

The issue of time in this statement included concerns about taking time away from the prescribed curricular outcomes. Other teachers mentioned the limitation of time needed to learn new knowledge and prepare new lessons in order to incorporate Indigenous perspectives. Sarah said that, "[a barrier] would be time and energy and re-do my lessons. I've got my lessons down, many times there's a time crunch, I get into the flow, and it's just habit." Christina built on the idea of time and energy to make changes to current teaching practices by commenting on other demands in the classroom such as marking, differentiation, advising, and supervision. She said,

> in my one class of 39 right now, I went and looked through the ELL [English Language Learner] codes and the LSP [Learner Support Plan] codes and in that one class, there's 16 kids that have some kind of coding. And so, when you take all of that into account, it's the extras or things you have to spend more time on that fall away.

It is evident from these two statements that priority is not given to learning about different perspectives and finding ways in which to incorporate them within in their science classrooms, with what they felt were constraints on their time.

Some teachers did not feel that they had enough time in class and within the curriculum to give different perspectives justice. Rachel said, "whenever possible, I try to include additional contributions/perspectives by those other than the traditional Western view usually presented. However, because of time constraints, often this is done more superficially or briefly than I would prefer." Rachel, in reporting on the disconnect between her current teaching practice of Scenario 2 and preferred practice of Scenario 3, said,

> The reality is, when you're constrained for time, the idea of delving into 'hey this is this one worldview, this is another, let's compare, let's contrast,' and hopefully in the end have them see that there's value in both of those views, that sadly, I think, is a very time-consuming process.

In this way, it seems that teachers place precedence on the particular science outcomes within class, seeing this as built into the structure of the courses in which they teach. Time could be interpreted from these responses as a limited resource in the classroom, giving value to particular content.

Summary.

The combination of the prescribed curriculum, the curricular load, and diploma examinations gives teachers implicit and explicit values to the information that they teach in their classrooms. Teachers were very much influenced by what was in the Program of Studies for the direction and content of their pedagogical practice. As Aboriginal perspectives did not make a significant, or even minimal appearance in a diploma exam, they did not feel that they were or needed to be an integral part of what was being taught. In this way, it is evident that teachers place value on what is taught in the science classroom, based on their interpretation of what is mandated by the Program of Studies in science. This is explored further in the discussion.

Teaching resources.

Another external constraint teachers identified were the resources available, particularly in the form of textbooks used within schools and in the professional development opportunities available to teachers. Teachers indicated frustration with the lack of importance placed on professional development on how to integrate Indigenous perspectives by the school district and the resources that were available to them to shift their teaching in a meaningful way. As a teaching resource, textbooks influenced what teachers included in the science classroom, particularly in terms of necessary content and enrichment. Some teachers said that the textbooks used in the science classroom did not mention Aboriginal perspectives. This assertion is evident when Trevor said, “I mean, there’s two textbooks that all Bio 30 teachers use in the province and the one I use, I can’t think of any examples and if it is in there, it would be very hidden.” Others thought that when Indigenous perspectives were included in textbooks, it was in a way that was condescending to Aboriginal experiences and knowledge. This notion was supported when Sarah remarked that inclusions in the textbook often lacked respect and she did not “think those students, or the other students gain anything by that.” Both Trevor and Sarah did not, however, mention instances in which they would research Indigenous perspectives on their own to make up for the issues they saw with textbook resources. When elaborating on the use of resources in her classroom, Anne said,

> I can trust people who wrote this textbook are going to give me all the information that I need to make kids successful. Like, unless I had that interest to go beyond, no. Right, so the dictators of how teachers teach really are the textbook creators. If the textbook creators deem it important, I’ll include it. Like, if the teachers, if they don’t deem it important, then I won’t include it.

Anne’s reliance on the textbook for information that will “make kids successful” along with her reluctance to go beyond the content of the textbook without personal interest in a topic combines internal constraints with a lack of provided resources for teachers. This is evident, as well, in teachers’ perceptions of professional development, seen below.

Professional development was reported by teachers to be lacking in providing teachers with resources to include Indigenous perspectives. Teachers felt that options were not available around Indigenous perspectives or for conversations about underlying beliefs that impact teaching practices. They felt that professional development offered by the school district indicated priorities in other directions. Rachel remarked,

> It's funny, we have those professional development days, we often focus on, again, the mechanics of what are we doing and how are we going about, you know, getting these ideas across to kids, but we don't actually talk about our views that are behind it. You know, what's driving us? We don't do that.

Rachel felt uncomfortable through the steps of the study in recognizing that she had not considered the impact that her underlying perception of science may have had on her teaching and thought time spent on these types of discussions in professional development would be beneficial. She stated, "maybe we shouldn't be focusing [in professional development] on, you know, ten fun ways to do an experiment. Maybe we should be talking about why we are doing this, and what does it mean."

Within the context of professional development around Indigenous perspectives, Christina said, "the [professional development]'s never really been there. Like if, with a lot of our PD, the onus is, like they put these things in the curriculum and then supports aren't put in place." In her interview, Karla asked "how are teachers going to do a good job [with knowing enough to integrate]? How are we ever going to get enough PD for them?" As evidenced by these two statements, teachers perceive professional development to be a valuable support for their teaching practice. Karla envisioned an online professional development resource to support teachers. She said,

> imagine if you're a teacher and you don't know this stuff, you don't know how to integrate and weave it into your lesson. So, you can just log on and there can be an FNMI

> symbol or something and you can click on that and go ‘oh, I didn’t know that, perfect, I’m going to use this’ and have it link directly to the outcomes.

Christina described what she thought would be helpful professional development by saying,

> I think we would need, if there was an educator in the province that was from an Indigenous culture, if they were able to make those links for us. So, the things, like medicines coming from a First Nations culture is a more direct connection, but there are other technologies besides snowshoes for example, that they’re using for heating their homes and what not. If they were able to put together that resource or if we were able to find a PD day to go out with one of the Elders and they could show use some of the technologies. I think that’s what we need; the school board needs to make time for us to go out and do those things.

It is evident from these statements that teachers consider it to be the responsibility of external agencies to provide information on Indigenous perspectives for teachers, rather than teachers seeking and developing an interest in the knowledge itself. This suggests that what teachers see as external constraints may actually be a barrier constructed from their own personal epistemic understanding around Indigenous perspectives.

Summary.

Teachers identified a lack of resources available to them to integrate Indigenous perspectives in a meaningful way. Textbooks were considered to be missing Indigenous perspectives or to include them in a condescending way that was not beneficial to students. Teacher statements suggest that textbooks had an influence on what information was important to include in a science classroom, as well as providing direction on enrichment to the curricular outcomes. Professional development was valued as a resource for how to incorporate Indigenous perspectives, but was felt by teachers to be lacking. There were clear indications that teachers felt that the school district did not give priority to giving teachers resources through professional development to incorporate Indigenous perspectives in a meaningful way. Teachers in this study did not consider it their responsibility to seek out information and resources to integrate these perspectives themselves, but rather perceived it to be up to external sources. This supports the assertion that there is an underlying internal barrier to incorporating Indigenous perspectives that impacts teachers more than external constraints.

Chapter 5: Discussion

Introduction

The research question posed for this study explored the factors that impacted actual and preferred practices around incorporating Indigenous perspectives in the science classroom. The previous chapter analyzed the quantitative and qualitative data obtained from this mixed methods study, built on a theoretical framework described in the literature review. This chapter discusses the major themes that emerged from the data in light of other literature.

This chapter is separated into five sections. The first two sections concentrate on the complexity of the research question and the limitations of the methodology to provide context for the discussion following them. They are both meant to help establish a framework from which conclusions can be drawn tentatively, but with confidence, from the data. An introduction to discussion of the results follows these two sections, beginning with an updated theoretical framework with a summary of results based on epistemic beliefs, context, and goals of teachers. A section devoted to the curriculum, as it is written by governing bodies and interpreted by teachers, begins the discussion of the results. This is developed as a separate piece because it was frequently mentioned through both qualitative portions of the study as heavily influencing teacher practice.

Throughout the interviews, teachers described constraints that they felt impacted them teaching in their preferred manner, as identified by their choice of preferred teaching scenario. These constraints are discussed from the perspective of the variability introduced by the individual teacher. The final section of this chapter explores what can be done with the information gathered from this study, including implications for teachers and external agencies, and potential avenues for future research.

Complexity of the Research Question

The original and revised research questions proved to be complex, upon analysis of the data. Throughout the analysis, the complex, and often times, muddled nature of this topic became evident as there did not seem to be a clear connection between epistemic beliefs of science and how teachers integrated Indigenous perspectives in their science classrooms. Other science epistemic belief research has shown connections between constructivist or empiricist approaches to science and classroom pedagogy (see literature review), but this seemingly clear relation between beliefs and pedagogical choices did not exist in the same way for integration of Indigenous perspectives. This issue is complex as it is difficult to separate key ideas into discrete sections, making structuring this discussion challenging. This is because many of the ideas that arose from the data overlap and seem to impact one another. While an attempt is made in this chapter to separate some of these ideas into sections, it should be known that overlap and interaction will, necessarily, exist.

It became evident that the original research question posed was more complex than what was originally conceived for three primary reasons. The first reason is that this research question is not the same as other research looking at how teachers think about and teach science and other forms of knowledge. It is unique in the fields of epistemic beliefs of science as well as the integration of Indigenous perspectives in the science classroom as it attempts to look at the connection between the two. What makes this especially challenging is that it attempts to connect two different epistemologies and look at how one set of beliefs affects another. Related to this, as the second reason for the complexity of the issue, is the issue and impact of different personal frameworks on how knowledge is filtered and validated. It became evident that participants in the study had a particular framework or worldview based on personal experiences and on their conception of themselves as science teachers. This had an impact on what they did with a domain of knowledge such as Indigenous knowledge that may be very different from their own worldview. Finally, for many teachers, Indigenous perspectives are tied to a particular group of students, culture, and history, which had an impact on how they approach integration. These reasons are discussed in more detail below, with reference to the analyzed data and existing literature.

The difference from other literature around epistemic beliefs.

As discussed in the literature review, the research question posed for this study is unique in both the field of epistemic beliefs of science as well as Indigenous perspectives in the science classroom as a gap exists when looking at the connection between the two. It became apparent when analyzing the data that teachers did not only have beliefs about science as knowledge, but also had beliefs about Indigenous knowledge and perspectives on the natural world. Other literature around the impact of teachers' epistemic beliefs of science on their classroom teaching practice focused on ways that teachers would present science to their students in their pedagogical choices. When devising the original study, I thought, perhaps naively, that if teachers thought about science in a particular way, this would have a specific impact on their choices of pedagogy around including Indigenous perspectives in the classroom. What makes this complex, however, is that to include Indigenous perspectives in a way that is not tokenistic, one should have a basic understanding of the *epistemology* of Indigenous ways of knowing, rather than a few examples of technologies and traditional practices (Brayboy & Castagno, 2008). There were no teachers within the study who were Aboriginal, and most did not have much experience or exposure to different Aboriginal communities in their areas (with the exception of Thomas and Anne). What makes this study challenging is that many of the participants did not have any particular ideas about the Aboriginal perspectives that they were asked about. This made it difficult for teachers to speak to their teaching practices about Indigenous perspectives, having not formed any particular beliefs, thoughts, or opinions of their own. While teachers did see ways in which they would integrate Indigenous perspectives and many liked Scenario 3 and 4 for the holistic nature of the lesson, responses still suggested that teachers' understanding of an Indigenous worldview was very limited.

The issue of differing personal frameworks.

Another consideration on the complexity of this topic and the lack of clear connections between epistemic beliefs and practice are the personal frameworks or worldviews of the participating teachers. Although these were not specifically targeted as part of the interview questions or other parts of the study, it was evident that there were other underlying beliefs that impacted how teachers considered alternative ways of knowing. As mentioned in the literature review, the interaction of various epistemic beliefs creates epistemological frameworks (Jones & Leagon, 2014) or epistemological worldviews (Schraw & Olafson, 2002). Schraw and Olafson (2002) use epistemological worldviews to describe a lens in which an individual views the world. It seemed that teachers were impacted by their personal worldview because there was not one general trend/descriptor of teacher based on the teaching scenario that they chose as their preferred practice. For example, although several teachers chose Scenario 4 as their preferred practice, they were dissimilar in why they would choose such a scenario and how they expressed their beliefs of scientific knowledge in the interview. Each teacher had a unique approach to his/her teaching practice and thoughts around integrating Indigenous perspectives in the science classroom.

The literature suggests that teachers build their own worldviews that serve as a lens and filter for what knowledge is valid in a variety of ways (Cobern, 1996; Gess-Newsome & Lederman, 1995). Gess-Newsome and Lederman (1995) suggest that the intention of teachers, their content and pedagogical knowledge, the needs of students, the autonomy of teachers, and time all have an influence on how teachers conceive the nature of science. When it comes to the interpretation of the curriculum, these worldviews have a filtering effect resulting in a different interpretation for each teacher (Tirri, Husu, & Kansanen, 1999). These scholars go on to say that "the teacher's own values and understandings [are] the standards for testing the claims of knowing" (Tirri, Husu, & Kansanen, 1999, p. 921). Kelly, Shultz, Weber-Pillax, and Lange (2009) describe the act of teaching itself as a "cultural exercise, embedded in at least one particular knowledge system and one particular set of beliefs" (p. 263). As previously mentioned, teachers in this research study did not come from an Aboriginal background and most seemed to have very little exposure to Aboriginal perspectives and ways of knowing. This suggests that teachers would not have developed their own worldviews in a way that includes an Aboriginal understanding or value system. It seems reasonable to suggest that teachers would then have filtered the written curriculum as well as the study items through their own frameworks (Lantz & Kass, 1987; Tirri, Husu, & Kansanen, 1999).

The majority of teachers in this study did not seem to recognize that their personal worldviews conflicted with that of an Aboriginal one. Notable exceptions to this trend were Trevor, who recognized that he did not know if Aboriginal perspectives could be related to a scientific way of thinking, and Sarah, who said that she would have to alter the way she thought about things in order to teach in a way that integrates Aboriginal ways of knowing. It has been suggested that most individuals are unaware of the extent that one's worldview affects what is seen as valid knowledge (Bechtel, 2016). Barnett and Hodson (2001) found that when teachers encounter knowledge in their practice that causes them anxiety or feelings of inadequacy, they were likely to resist or reject that knowledge. Dion (2007) describes this as being the "perfect stranger," in regards to encountering Aboriginal people and culture. She discovered that teachers were encouraged to include Aboriginal perspectives in their classrooms, but that their understanding of Aboriginal people and culture was limited and often acquired through the dominant discourse. The "perfect stranger" developed from "what teachers know, what they do not know, and what they *refuse* to know" (my emphasis) (Dion, 2007, p. 331). Teachers did not see it as their responsibility to develop an understanding of Aboriginal perspectives, rather seeing it as the responsibility of external agencies to provide the information for them. This is discussed further in a later section.

The connection to students, culture, and history.

An interesting layer to the complexity of this topic was the perception of teachers that integrating Aboriginal perspectives in their classrooms was the "right thing to do" for a particular group of students. Teachers, such as Christina and Thomas, saw the inclusion of Aboriginal perspectives in their classes as a way to engage Aboriginal students in science, suggesting that they saw this as an ethical act. As was described in the case study analyses, Aboriginal knowledge was felt to be important for *Aboriginal* students, not all students. Teachers described the impact that student demographic in their classrooms had on how they enriched various science topics. Scholars have suggested that students view the science curriculum as being impersonal, dismissive of their worldview, and boring (Aikenhead, 2006). The data analysis suggests that the participating teachers try to address these issues by including examples and activities in their classes that would appeal to the demographic of students present.

While including Aboriginal perspectives in the class may be a way to engage Aboriginal students in the classroom, the data showed that some teachers viewed inclusion from a political perspective. Michael and Anne both mentioned that they thought the inclusion of Aboriginal perspectives in the curriculum was for political reasons, based on the current climate in Canada between the government and the First Nations people. For them, including Aboriginal perspectives held *less* value because of what they saw as poorly established motivations. Christina mentioned a political aspect of inclusion, although from the view that it can be positive in regards to reconciliation with Aboriginal communities in Canada. As described in her case study, Christina acknowledged the Truth and Reconciliation Commission, also referenced in the literature review with regard to the mandate of education. As this document has been publicly released, it seems unwise to ignore the impact that it may have had on the conversations had with teachers. An Aboriginal perspective is not objective, or universal (Lowan-Trudeau, 2014), but is attached to a particular group of people, with whom there has often been a dark history in Canada. This perspective is attached to students in classrooms who often, in my experience, face challenges that other students do not. At the end of his interview, Thomas went into a long description of some of the issues that the Aboriginal students in his school dealt with. These included issues of violence, addiction, abandonment, and racism. While it is important to approach the data with as objective a lens as possible, it is also challenging to do so. This is something to consider when examining teacher responses as well. Is it possible, or ethical, to separate the knowledge from the people that it comes from? What impact does the history and current relationship between Aboriginal communities and other Canadians have on what happens in science classrooms around Aboriginal perspectives? I am aware that these questions were beyond the scope of the study, however they came to mind when coming to understand the complexities of this topic that became evident during the analysis.

Summary.

This section was an attempt to impress upon the reader the underlying complexity of this topic that arose while analyzing the data. Although the data did not provide the clear connect or disconnect that I was naively hoping for, it did shed light on a host of factors that may impact one's teaching practice. As elaborated on in the literature review when looking at the purpose of this study, it is imperative to open up the conversation around Indigenous perspectives in the classroom and the multiple considerations that should be made when researching in this area. The rest of this discussion focuses more on particular ideas that arose from the data around factors impacting teacher practice in incorporating Indigenous perspectives. It was felt that this section was important though to address the difficulty and complexity of working with these ideas.

Limitations of the Methodology

Epistemic beliefs have been shown in the literature to be difficult to measure due to their multi-faceted nature (DeBacker et al., 2008; Duell & Schommer-Aikins, 2001; Hofer, 2000). When developing the methodology to look at this study's research question, it was decided that a mixed methods approach would be used for its ability to address many different facets of epistemic beliefs (Deniz, 2011). While analyzing the data, several limitations to information collected about epistemic beliefs that have been mentioned in the literature also became evident. Hammer and Elby (2012) described epistemic beliefs as corresponding to some sort of cognitive structure, which, when measured, is assumed to be conscious and accessible. Because Hammer and Elby's discussion focused on students and not teachers, a conscious and accessible cognitive structure was an assumption I made and potentially took for granted before analyzing the data. This was evident in the difficulty that some teachers had in articulating their beliefs about scientific knowledge and teaching Aboriginal perspectives. The time period that was used for the study may have been a limiting factor in this in that teachers were not given time to reflect on their beliefs, as may have been the case had different methods been used. However, the chosen procedure did provide a snapshot of the current state of these teachers engaging with this topic.

The survey was partially intended as an intervention to have teachers to reflect on some of their epistemic beliefs of science knowledge if they had not already previously done so. The degree to which teachers actually considered these beliefs, potentially for the first time, seemed to not be the same for each participant, another caution that comes from the literature (Hofer & Sinatra, 2010). The survey was intended to provide information on the epistemic beliefs that teachers had about science as knowledge. Several changes were made to the Scientific Epistemic Beliefs survey developed by Tsai et al. (2011) to make it more applicable to teachers and the context of this study. However, I recognize that these changes introduce error into the analysis of the quantitative data obtained from this survey. The revised survey was not re-administered to individuals not participating in the study to ensure the validity and reliability of the instrument. With that consideration, I still consider the survey to be valuable as an intervention tool. The low number of participants necessitated simple descriptive statistics over a more complex analysis process, which is probably more appropriate with the untested changes that were made.

The impact of the use of the survey as an intervention was most clearly seen in Rachel's interview. She described experiencing difficulty in articulating what her own beliefs around science were in the survey and thought about those beliefs upon completing the quantitative portion of the study. She felt discomfort when she recognized that she had not thought about these ideas before and that they probably had an effect on her teaching. This was the hoped-for response with the methods and sequence of data collection chosen for this study, although other teachers did not report this experience. There have been a couple suggestions in the literature around this issue. Maclellan (2015) said that,

> responses to self-questionnaires mask the alignment of the respondent's interpretation of the questionnaire with the researchers' theoretical assumptions. Such ambiguity could be particularly gross if the respondent has never been asked to engage in such reflection before and/or if the respondent has difficulty in grasping linguistic/conceptual meaning. (p. 177)

This is also mentioned by Hofer and Pintrich (1997) in relation to the use of interviews in that the interviewer has established a framework to look at epistemological theories/beliefs and therefore may miss out on ideas that are more personally constructed by the interviewee. Both of these statements taken together suggest that there can be incongruences between the interpretations of the researcher and the participant in regards to the data collection tools being used. Although the mixed methods approach may have been able to look at multiple aspects of teachers' epistemic beliefs, it could not account for the teachers' interpretation of the survey items and the interview questions (Koulaidis & Ogborn, 1995). Interestingly, one teacher did add extra notes in his typed scenario responses in regards to the survey statements, asking questions around what was meant by various parts of the statements, or what his interpretation of it might be. This was not included with the data analyzed, but it is something to consider if this survey was to be used again, somehow incorporating teachers' underlying assumptions and interpretations of the survey statements into the data. Although this was beyond the scope of the study, having this information may have aided in the interview process, as a teacher's underlying framework potentially could have been examined. This question could be the focus of future research, particularly in looking at the development of reliable instruments to measure epistemic beliefs.

Another issue of interpretation came with responses to the constructed teaching scenarios. As was mentioned in the analysis of this data, labeling teachers as having an approach which was more in line with scientism, tokenism, epistemological pluralism, or multi-science did not come from the particular scenarios that were chosen, but rather from the explanations provided within the interviews. This was particularly relevant when looking at the reasoning for choosing their preferred scenario. It was decided to look a teachers' reasoning as opposed to which scenario they selected because it became clear that teachers had different interpretations or conceptions of how these limited descriptions might play out in a classroom. For example, no teachers selected Scenario 4 as their preferred practice, who would be described as having a multiscience perspective. The research question was designed to look at how a teacher's epistemic beliefs of science impacted inclusion of Indigenous perspectives in the classroom and this could not be done simply through which scenario they chose. The interviews were a crucial part of this study as they allowed for a clearer picture of response to this question. Using only the self-report data in the survey and scenario responses would have been inappropriate and is in line with cautions in the literature in making any conclusions about a teacher's epistemic beliefs based on this (see Fishman, Marx, Best, & Tal, 2003; Veal et al., 2016). Fishman et al. (2003) suggests that making direct observations of teachers in the classroom to be a more reliable way to measure pedagogy.

Previous studies looking at the role of epistemic beliefs of science on teaching practice examined it in terms of empiricist versus constructivist ways of approaching pedagogy in the science classroom (Blanco & Niaz, 1997; Gallagher, 1991; Hashweh, 1996; Tsai, 2007). The research focus on this study however, additionally incorporated ideas that teachers had around the inclusion of Indigenous perspectives which shifts the question from just being about Western science knowledge. As this study addressed a gap in the literature around the relationship between epistemic beliefs of science and teaching practices around integrating Indigenous knowledge in the science classroom, the methodology chosen was a "best guess" as to what might provide information about this. The issue of looking at beliefs of other perspectives are elaborated on in the above section, but it must be noted that there may be many facets to the beliefs about knowledge that could not necessarily be examined by the methods chosen from existing studies. While this may not have been as much of an issue for those teachers who have thought about their conception of science and how they specifically teach it based on that, this could have impacted teachers who did not share these characteristics. Measuring these teachers' understandings would have been difficult with the methods chosen compared to teachers who could articulate what they thought and how it related to their practice.

Summary.

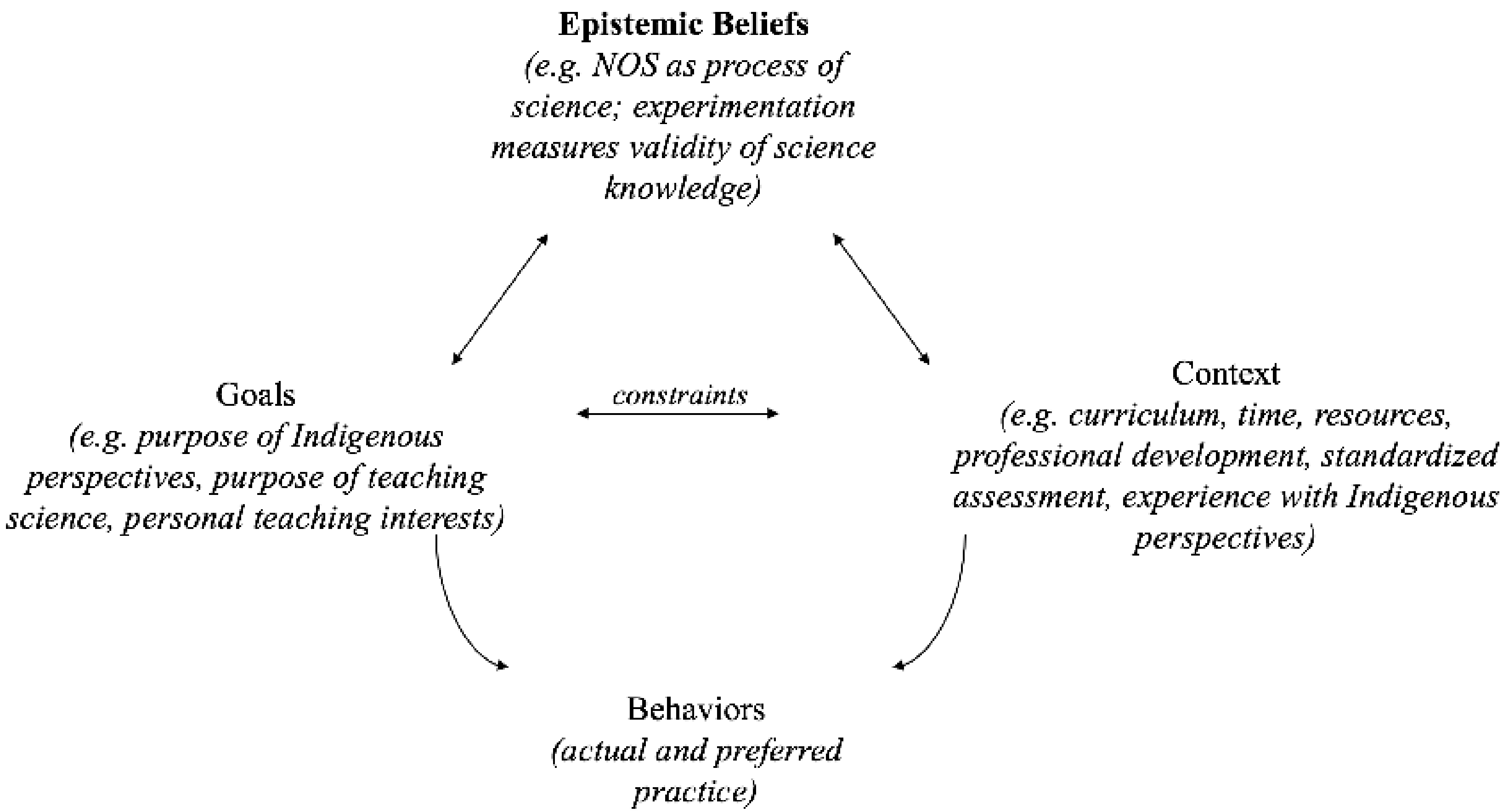
The methodology chosen for this study provided challenges to the interpretation of the data. As was previously described, epistemic beliefs are difficult to measure. While methods have been used to relate classroom practice to epistemic beliefs of science, this has previously been done in regard to teaching science, rather than integrating another domain of knowledge. As such, the methodology chosen was a starting point for further discussion in this area.

Discussion of the Results

This section discusses the results of the data analysis and its relation to pre-existing literature. McRobbie and Tobin's (1995) model for teacher behavior was revised for this research study (see Figure 5) based on emerging data. Figure 10 below depicts this revised model with a summary of findings for each variable impacting teaching behavior as a reference for the discussion that follows. A discussion of curriculum as written and interpreted by teachers begins the discussion of the results. Following this is a section exploring the variable of the teacher in regards to practice, focusing on the internal and external constraints identified in the data and literature. Examples of findings shown in Figure 10 are referred to throughout this discussion.

Figure 10

Revised McRobbie and Tobin's (1995) Model with a Summary of Findings



Curriculum.

The written curriculum was mentioned several times throughout teachers' responses and so warrants its own section in this discussion. Within this section, the impact of curriculum on the incorporation of Indigenous perspectives in the science classroom is discussed in two ways. First the curriculum will be discussed in regard to the actual document that teachers see and use in their teaching practice and how that document may give direction to teachers on what is important in that science classroom. How teachers interpreted that curriculum and the factors that impacted that interpretation makes up the second portion of this discussion.

The written curriculum.

Consistent in all the interviews was the perception that Aboriginal perspectives were something to be added to the classroom, as enrichment to the outcomes of the curriculum. Several reasons were given by teachers about why their practice did not currently reflect what they thought would be appropriate in terms of integration, discussed in the next section. However, why teachers did not see Aboriginal perspectives as a teachable part of the Program of Studies was not specifically remarked upon by any of the teachers in their interviews. As seen in the data, the closest that some teachers came to acknowledging that it was part of the written curriculum was as an attitude outcome. Inferences that can be drawn from the data would suggest that the curricular documents themselves and the way that they are assessed may leave at least some ambiguity as to how this should be approached.

As previously outlined in greater detail in the literature review, Aboriginal perspectives are included within the Program of Studies in the opening statements of the document, as Attitude outcomes, and as italicized suggestions for how to teach a particular outcome (Alberta Education, 2014) (see literature review for a detailed description of how Aboriginal perspectives are included). For example, one italicized suggestion is that teachers can incorporate Aboriginal perspectives by “evaluat[ing] the traditional Aboriginal method for determining alkaline properties of a substance” (Alberta Education, 2014, p. 14). What is noticeable about most of these italicized statements is the use of the term “traditional.” This insinuates two things. Firstly, it looks at Aboriginal perspectives and technologies as something historic and potentially not as relevant as other more recent knowledge (Aikenhead, 2006). Secondly, it makes a blanket statement around “Aboriginal” perspectives, not recognizing the unique nature of different First Nations communities (Hermes, 2000; Simpson, 2004). While not specifically related to the term “traditional,” these statements also separate out the unifying spirituality in Aboriginal epistemologies by focusing primarily on technologies and tools used by Aboriginal communities (Aikenhead, 2001). In doing these things, the Program of Studies that teachers use may inadvertently be perpetuating a more tokenistic inclusion of these perspectives in the science classroom.

Within the Program of Studies, a qualification is made about these italicized statements, saying that they “**do not form part of the required curriculum**” (emphasis included) (p. 6). This may contribute to the perception that outcomes regarding Aboriginal perspectives are additional to what is necessary to teach in the classroom. When looking at this in light of the various constraints that teachers identified facing in their work, in particular, personal interests and their effect on enrichment materials, epistemic constraints with lack of exposure and knowledge surrounding Aboriginal perspectives and experience, and lack of resources, it is reasonable that these ideas would be viewed by teachers as being in addition to what is taught in the classroom, and as many teachers (eg., Anne, Sarah, Christina) said, “would be the first to go.”

As previously described in the literature review, teachable outcomes may be understood by teachers as “testable outcomes.” The “required curriculum” as described above is part of the assessable curriculum, particularly in the form of standardized tests. In Alberta, the diploma exam in 30-level courses (generally written in grade 12), are worth 30% of a student’s overall course mark (Alberta Education, 2017). In the interviews, several teachers made comments about wanting to prepare students as best they can for the diploma exams, preferring to focus on outcomes that would appear on the exams. Having a standardized assessment at the completion of a 30-level course values certain ideas over others in what should be included in the classroom. This should be a consideration when looking at reasons for why teachers see Aboriginal perspectives as an add-on. The diploma exam is comprised of multiple choice and numerical response questions that assesses students on the knowledge and skills outcomes in the Program of Studies (Alberta Education, 2017). When Aboriginal perspectives are included in the curriculum as italicized comments or as an attitude outcome that cannot be tested on an exam with this format, it seems reasonable that it would not be considered as important to teachers. Within this study and other studies (e.g. Shizha, 2007), teachers did not consider Indigenous knowledge to be a necessary component of their teaching as these perspectives or outcomes did not appear on government-issued standardized assessments.

Taken together, how the curriculum is written and subsequently assessed reasonably have an effect on teacher practice. This was alluded to by teachers within the interviews and the scenario responses. The power of how curricular documents are written and present knowledge has been discussed in the literature. Aoki (1991) cautions that these documents are always someone’s perspectives on knowledge and what is considered valuable. The language that is used within curriculum confers power (Aoki, 2005). This is evident in the discussion above in the continual use of “traditional” to describe Aboriginal perspectives and technologies, as well as how they are presented in the form of italicized statements. The content, as well as how these perspectives are included have an impact on what is considered valid knowledge (Garroutte, 1999). Although the Program of Studies outlines at the beginning of the document the intentions of including Aboriginal perspectives in the science curriculum (as seen above and in the literature review), it seems to be unclear to teachers, as evidenced by their interview responses (see Chapter 3), how that translates into pedagogy. Wiseman, Onuczko, and Glanfield (2015) saw Aboriginal perspectives in their study as an add-on to the curriculum, rather than a different way for teachers to teach, as might be the intention of the curriculum writers. One implication of this study may be that there needs to be more dialogue between curriculum writers and teachers as to what the specific intentions and expectations are around integrating Aboriginal perspectives in the science classroom are. From this discussion and limited analysis of the Program of Studies, there seems to be a disconnect between the outlined intention and the practical guide for what should be included in the classroom based on curricular outcomes and standardized assessment.

The interpretation of the curriculum.

It became quickly evident in the qualitative data components of this study that teachers did not consider Aboriginal perspectives to be part of the written curriculum, and therefore, not a teaching imperative. Maclellan (2015) noted that the way that curriculum is translated depends on the teacher, something frequently supported by the data in this study. The question that seemed to be a filter for teachers in regards to the science curriculum is “what do students need to learn?” While the science Program of Studies, as developed by governing bodies, dictates what it feels as being important for students to know about science, it is interpreted and translated by the individual teacher. The specific effects of the individual teacher are discussed in a later section, but the general results are examined here.

An individual teacher's personality and beliefs about teaching and learning had a significant impact on what was interpreted as the teachable and testable curriculum. Each interview supported this notion; each teacher had something unique to say about how they view teaching science. As seen in the Analysis chapter, Eli, Daniel, and Sarah spoke to teaching their students to challenge everything as a priority in their science classroom, while Michael focused his teaching in science on it being a system of explanatory models. Thomas tried to be culturally sensitive by giving students the opportunity to learn particular outcomes in the science curriculum through various projects that they could bring some of their own cultural experiences into. Anne enriched the physics portion of her general science courses and simply tried to get through the biology and ecology sections. It was not evident in any of the interviews, however, that the inclusion of Aboriginal perspectives was a priority. Teachers interpreted the curriculum in a particular way and enriched it based on their own interests and personality (discussed in more detail later).

Statements made by teachers in the interviews did indicate why they did not consider Aboriginal perspectives in the curriculum to be an important part of the science classroom. Teachers said that Aboriginal perspectives were not part of standardized tests and so were not a priority in the classroom. As well, they mentioned the lack of professional development for including these perspectives in the classroom. Their responses suggested that teachers interpreted these two factors as indicating the lack of importance that external agencies put on Aboriginal perspectives in the science classroom, so, why should they? Related to this were concerns about the impact of actually taking time to include these perspectives. They felt that inclusion would affect success on assessments as it would take time away from what they considered to be the “important” outcomes in class. Teachers were concerned that Aboriginal perspectives are not relevant to all students in their classrooms, as seen in the scenario responses, as well as interviews such as Anne and Christina. Similarly, some teachers indicated concerns about including alternative perspectives to Western science being solely focused on Aboriginal, excluding other students in a culturally diverse classroom. Anne mentioned that she felt that Aboriginal perspectives “outdated themselves” and were just not relevant to students in our modern classrooms. Underlying all of these concerns seems to be a resistance to adding something that teachers do not consider as an important part of the curriculum (if they were to see it as part of it at all). This resistance is discussed in more detail in the next section, but it is important to mention alongside the above critique of the written curriculum as they may impact each other. How the curriculum is written with the placement of Aboriginal perspectives with more Western science objectives, particularly either as attitude outcomes or as italicized suggestions of how to enrich/teach a particular outcome, has an effect on how a teacher interprets the curriculum. The interpretation of the curriculum, as evidenced by the data, is influenced by many factors, but it would seem that the actual document itself does impact how teachers view particular knowledge.

Summary.

The written curriculum, or Program of Studies, was referenced often throughout the interviews as a resource for the content of the science classroom. It was referred to as something that teachers were responsible for as deliverers of the curriculum in their classrooms. Given the importance that teachers placed upon the curriculum, it is necessary to examine it in more detail in regards to the inclusion of Aboriginal perspectives. As is seen in the analysis above and subsequent discussion, the curriculum as written may have had an influence on how teachers interpret it in their classrooms. The use of particular language, placement of the intention of integrating Aboriginal perspectives, and actual inclusion of Aboriginal technologies and experiences as italicized statements, seems to have an impact on what teachers see as the hierarchy of important outcomes to teach in their classrooms. The next section goes into more depth on the impact that the individual teacher has on the sharing and valuing of knowledge in the science classroom, as could be inferred from the data.

The teacher variable: Internal and external constraints.

For most teachers, Indigenous perspectives were not currently being included in their classes, and if it was, it was in a tokenistic manner. This section looks at the constraints identified by teachers, both internal and external, and the responsibility of teachers regarding classroom pedagogy and content. As discussed in the previous section about the complexity of this research topic, a primary variable in the integration of Indigenous perspectives in the science classroom is the teacher. While analyzing the data, it was evident that the individual teacher, with his/her knowledge base, personality, perception of teaching, personal values, context, and teaching goals, had an impact on how he/she taught science. Each teacher was unique in how he/she interpreted their teaching context, what their goals for their classroom were, and what their epistemic beliefs of science and beliefs of teaching were. There was a disconnect for many teachers between what they were currently doing in the classroom regarding inclusion of Aboriginal perspectives (i.e., 15/20 teachers selected Scenario 2 as best reflecting their current practice) and what they would prefer to do (i.e., 14/20 teachers chose a different scenario as reflecting their preferred practice). Teachers gave several reasons as barriers to teaching in their preferred scenario. Some of these were considered to be external to the teacher (i.e., time, curriculum, and resources), while others were seen as being inherent to the teacher (i.e., personal knowledge and experience with Aboriginal perspectives, epistemic beliefs of science, personal interest and teaching beliefs).

These constraints are discussed in this section in the context of the impact that the person and personal framework of the teacher has on integration of Indigenous perspectives in the classroom. This is separated into three sections. The first section focuses on teacher knowledge and teaching beliefs, personal interests, and epistemic beliefs of science as inherent constraints to practice. Following this is a discussion of the value placed on knowledge in the classroom with the pedagogical choices that teachers make, integrating the constraints that teachers identified as external to themselves. Finally, a more in-depth discussion of a teacher's responsibility regarding content and pedagogy in the science classroom, in light of these identified constraints is developed. As with other sections in this discussion, each section includes examples from the collected and analyzed data, and how these are supported with references from the literature.

The internal constraints to inclusion.

As discussed previously, how teachers choose to teach, both consciously and unconsciously, is impacted by their personal frameworks or worldviews that have been developed through their own experiences and knowledge (Bechtel, 2016; Cobern, 1996; Gess-Newsome & Lederman, 1995; Lantz & Kass, 1987). When encountering new knowledge, one's worldview carries presuppositions that impact how they view and validate that knowledge (Cobern, 1996). Lederman (1999) found in his study that classroom practice was not necessarily influenced only by the conception of science that teachers had. Rather, it was impacted by teachers' experiences, the intentions they had in the classroom, and their perception of students (Lederman, 1999). This finding is supported by the model for teacher behavior described by

McRobbie and Tobin (1995) where context (i.e., teacher experiences), goals (i.e., teacher intention for the classroom), and other beliefs (i.e., perception of students) all impact teaching practice. In Lederman (1999), teachers also reported that their preferred and actual practice did not align, as was also seen with many teachers in this research project. Lederman and Lederman (2014) found in their review of the literature that there were several variables that impacted how teachers translated their notion of the NOS into their teaching practice. These included organizing and managing their classrooms, constraints that they felt from the institution, concerns they had with the ability and motivation of students, their own personal teaching experience, the pressure they felt to cover the content, and unease with their understanding of NOS and what they perceived as being the lack of resources to adequately assess student understanding of NOS (Lederman & Lederman, 2014). These findings throughout the literature echoed those found in this study. McRobbie and Tobin's (1995) model for teacher behavior puts these concerns into factors that impact teacher actions: goals, beliefs, and context. Even though these studies from the literature focus on how the NOS is translated in the science classroom, this may also be related to how teachers choose to integrate Indigenous perspectives in the classroom as many of these concerns were similar to what teachers in this study reported as contributing to a disconnect between their current and preferred practice.

The impact of personal experience and knowledge, or lack thereof, with Indigenous perspectives was a prominent theme that emerged from the analyzed data. As stated earlier, teaching has been described as a "cultural exercise, embedded in at least one particular knowledge system and one particular set of beliefs" (Kelly, Shultz, Weber-Pillax, & Lange, 2009, p. 263). When this is read in light of other literature around the impact of teachers' epistemic beliefs on practice (see literature review for further discussion and references), it begs the question of whether teachers, for whom Indigenous perspectives is not part of their personal culture and epistemological framework, can actually teach these perspectives in a way that is appropriate. Proponents of Indigenous science in the literature (see Aikenhead, 2001, 2006; Aikenhead & Michell, 2011; Aikenhead & Ogawa, 2007; Cajete, 2000, 2004; Hatcher, Bartlett, Marshall, Marshall, 2009; Kim, 2015) seem to be in agreement that a much broader understanding of the epistemology underlying Aboriginal perspectives needs to be understood to be able to teach it in a respectful way. In this study, teachers such as Sarah, Trevor, Christina, and Anne all said that they “don’t know” what an Indigenous perspective would look like and that they “don’t know where to look” for these types of resources. These teachers, along with others, did not seem to have a sense of urgency to find information to enhance their practice. They seemed content with being what Dion (2007) has described as “the perfect stranger.”

Teachers’ personal interests and values were found to impact how they enrich the content in the science classroom. This has been seen elsewhere in the literature as well. In a study looking at academics’ teaching experiences, it was shown that teachers have unique understandings of what it means to know their subject and as consequence, will represent that subject differently to their students (Prosser et al., 2005). Other literature has shown that there are many factors that influence the choices teachers make about their pedagogy. Lyons (1990) calls this “nested knowing,” where a teacher’s work is an interaction between knowledge and values, his/her approach to teaching, and assumption he/she makes about knowing. Other scholars consider the “on-the-job social construction of what it means to be a science teacher” (Deneroff, 2016, p. 214) as having a significant influence on teaching practice.

The impact of teachers’ epistemic beliefs of science on how they might perceive Indigenous perspectives should be noted, as this was the original focus of the study. Teachers in this study held a process-focused view of science that related an understanding of science to how to “do” science. Some teachers, such as Michael, Anne, and Christina, went so far to say that if a particular cultural worldview did not try to “find out [the] why” of natural phenomena, that it could not be considered scientific. The conflation between what science is (NOS) and a process in science has also been observed in the literature (Abd-El-Khalick, Bell, & Lederman, 1998). An experimental way to test knowledge claims places value on the explanations that a scientific process provides (Gallagher, 1991). Using experimentation as the measure of validity of knowledge may explain the perception that Indigenous knowledge is not “valid science” that some teachers held in this study. There is an issue with this perception of science, as Gough (1998) suggests, because the production of scientific knowledge is stereotyped and mythologized. This perception is important to explore as the development of what students perceive as science is affected by teacher beliefs (Lidar, Lundqvist, & Ostman, 2006). As conveyed in greater detail in the literature review, a deeper understanding of the nature of Western science should be a priority for teachers and teacher educators in how epistemic beliefs of science are developed. The process-focused definition of science that many teachers had was limiting to their understanding of how Indigenous perspectives could be incorporated in a non-tokenistic way.

The external constraints and the value they place on teaching practice.

As has been mentioned previously, and intentionally included in the analysis of the interview data, is the lack of recognition that Aboriginal perspectives are part of the teachable curriculum. The data suggested that teachers saw a place for inclusion of some sort by choosing more integrated scenarios as their preferred practice, but were quick to offer ways in which they felt they were unable to actually do this in their classrooms. The previous section focused on the internal constraints that teachers specifically mentioned in the interviews or implied in their responses. This section looks at the identified external constraints that teachers felt and the impact that they had on teaching in the science classroom.

The following section discusses the impact that the use of time, teaching resources, and administrative support through professional development have on pedagogical choices teachers make. One major issue for teachers in this study was the availability of resources to help them integrate Aboriginal perspectives in the classroom. Teachers reported in another study that they found "perceived or actual obstacles such as lack of resources, time, and administrator support as well as the pressure of standardized testing and coverage of material that seem to prevent the actualization of some of teachers' ideas in the classroom (Kazempour & Amirshaokoohi, 2014, p. 287). The impact of the written curriculum and standardized testing was the focus of a previous section. What a teacher chooses to do in the classroom affects the abilities, knowledge, attitudes, and understandings of the student (Ballone & Czerniak, 2001).

Time.

Time, from the interviews, was reported as a significant factor for teachers as they planned and implemented curriculum. Teachers said they had a limited amount of time in which to complete what they considered to be the required content of the Program of Studies. They also made choices in how they used their personal time to frame said curriculum into their own teaching style and philosophies to help students learn. While the amount of time given for a course may be outside of a teacher's control, the way that time is delegated by the teacher within their classroom to particular content or activities denotes value to particular ideas. Teachers mentioned this within the interviews; time is spent on topics that they felt were important for understanding, for continuing on in that subject, and for success on standardized assessments. In relation to Indigenous perspectives, teachers mentioned that they felt it would take time away from what they needed to teach. This was particularly evident in responses that indicated that teachers liked Scenario 2 because it quickly acknowledged the contributions of Aboriginal people to scientific knowledge and then allowed the teacher to “move on.” The concept of “moving on” suggests that some teachers might feel that the curriculum as something to work through, outcome by outcome. One contributing factor to this may be the way in which the Program of Studies in science is written as specific knowledge, skills, and attitude outcomes that students (and teachers) are responsible for. How standardized assessments are constructed may also play a role. Teachers valued time and felt it was wasted when not spent on what they described as outcome-heavy curriculum.

What teachers spent time on, whether in the classroom with students or in their own preparation to teach, places value on particular ideas. Spending time on something in a classroom, as suggested by the data collected in the qualitative portion of this study, would signal to students that it was important for their learning and success in the subject. As evidenced from the data, teachers currently use Aboriginal perspectives as a way to provide some context for what they consider to be a more *important* topic. The epistemic beliefs of a teacher and subsequent teaching practice, as suggested in the literature (e.g., Brickhouse, 1990; Fitzgerald & Cunningham, 2012; Richardson, 1996; van Driel, Beijaard & Verloop, 2001), would have an effect on the developing epistemologies of their students. Lidar, Lundqvist, and Ostman (2006) describe these as “epistemological moves” where the teacher gives students direction in deciding what counts as knowledge and the ways in which to get it. Time would have a considerable impact on these epistemological moves as it was evident that teachers valued time, which would be translated to their students in how time was used in the classroom.

Textbooks.

One particular teaching resource that was mentioned in the interviews was the textbooks used in science classrooms. As seen in Section 3 of the analysis, teachers found the inclusion of Aboriginal perspectives to be minimal, and when included, condescending to Aboriginal people. This observation was also made in another Canadian study where teachers reported that they found textbooks to be focused more on the traditional and historical aspects of Indigenous knowledge, rather than any contemporary contributions (Kim, 2015). Aikenhead (2006) found that the inclusion of Aboriginal science in Canadian textbooks as stereotyping Aboriginal people, decreasing the relevancy of Aboriginal science by using past tense verbs, and putting Western science epistemologies above Aboriginal epistemologies. Anne described putting trust in what the authors of the textbooks chose to include as being important to the content of her science class. More discussion around the professional responsibility of teachers in interpreting and using resources is in the next section, however, it does seem that conversations that are critical of the resources provided to teachers and students should be taking place. While this is partly the responsibility of the teacher, it also falls upon governing bodies and school districts to support resources that reflect their curricular intentions.

Professional development.

Professional development, or the lack thereof, as perceived by the interviewed teachers, was one area of support that teachers felt was lacking as to how they should integrate Indigenous perspectives in their classrooms. Suggestions of how professional development can be used as a tool to facilitate conversations about epistemic beliefs and their impact on teaching practices, as well as what Aboriginal perspectives are and how that might look in a science classroom are discussed in the section of this chapter called “Going Forward.” It is mentioned here though as it was a barrier repeatedly mentioned by teachers. The data suggested that teachers thought that professional development had potential in influencing their teaching practice, but felt that there was not enough provided to them. Rachel, for instance, found that professional development that did exist focused primarily on classroom activities. She thought that the focus of the school district in helping teachers develop their practice had traditionally been on *what* happens in the classroom instead of *why* something happens in the classroom. For the teachers who mentioned professional development, their comments suggested that there was implicit value placed by the priorities of the school and school district in professional development. The final section of this discussion looks in more detail at the ways in which the value that professional development denotes may be mitigated and used for developing a teacher's understanding of Indigenous perspectives and the science classroom.

Teacher responsibility in the classroom.

As previously described in the literature review, teachers in Alberta are expected to adhere to the Teaching Quality Standards (TQS) as issued by Alberta Education. In this document, it states that "quality teaching occurs when the teacher's ongoing analysis of the context, and the teacher's decisions about which pedagogical knowledge and abilities to apply, result in optimal learning for all students" (Alberta Education, 2019, p. 3). Part of the expectations of teachers is that they engage in "career-long professional learning and ongoing critical reflection to improve teaching and learning" (p. 4). They are also expected to apply "a current and comprehensive repertoire of effective planning, instruction, and assessment practices" (p. 5), which includes "address[ing] the learning outcomes in programs of study" (p. 5). This document suggests that it is the professional responsibility of the teacher to understand and teach *all* the learning outcomes in the programs of study. As well, it also suggests that it is the responsibility of the teacher to seek out ways in which to improve their professional knowledge and practice.

This is an important distinction to make as interviewed teachers generally did not see it as their responsibility to seek out information about Aboriginal perspectives in order to attend to those outcomes in the curriculum. Their responses suggested that they saw it to be the responsibility of external agencies such as the school district, government bodies, and teacher education programs to provide the information and tools for teachers to use. As seen in the data and in this discussion, teachers cite many situational constraints as why they do not include Indigenous perspectives in the classroom. However, this did not seem to be the case for more science-based objectives in the curriculum as teachers reported focusing time for instruction and enrichment. This could be for a variety of reasons, but part of this may be in how a teacher identifies him/herself as a science teacher. This has been shown to have an impact on the professional choices that they make and how they justify these to others (Sutherland, Howard, & Markauskaite, 2010). Jones and Leagon (2014) consider teacher self-efficacy to be influenced by previous experiences and feedback from peers. In this way, it becomes part of one's belief system (Jones & Leagon, 2014). Several teachers mentioned not being comfortable with teaching Indigenous perspectives. It is possible that teachers do not feel efficacious about integrating Indigenous perspectives in a science classroom and so have built this into their belief system around those ways of knowing. While this does not take away the teacher's responsibility when seeking out resources and understanding of Indigenous perspectives, just as they would do with any science outcome, it does provide some context as to why this might be the case.

Summary.

The variable of teacher in how Indigenous perspectives are integrated and presented in the science classroom was something that became evident throughout the analysis of the data. The beliefs that teachers have about science, but also about Indigenous perspectives were important for their teaching practice. Teachers' responses did not indicate that they felt the same sense of responsibility for learning and integrating Indigenous perspectives in their classrooms as they would more traditional science objectives. The next section considers what should be done with this information in going forward from the data and discussion.

Moving Forward

Throughout the analysis and discussion, the question at the back of my mind is, "now what?" What are ways in which to go forward from this study into further research or as actions that may address some of the concerns that arose from the data? What has become increasingly clear from the data is that these teachers have epistemic frameworks or worldviews that impact how they view the integration of Indigenous perspectives in the classroom. These teachers, generally, have a limited and limiting understanding of science that has a filtering effect on what they see as being valid knowledge in the science classroom. These teachers do not interpret the curriculum in such a way that recognizes the presence of Indigenous perspectives or do not see them as an important teachable and assessable outcome. These teachers do not consider it their responsibility to find information and resources in order to integrate Indigenous perspectives in their science classrooms in an authentic way. The following section presents different ways that these conclusions may be addressed by teachers and by external groups such as school districts, governing bodies, and post-secondary institutions.

Ideas for the teacher.

A simplistic view to take from the conclusions drawn above would be that teachers are not educated in a way that helps them to see a broader understanding of science in order to value Indigenous perspectives in the science classroom. It is also simplistic to suggest that the written curriculum and standardized assessments do not present Aboriginal perspectives in a way that indicates value to the teacher using these tools to guide his/her teaching. It would be easy to shift the onus from the teacher about what is happening in most classrooms regarding Indigenous perspectives to the agents who prepare and support them as teachers. This is addressed and discussed below. However, it is important that teachers take some ownership and responsibility for this, rather than be passive recipients of knowledge as they hold power in their classrooms with what their students consider to be valid knowledge (Ballone & Czerniak, 2001). There are two primary ways suggested here that teachers may begin taking responsibility for this process: first, becoming aware of their epistemic beliefs and other factors that impact their teaching, and second, becoming critical of them.

Throughout the literature, scholars stress the importance of teachers' awareness of their personal epistemological beliefs. The rationale is that teachers are unable to make changes to their practice if they are unaware of their beliefs (Maclellan, 2015; Maggioni & Parkinson, 2008). Scholars suggest that inexperienced teachers have little explicit knowledge of their own epistemological worldview (Calderhead, 1996; Patrick & Pintrich, 2001), although the data from this study would suggest that experienced teachers also have little knowledge about their epistemological worldview. Rachel was the only teacher who described the experience of realizing that she may have had a way that she views knowledge and that had an effect on what she did in the classroom. She found it difficult, though, to specifically name those beliefs. Other teachers alluded to their ideas about science and how that influenced how they approached teaching science. Thomas had a specific definition of science that he gave students ("testable, repeatable, observable, and you can make predictions") that his interview responses suggested that he recognized to have a filtering effect on how he viewed knowledge labeled as science. Sarah also mentioned how she would have to change the way she thought to teach in a way that integrated Indigenous perspectives in her science classrooms. Becoming explicitly aware of and addressing one's own beliefs and assumptions should be the norm for teachers, rather than the exception.

Becoming critical of the beliefs that one holds should go with a developing awareness of them. Abd-El-Khalick, Bell, and Lederman (1998) suggest that teachers should become aware of the rationale for teaching the NOS in their classrooms. These authors refer to the NOS as the "epistemological commitments underlying the activities of science" (p. 418). Similar to this study, the teachers in Abd-El-Khalick, Bell, and Lederman's (1998) research also conflated the process of science with what they considered to be the NOS. Being aware and critical of one's understanding of NOS and how it is presented in classrooms should be a priority for teachers. Alongside this must be an awareness of one's beliefs around Indigenous perspectives. Brayboy and Castagno (2008) suggest that teachers need to look at their epistemological concerns as part of the conversation of Indigenous science and providing more culturally responsive education. It is evident from the analysis of the data of this study that teachers have not considered their epistemological concerns with Indigenous perspectives in the science classroom. They speak to concerns that including these perspectives would have on time in the classroom for what is considered more important objectives, but most do not mention the disconnect that they feel between the differing epistemologies of Indigenous perspectives and Western science. Teachers often mentioned the context in which they taught (i.e., time constraints, curricular constraints, administrative pressure), but seemed to consider these outside their realm of influence. The context could then be used by teachers as something that prevented them from teaching as they thought they wished. Becoming critical of their own worldviews and perspectives on what knowledge should be presented in a science classroom and *why* they think this would be an interesting direction for teacher action and future research.

Ideas for school districts, governing bodies, and post-secondary institutions.

School districts, governments, and post-secondary institutions also have a role in how Indigenous perspectives are incorporated in science classrooms in Alberta. Though there may be other possibilities, three areas are identified in the data that these external agencies could contribute to: professional development, curriculum, and teacher education programs.

School districts: professional development.

The use of professional development to support teachers in building their knowledge about Indigenous perspectives and ways to integrate these perspectives into a science classroom was a popular solution presented by several teachers in the interviews. Several teachers mentioned professional development either as being an influential aspect of the formation of their beliefs around teaching science or as a barrier to the inclusion of Aboriginal perspectives in the classroom in its shallow or absent purpose of actually addressing how this could be done. From this, it seemed that teachers thought that professional development could have potential in influencing their teaching practice, although many felt there was a lack of it provided to them. Several issues have been seen with professional development throughout the literature. Some studies have found that teachers find professional development to be a waste of time and usually will continue to teach the same way, even with professional development meant for reformed practice (Deneroff, 2016; Windschitl, 2004). These echoed sentiments provided by teachers in the interviews who said that it tended to primarily focus on classroom activities, rather than looking at the root of what is done in the classroom.

While there have been many examples of why professional development does not work, there have also been studies that look at what makes it more effective in influencing teaching practice. Effective professional development has been described as being context bound (Fishman, et al., 2003), which is an important consideration when beginning to look at its content. There may need to be specificity within the constructed professional development to help give teachers a framework to start. Other studies have described the need for teachers to consider and reflect on their beliefs, especially how it might affect their practice, within ongoing professional development (Arce, Bodner, & Hutchinson, 2014; Maggioni & Parkinson, 2008; Stolberg, 2007). This is important for professional development to be effective as teachers who question the efficacy of content or practices given in professional development are less likely to incorporate it into their classroom practice (Richardson, 1996). With the frequent questioning of teachers as to "why Aboriginal?" as the culture that was focused upon in terms of integration in the classroom with their classes becoming more culturally diverse, this is an important consideration. If teachers' do not see the content of professional development as useful or applicable to them, it is unlikely that they will merge any of those ideas into their teaching practice (Arce, Bodner, & Hutchinson, 2014)). Looking at underlying beliefs and attitudes that teachers have around teaching may make these sessions more engaging for teachers and have a greater effect for their practice (Jones & Leagon, 2014).

The issue of time was at the forefront for many teachers, so intentionally setting time aside for this type of conversation and thinking might be very beneficial for teachers. Time has been shown to impact the success of professional development. Studies show that professional development must take place over an extended period of time for there to be any change in pedagogy (Kazempour & Amirshokoohi, 2014; Supovitz & Turner, 2000). Giving teachers the opportunity to collaborate with their peers has also been suggested as an essential component of professional development (Desimone et al., 2002; Kazempour & Amirshokoohi, 2014). Jones and Leagon (2014) suggest that professional development should build in opportunities where teachers can see how other teachers successfully do things in their classrooms. This would provide teachers with concrete examples of how different teaching practices can be done well, helping teachers feel success (Jones & Leagon, 2014; McKeown, Abrams, Slattum, & Kirk, 2016; Yoo, 2016). Weaving those best practices suggested in the literature into the foundation of professional development planning and implementation could have a profound effect on teachers' beliefs systems (McKeown, et al., 2016).

Governing bodies: curriculum.

Concerns about the curriculum, both how it is written and how it is interpreted by teachers, have made up a significant part of this discussion. Teachers spoke to their concerns that the intention of including Aboriginal perspectives in the curriculum, reflected a politicized view of Aboriginal perspectives and culture. Other Canadian curriculum theorists have proposed alternative ways to look at the presence of Indigenous perspectives in Canadian curriculum. Cynthia Chambers (2008) describes the idea of a "curriculum of place" which encourages what and how we learn to be cognizant of the place in which it resides. She teaches in Southern Alberta and so the knowledge and wisdom of the Blackfoot people of that area are important to her and her practice (Chambers & Blood, 2009). Referring to the differing cultures in Canada, Chambers (2012) suggests that the story of Canada is the collective story of all who live here, saying that

> the commons is what sustains us all: it is the true curriculum, the one that calls us to renew our relationships with one another, that calls us to renew our commitment to what we have in common, to our stake in the work and its survival. (Chambers, 2012, p. 30)

Wiseman (2016) suggests that Indigenous perspectives and Western perspectives can "circulate together in teaching and learning" (p. 110). Teachers make the assumption that Indigenous perpsectives are an add-on to the curriculum, when perhaps they should be viewed as a different way in which to teach (Wiseman, Onuczko, & Glanfield, 2015). There is disagreement in the literature about how to integrate Indigenous and Western epistemologies (see literature review). Simply inserting the information about Indigenous perspectives and Indigenous science into the science curriculum does not change the hierarchy of knowledge in the science classroom (Brayboy & Castagno, 2008). Lowan-Trudeau (2014) cautions against integrating Indigenous knowledge into Western ideas, instead suggesting that a blending process may be more useful to create a bridge where commonalities can be found, rather than just differences.

Post-secondary institutions: teacher education programs.

Finally, teacher education programs should be critical of how they present the integration of Indigenous perspectives in the science classroom as post-secondary has been identified as a site in which pre-service teachers develop beliefs about knowledge (Schraw & Olafson, 2002). De Carvalho (2016) sees value in teacher education programs devoting time to help pre-service science teachers to "develop a meaningful understanding of science epistemology and philosophy" (p. 256) that will enable them to engage with conceptualizing how science can be taught in their school contexts. Other scholars advocate for teachers to build understandings of culture and cultural experiences in teacher preparation programs, helping them to become culturally responsive and critical of curricular and instructional resources (Gay, 1996, 2002). To engage critically with the curriculum and how knowledge is presented, teachers require knowledge and experiences that should be part of teacher education programs (Brayboy & Castagno, 2008; Dion 2007; Ogawa, 1995). This is important as teachers can help students become critical of how knowledge is presented (Brayboy & Castagno, 2008).

Summary.

While it is the professional responsibility of the teacher to engage with Indigenous perspectives in his/her classrooms in a respectful way, there are ways in which external agencies can help support this. School districts, governing bodies, and post-secondary institutions all have an opportunity to begin critically engaging with the concerns that were brought up by teachers in this study. Through the development of professional development, curriculum, and teacher education programs that use the literature to establish a "best practice" for integrating, or rather, blending Indigenous perspectives and Western science perspectives in a way that is respectful, teachers' beliefs of these epistemologies and the impact on their pedagogy may be supported.

Chapter 6: Conclusion

This research project developed because of an increased emphasis of incorporation of Indigenous perspectives in education documents in Alberta. The recent revision of the Teacher Quality Standard (Alberta Education, 2019) has prompted more conversations about Indigenous worldviews in the classroom. Curricular documents in Alberta also contain statements about Indigenous perspectives in the classroom, with statements that are meant to guide teachers in how this might be accomplished in their own practice. There has been considerable research into the importance of including Indigenous perspectives in the classroom, as well as much discussion on various ways in which this might be done. Research has examined the factors impacting teacher practice, which can include beliefs that teachers have about teaching and about knowledge (epistemic beliefs), the context that teachers teach in, and teachers' personal teaching goals, as well as the goals of the school district and governing bodies.

There is a gap however, in exploring the factors that impact the actual and preferred practice of teachers when integrating Indigenous perspectives in the science classroom. This research study sought to investigate these factors using a mixed methods methodology. Through the use of a survey, constructed teaching scenarios, and semi-structured interviews, it was discovered that many factors impact teacher practice around integrating Indigenous perspectives. Although it was thought at first that epistemic beliefs of science would be the primary influence for teachers in this, the data that emerged strongly suggested that there were a host of other factors that impacted teacher practice. Reframing the study around a revised version of McRobbie and Tobin's (1995) model for teacher behavior (see Figure 5) enabled me to expand my view of teaching practice around Indigenous perspectives in the science classroom.

This study is unique and timely as the conversations around Indigenous perspectives in the classroom are occurring, but there is little discussion of what might encourage or limit a teachers' actual practice. The findings of this study is a starting point for further research that will support teachers in this current shift in education in a way that addresses the multiple facets of teaching practice.

References

Abd-El-Khalick, F. (2005). Developing deeper understandings of the nature of science: The impact of a philosophy of science course on preservice teachers' views and instructional planning. *International Journal of Science Education, 27*, 15-42.

Abd-El-Khalick, F. (2012). Nature of science in science education: Toward a coherent framework for synergistic research and development. In B.J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 1041-1060). Dordrecht: Springer.

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82*(4), 417-436.

Aikenhead, G. S. (1987). A module for teaching scientific decision making. *Bulletin of Science, Technology, and Society, 7*, 137-145.

Aikenhead, G. S. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education, 27,* 1-51.

Aikenhead, G. S. (2000). "Rekindling traditions: Cross-cultural science and technology units" project. Retrieved from https://www.usask.ca/education/ccstu/units/snowshoes.html.

Aikenhead, G. (2001). Integrating Western and Aboriginal sciences: Cross-cultural science teaching. *Research in Science Education, 31*, 337-355.

Aikenhead, G. S. (2006). *Science education for everyday life: Evidence-based practice*, New York, NY: Teachers College Press.

Aikenhead, G. S., & Jegede, O. J. (1999). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching, 36*(3), 269-287.

Aikenhead, G. & Michell, H. (2011). *Bridging cultures: Indigenous and scientific ways of knowing nature,* Toronto, ON: Pearson Canada Inc.

Aikenhead, G. S. & Ogawa, M. (2007). Indigenous knowledge and science revisited. *Cultural Studies of Science Education, 2,* 539-620.

Alberta Education (2014). Science 10: Program of studies. Retrieved from https://education.alberta.ca/media/3069384/pos_science_10.pdf.

Alberta Education (2017). Preparing to write a math or science diploma examination 2017-2018: A guide for students. Retrieved from https://education.alberta.ca/media/3653521/07-mathscience-guide-for-students-2017-2018_20170912.pdf.

Alberta Education (2019). Teaching Quality Standard. Retrieved from https://education.alberta.ca/media/3739620/standardsdoc-tqs-_fa-web-2018-01-17.pdf.

Alters, B. J. (1997). Whose nature of science? *Journal of Research in Science Teaching, 34*(1), 39-55.

Aoki, T. (1991). "Teaching as indwelling between two curriculum worlds." In William F. Pinar (Ed.) & Rita Irwin (Ed.), *Curriculum in a New Key: The Collected Works of Ted Aoki* (pp. 159-165). Routledge.

Aoki, T. T. (2005). In the midst of slippery theme-words: Living as designers of Japanese Canadian curriculum. In W. F. Pinar & R. L. Irwin (Eds.), *Curriculum in a new key: The collected works of Ted T. Aoki* (pp. 263-277). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Arce, J., Bodner, G. M., & Hutchinson, K. (2014). A study of the impact of inquiry-based professional development experiences on the beliefs of intermediate science teachers about "best practices" for classroom teaching. *International Journal of Education in Mathematics, Science and Technology, 2*(2), 85-95.

Ballone, L. M., & Czerniak, C. M. (2001). Teachers' beliefs about accommodating students' learning styles in science classes. *Electronic Journal of Science Education, 6*(2).

Barnett, J. & Hodson, D. (2001). Pedagogical context knowledge: Toward a fuller understanding of what good science teachers should know. *Science Education, 85*(4), 426-453.

Barnhardt, R. & Kawagley, A. O. (2005). Indigenous knowledge systems and Alaska Native ways of knowing. *Anthropology and Education Quarterly, 36*(1), 8-23.

Barthes, R. (1985). *Mythologies*. New York: Hill and Wang.

Barzilai, S. & Zohar, A. (2014). Reconsidering personal epistemology as metacognition: A multifaceted approach to the analysis of epistemic thinking. *Educational Psychologist, 49*(1), 13-35.

Bechtel, R. (2016). Oral narratives: Reconceptualising the turbulence between Indigenous perspectives and Eurocentric science views. *Cultural Studies of Science Education, 11*, 447-469.

Bendixen, L. D. & Rule, D. C. (2004). An integrative approach to personal epistemology: A guiding model. *Educational Psychologist, 39*(1), 69-80.

Benson, G. D. (1989). Epistemology and science curriculum. *Journal of Curriculum Studies, 21*(4), 329-344.

Blanco, R. & Niaz, M. (1997). Epistemological beliefs of students and teachers about the nature of science: From 'baconian inductive ascent' to the 'irrelevance' of scientific laws. *Instructional Science, 25*, 203-231.

Bogdan, R. C. & Biklen, S. K. (2007). *Qualitative research for education: An introduction to theories and methods* (5th ed.). Boston, MA: Pearson Education, Inc.

Bol, L. & Strage, A. (1996). The contradiction between teachers' instructional goals and their assessment practices in high school biology courses. *Science Education, 80*(2), 145-163.

Boren, J., Baker, T. T., Hurd, B. J., Mason, G., & Knight, J. E. (2004). Tanning deer hides and fur skins. *Bringing Science to Your Life: Guide L-103.* Retrieved from https://www.uaex.edu/environment-nature/wildlife/youth-education/TR%20Tanning%20deer%20hide%20AZ.pdf.

Brayboy, B. M. J., & Castagno, A. E. (2008). How might Native science inform "informal science learning?" *Cultural Studies of Science Education, 3,* 731-750.

Brickhouse, N. W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education, 41*(3), 53-62.

Bruner, J. (1986). *Actual minds, possible worlds.* Cambridge: Harvard University Press.

Buehl, M. M., & Alexander, P. A. (2001). Beliefs about academic knowledge. *Educational Psychology Review, 13*(4), 385-418.

Cajete, G. (2000). *Native science: Natural laws of interdependence*. Santa Fe, NM: Clear Light Publishers.

Cajete, G. (2004). Philosophy of Native science. *American Indian Thought,* 45-57.

Calderhead, J. (1996). Teachers: Beliefs and knowledge. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of Educational Psychology* (pp. 709-725). New York: MacMillan.

Chambers, C. (2008). Where are we? Finding a common ground in a curriculum of place. *Journal of the Canadian Association for Curriculum Studies, 6*(2), 113-128.

Chambers, C. (2012). “We are all treaty people: The contemporary countenance of Canadian curriculum studies”. In N. Ng-A-Fook & J. Rottman (Eds.), *Reconsidering Canadian curriculum studies* (pp. 23–38). New York, NY: Palgrave Macmillan.

Chambers, C. M., & Blood, N. J. (2009). “Love thy neighbour”: Repatriating precarious Blackfoot sites. *International Journal of Canadian Studies,* (39), 253–279.

Chu, M-W. (2009). *Exploring science curriculum emphases in relation to the Alberta physics program of study* (published master’s thesis). University of Alberta, Edmonton, Canada.

Cobern, W. W. (1996). Worldview theory and conceptual change in science education. *Science Education, 80*(5), 579-610.

Cobern, W. W. & Loving, C. C. (2001). Defining “science” in a multicultural world: Implications for science education. *Science Education, 85*(1), 50-67.

Conley, A. M., Pintrich, P. R., Vekiri, I., & Harrison, D. (2004). Changes in epistemological beliefs in elementary students. *Contemporary Educational Psychology, 29*, 186-204.

Couteret, L., King, C., & Thomas, G. (2018). Bridging the gap between theory and practice in science education: Really? When? How? Why? In D. C. Young, W. L. Kraglond-Gauthier, & T. G. Ryan (Eds.), *Readiness for the field: Perspectives from within the triangle of teacher education* (pp. 35-55). Champaign, IL: Common Ground Research Networks.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Thousand Oaks, CA: SAGE Publications, Inc.

De Carvalho, R. (2016). Science initial teacher education and superdiversity: Education science teachers for a multi-religious and globalized science classroom. *Cultural Studies of Science Education, 11*, 253-272.

DeBacker, T. K., Crowson, H. M., Beesley, A. D., Thoma, S. J., & Hestevold, N. L. (2008). The challenge of measuring epistemic beliefs: An analysis of three self-report instruments. *The Journal of Experimental Education, 76*(3), 281-312.

Deneroff, V. (2016). Professional development in person: Identity and the construction of teaching within a high school science department. *Cultural Studies of Science Education, 11*, 213-233.

Deniz, H. (2011). Examination of changes in prospective elementary teachers' epistemological beliefs in science and exploration of factors mediating that change. *Journal of Science Education and Technology, 20,* 750-760.

Desimone, L. M., Porter, A. C., Garet, M. S., Yoon, K. S., Birman, B. F. (2002). Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Educational Evaluation and Policy Analysis, 24*(2), 81-112.

Dey, I. (1999). *Grounding grounded theory: Guidelines for qualitative inquiry*. San Diego, CA: Academic Press.

Dion, S. D. (2007). Disrupting molded images: Identities, responsibilities, and relationships – teachers and indigenous subject matter. *Teaching Education, 18*(4), 329-342.

Duell, O. K. & Schommer-Aikins, M. (2001). Measures of people's beliefs about knowledge and learning. *Educational Psychology Review, 13*(4), 419-449.

Duffee, L. & Aikenhead, G. S. (1992). Curriculum change, student evaluation, and teacher practical knowledge. *Science Education, 76,* 493-506.

Eisner, E. W. (1979). *The educational imagination: On the design and evaluation of school programs.* New York: MacMillan.

Enderle, P., Dentzau, M., Roseler, K., Southerland, S., Granger, E., Hughes, R., Golden, B., & Saka, Y. (2014). Examining the influence of RETs on science teacher beliefs and practice. *Science Education, 98*(6), 1077-1108.

Fishman, B. J., Marx, R. W., Best, S., & Tal, R. T. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and Teaching Education, 19*, 643-658.

Fitzgerald, J. & Cunningham, J. W. (2012). Mapping basic issues for identifying epistemological outlooks. In P. R. Pintrich & B. K. Hofer (Eds.), *Personal Epistemology: The psychology of beliefs of knowledge and knowing* (pp. 209-228). Mahweh, NJ: Taylor and Francis.

Gallagher, J. J. (1991). Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. *Science Education, 75*(1), 121-133.

Garroutte, E. (1999). American Indian science education: The second step. *American Indian Culture and Research Journal, 23*(4), 91-114.

Gaskell, P. (1992). Authentic science and school science. *International Journal of Science Education, 14,* 265-272.

Gaskell, J. (2003). Engaging science education within diverse cultures. *Curriculum Inquiry, 33*(3), 235-249.

Gay, G. (1996). A multicultural school curriculum. In C. A. Grant & M. L. Gomez (Eds.), *Making Schooling Multicultural: Campus and Classroom*, (pp. 37-54). New Jersey: Prentice-Hall, Inc.

Gay, G. (2002). Preparing for culturally responsive teaching. *Journal of Teacher Education, 53*(2), 106-116.

Gess-Newsome, J. & Lederman, N. G. (1995). Biology teachers perception of subject matter structure and its relationship to classroom practice. *Journal of Research in Science Teaching, 32,* 301-325.

Gess-Newsome, J., Southerland, S. A., Johnston, A., & Woodbury, S. (2003). Educational reform, personal practical theories and dissatisfaction: The anatomy of change in college science teaching. *American Educational Research Journal, 40*(3), 731-767.

Ghosh, R. & Abdi, A. A. (2013). *Education and the politics of difference: Select Canadian perspectives, 2nd Edition.* Toronto: Canadian Scholars' Press Inc.

Gough, N. (1998). 'If this were played upon a stage': School laboratory work as a theatre of representation. In J. Wellington (Ed.), *Practical work in school science: Which way now?* London: Routledge.

Gregoire, M. (2003). Is it a challenge or a threat? A dual-process model of teachers' cognition and appraisal processes during conceptual change. *Educational Psychology Review, 15*(2), 147-179.

Guba, E. & Lincoln, Y. (1987). *The politics of program evaluation.* Beverly Hills, CA: Sage.

Guba, E., & Lincoln, Y. (1989). *Fourth generation evaluation*. Beverly Hills, CA: Sage

Habermas, J. (1974). *Knowledge and human interests* (2nd ed.). J.J. Shapiro (Ed.). London: Heinemann.

Hammer, D. & Elby, A. (2012). On the form of a personal epistemology. In P. R. Pintrich & B. K. Hofer (Eds.), *Epistemology: The psychology of beliefs of knowledge and knowing* (pp. 121-144). Mahweh, NJ: Taylor and Francis.

Hashweh, M. Z. (1996). Effects of science teachers' epistemological beliefs in teaching. *Journal of Research in Science Teaching, 33*(1), 47-63.

Hatcher, A., Bartlett, C., Marshall, M., & Marshall, A. (2009). Two-eyed seeing: A cross-cultural science journey. *Green Teacher, 86*, 3-6.

Hermes, M. (2000). The scientific method, Nintendo, and Eagle feathers: Re-thinking the meaning of "culture-based" curriculum in Ojibwe tribal school. *Qualitative Studies in Education, 13*, 387-400.

Hesse-Biber, S. Nagy (2010). *Mixed methods research: Merging theory with practice.* New York: Guilford Press.

Hipkins, R., Barker, M., & Bolstad, R. (2005). Teaching the 'nature of science': Modest adaptations or radical reconceptions? *International Journal of Science Education, 27*(2), 243-254.

Hofer, B. (2000). Dimensionality and disciplinary differences in personal epistemology. *Contemporary Educational Psychology, 25*, 378-405.

Hofer, B. K. (2004). Epistemological understanding as a metacognitive process: Thinking aloud during online searching. *Educational Psychologist, 39*(1), 43-55.

Hofer, B. K. & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research, 67*(1), 88-140.

Hofer, B. K. & Pintrich, P. R. (2002). *Personal epistemology: The psychology of beliefs about knowledge and knowing.* Mahwah, NJ: Lawrence Erlbaum

Hofer, B. K. & Sinatra, G. M. (2010). Epistemology, metacognition, and self-regulation: Musings on an emerging field. *Metacognition Learning, 5*, 113-120.

Hogan, K. (2000). Exploring a process view of students' knowledge about the nature of science. *Science Education, 84*(1), 51-70

Jenkins, E. W. (1996). The ‘nature of science’ as a curriculum component. *Journal of Curriculum Studies, 28*(2), 137-150.

Johnston, P., Woodside-Jiron, H., & Day, J. (2001). Teaching and learning literate epistemologies. *Journal of Educational Psychology, 93*(1), 223-233.

Jones, M. G. & Leagon, M. (2014) Science teacher attitudes and beliefs: Reforming practice. In Lederman, N. G. & Abell, S. K. (Eds.) *Handbook of Research on Science Education, Volume II* (pp. 830 – 847). New York, NY: Routledge.

Kang, N-H. & Wallace, C. S. (2004). Secondary science teachers’ use of laboratory activities: Linking epistemological beliefs, goals, and practices. *Science Education, 89*(1), 140-165.

Kazempour, M., & Amirshokoohi, A. (2014). Transitioning to inquiry-based teaching: Exploring science teachers’ professional development experiences. *International Journal of Environmental and Science Education, 9*, 285-309.

Kelly, J., Shultz, L., Weber-Pillax, C., & Lange, E. A. (2009). Expanding knowledge systems in teacher education: Introduction. *The Alberta Journal of Educational Research, 55*(3), 263-268.

Kilian-Schrum, S. (1996). An investigation into the implementation of a high school science program with an STS dimension. In K. Calhoun, R. Panwar & S. Shrum (Eds.), *Proceedings of the 8th symposium of IOSTE*.Vol. 1. Edmonton, Canada: Faculty of Education, University of Alberta, pp. 104-108.

Kim, E. J. (2015). Neo-colonialism in our schools: Representations of indigenous perspectives in Ontario science curricula. *McGill Journal of Education, 50*(1), 1-25.

King, P. M. & Kitchener, K. S. (2004). Reflective judgment: Theory and research on the development of epistemic assumptions through adulthood. *Educational Psychologist, 39*(1), 5-18.

Koulaidis, V., & Ogborn, J. (1995). Science teachers' philosophical assumptions: How well do we understand them? *International Journal of Science Education, 17*(3), 273-283.

Lantz, O., & Kass, H. (1987). Chemistry teachers' functional paradigms. *Science Education, 71,* 117-134.

Leach, L., Neutze, G., & Zepke, N. (2001). Assessment and empowerment: Some critical questions. *Assessment and Evaluation in Higher Education, 26*(4), 293-305.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29,* 331-359.

Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching, 36*(8), 916-929.

Lederman, N. G. & Lederman, J. S. (2014). Research on teaching and learning of nature of science. In Lederman, N. G. & Abell, S. K. (Eds.) *Handbook of Research on Science Education, Volume II* (pp. 830 – 847). New York, NY: Routledge.

Lidar, M., Lundqvist, E., & Ostman, L. (2006). Teaching and learning in the science classroom: The interplay between teachers' epistemological moves and students' practical epistemology. *Science Education, 90*(1), 148-163.

Lincoln, Y. S., & Guba, E. (1985). *Naturalistic inquiry.* Beverly Hills, CA: Sage.

Longbottom, J. E. & Butler, P. H. (1999). Why teach science? Setting rational goals for science education. *Science Education, 83*(4), 473-492.

Loving, C. C. (1997). From the summit of truth to its slippery slopes: Science education's journey through positivist-postmodern territory. *American Educational Research Journal, 34*(3), 421-452.

Lowan-Trudeau, G. (2014). Considering ecological metissage: To blend or not to blend? *Journal of Experimental Education, 37*(4), 351-366.

Luft, J. A. (2001). Changing inquiry practices and beliefs: The impact of an inquiry-based professional development programme on beginning and experienced secondary science teachers. *International Journal of Science Education, 23*, 517-534.

Lyons, N. (1990). Dilemmas of knowing: Ethical and epistemological dimensions of teachers' work and development. *Harvard Educational Review, 60*(2), 159-180.

Maclellan, E. (2015). Updating understandings of 'teaching: Taking account of learners' and teachers' beliefs. *Teaching in Higher Education, 20*(2), 171-182.

Maggioni, L. & Parkinson, M. M. (2008). The role of teacher epistemic cognition, epistemic beliefs, and calibration in instruction. *Education Psychological Review, 20,* 445-461.

Maggioni, L., Riconscente, M., & Alexander, P. A. (2006). Perceptions of knowledge and beliefs among undergraduate students in Italy and the United States. *Learning and Instruction, 16*(5), 467-491.

Markis, S. & Eilks, I. (2012). A comparison of student teachers' beliefs from four different science teaching domains using a mixed methods design. *International Journal of Science Education, 34*(4), 589-604.

Marshall, C., & Rossman, G. B. (2011). *Designing qualitative research* (5th ed.). Thousand Oaks, CA: Sage.

Maxwell, J. A. (1996). *Qualitative research design: An interactive approach.* Thousand Oaks, CA: Sage.

McKeown, T. R., Abrams, L. M., Slattum, P. W., & Kirk, S. V. (2016). Enhancing teachers' beliefs through an inquiry-professional development program. *Journal of Education in Science, Environment, and Health, 2*(1), 85-97.

McKinley, E. (2005). Locating the global: Culture, language, and science education for indigenous students. *International Journal of Science Education, 27*(2), 227-241.

McRobbie, C. & Tobin, K. (1995). Restraints to reform: The congruence of teacher and student actions in a chemistry classroom. *Journal of Research in Science Teaching, 32*(4), p. 373-385.

Muis, K. R. (2007). The role of epistemic beliefs in self-regulated learning. *Educational Psychologist, 42*(3), 173-190.

Muis, K. R., Bendixen, L. D., & Haerle, F. C. (2006). Domain-generality and domain-specificity in personal epistemology research: Philosophical and empirical reflections in the development of a theoretical framework. *Educational Psychology Review, 18,* 3-54.

Munby, H. & Roberts, D. (1998). Intellectual independence: A potential link between science teaching and responsible citizenship. In D. Roberts & L. Ostman (Eds.), *Problems of meaning in science curriculum* (pp. 101-114). New York: Teachers College Press.

Nadasdy, P. (1999). The politics of TEK: Power and the "integration" of knowledge. *Arctic Anthropology, 36*(1-2), 1-18.

Ochalla, D. N. & Onyancha, O. B. (2005). The marginalized knowledge: An infometric analysis of indigenous knowledge publications (1999-2004). *South African Journal of Libraries and Information Science, 71*, 247-248.

O'Loughlin, M. (1992). Rethinking science education: Beyond Piagetian constructivism toward a sociocultural model of teaching and learning. *Journal of Research in Science Teaching, 29*, 791-820.

Ogawa, M. (1995). Science education in a multiscience perspective. *Science Education, 79*, 583-593.

Osborne, J. (2007). Science education for the twenty-first century. *Eurasia Journal of Mathematics, Science and Technology Education, 3*(3), 173-184.

Patrick, H., & Pintrich, P. R. (2001). Conceptual change in teachers' intuitive conceptions of learning, motivation, and instructions: The role of motivational and epistemological beliefs. In B. Torf and R. Sternberg (Eds.), *Understanding and teaching the intuitive mind* (pp. 117–143). Mahwah, NJ: Erlbaum.

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage.

Peers, I. (1996). *Statistical analysis for education and psychology researchers*. London: Falmer Press.

Pomeroy, D. (1993). Implications of teachers' beliefs about the nature of science: Comparison of the beliefs of scientists, secondary science teachers, and elementary teachers. *Science Education, 77*(3), 261-278.

Pomeroy, D. (1997). STL in a culturally diverse world. In E. W. Jenkins (Ed.), *Innovations in science and technology education* (Vol. VI) (pp. 59-76). Paris: UNESCO.

Pratt, D. D. (1992). Conceptions of teaching. *Adult Education Quarterly, 42*(4), 203-220.

Prosser, M., Martin, E., Trigwell, K., Ramsden, P., &Lueckenhausen, G. (2005). Academics' experience of understanding of their subject matter and the relationship of this to their experiences of teaching and learning. *Instruction Science, 33,* 137-157.

Rich, N. (2012). Introduction: Why link *Indigenous* ways of knowing with the teaching of environmental studies and sciences? *Journal of Environmental Studies and Sciences, 2*, 308-316.

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula, T. Buttery, & E. Guyton (Eds.), *Handbook of research on teacher education* (pp. 102-119). New York: Simon and Schuster Macmillan.

Rizk, N., Jaber, L., Halwany, S., & BouJaoude, S. (2012). Epistemological beliefs in science: An exploratory study of Lebanese university students' epistemologies. *International Journal of Science and Mathematics Education, 10*(3), 473-496.

Roberts, D. A. (1982). Developing the concept of "curriculum emphases" in science education. *Science Education, 66*(2), 243-260.

Roberts, D. A. (1988). What counts as science education? In P. Fensham (Ed.), *Development and Dilemma in Science Education* (pp. 27-55). Philadelphia: The Falmer Press.

Roberts, D. A. (1995). Junior high school science transformed: Analyzing a science curriculum policy change. *International Journal of Science Education, 17*(4), 492-504.

Roberts, D. A. (1998). Analyzing school science courses: The concept of companion meaning. In D. A. Roberts and L. Ostman (Eds.), *Problems of meaning in science curriculum* (pp. 5-12). New York, NY: Teachers College Press.

Rule, A. C. (2006). Editorial: The components of authentic learning. *Journal of Authentic Learning, 3*(1), 1-10.

Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology, 82,* 498-504.

Schraw, G., Bendixen, L. D., & Dunkle, M. E. (2002). Development and validation of the Epistemic Belief Inventory (EBI). In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 261-275). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Schraw, G. & Olafson, L. (2002). Teachers' epistemological world views and educational practices. *Issues in Education, 8*(2), 99.

Schwartz, R. & Lederman, N. G. (2008). What scientists say: Scientists' views of the nature of science and relation to science context. *International Journal of Science Education, 30*(6), 727-771.

Shizha, E. (2007). Critical analysis of problems encountered in incorporating indigenous knowledge in science teaching by primary school teachers in Zimbabwe. *Alberta Journal of Educational Research, 53*(3), 302-319.

Siegal, H. (2002). Multiculturalism, universalism, and science education: In search of common ground. *Science Education, 86*(6), 803-820.

Simpson, L (2004). Anticolonial strategies for recovery and maintenance of Indigenous knowledge. *American Indian Quarterly, 28*, 373-384.

Snively, G. & Corsiglia, J. (2001). Rediscovering indigenous science: Implications for science education. *Science Education, 85*, 6-34.

Southerland, S. A. (2000). Epistemic universalism and the shortcomings of curricular multicultural science education. *Science & Education, 9*, 289-307.

Stolberg, T. (2007). The religio-scientific frameworks of pre-service primary teachers: An analysis of their influence on their teaching of science. *International Journal of Science Education, 29*(7), 909-930.

Sund, P. (2016). Discerning selective traditions in science education: A qualitative study to teachers' responses to what is important in science teaching. *Cultural Studies of Science Education, 11*, 387-409.

Sund, P. & Wickman, P. O. (2011). Socialization content in schools and education for sustainable development – I. A student of teachers' selective traditions. *Environmental Education Research, 17*(5), 599-624.

Supovitz, J.A., & Turner H. M. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching, 37*(9), 963-980.

Sutherland, L., Howard, S., & Markauskaite, L. (2010). Professional identity creation: Examining the development of beginning preservice teachers' understanding of their work as teachers. *Teaching and Teacher Education, 26*(3), 455–465.

Tobin, K. & Imwold, D. (1993). The mediational role of constraints in the reform of mathematics curricula. In J. A. Malone & P. C. S. Taylor (Eds.), *Constructivist interpretations of teaching and learning mathematics* (pp. 15-34). Perth, Australia: Curtin University Press.

Tobin, K. & McRobbie, C. (1996). Cultural myths as constraints to the enacted science curriculum. *Science Education, 80*(2), 223-241.

Tirri, K, Husu, J., & Kansanen, P. (1999). The epistemological stance of the knower and the known. *Teaching and Teacher Education, 15,* 911-922.

Truth and Reconciliation Commission of Canada (2015). Truth and Reconciliation Commission of Canada: Calls to Action. Winnipeg, Manitoba. Retrieved from http://www.trc.ca/websites/trcinstitution/File/2015/Findings/Calls_to_Action_English2.pdf

Tsai, C. (2002). A science teacher's reflections and knowledge growth about STS instruction after actual implementation. *Science Education, 86,* 23-41.

Tsai, C. (2007). Teachers' scientific epistemological views: The coherence with instruction and students' views. *Science Education, 91*(2), 222-243.

Tsai, C., Ho, H. N. J., Liang, J., & Lin, H. (2011). Scientific epistemic beliefs, conceptions of learning science and self-efficacy of learning science among high school students. *Learning and Instruction, 21*, 757-769.

van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teacher, 38*(2), 137-158.

van Driel, J. H., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching, 35*(6), 673-695.

Veal, W. R., Lloyd, M. E. R., Howell, M. R., & Peters, J. (2016). Normative beliefs, discursive claims, and implementation of reform-based science standards. *Journal of Research in Science Teaching, 53*(9), 1419-1443.

Windschitl, M. (2004). Folk theories of "inquiry": How preservice teachers reproduce the discourse and practices of an atheoretical scientific method. *Journal of Research is Science Teaching, 41*(5), 481-512.

Wiseman, D. (2016). *Acts of living with: being, doing, and coming to understand Indigenous perspectives alongside science curricula* (published master's thesis). University of Alberta, Edmonton, Canada.

Wiseman, D., Onuczko, T., & Glanfield, F. A. (2015). Resilience and hope in the garden: Intercropping Aboriginal and Western ways of knowing to inquire into science teacher education. In H. Smits & R. Naqvi (Eds.), *Framing Peace: Thinking about and enacting curriculum as "radical hope"* (pp. 237-252). New York, NY: Peter Lang Publishing

Yoo, J. H. (2016). The effect of professional development on teacher efficacy and teachers' self-analysis of their efficacy change. *Journal of Teacher Education for Sustainability, 18*(1), 84-94.

Appendix

Appendix 1: Summary of Curriculum Emphases from Chu (2009)

Curriculum Emphasis	Explanation
Everyday Coping	The use of science to understand everyday occurrences and technology.
Structure of Science	How science functions; emphasis on evidence-based explanations and the scientific method in how scientific knowledge is developed.
Science, Technology, and Decisions	The relationship between scientific explanations, technology, and decision-making in society.
Scientific Skill Development	Skills basic to scientific inquiry; the scientific process.
Correct Explanation	Science regarded as valid and reliable knowledge from experts to give explanations for natural phenomena.
Self as Explainer	Examining and understanding the factors that impact how one develops knowledge and understanding.
Solid Foundation	Science taught as an accumulation of knowledge, with knowledge taught to scaffold the next level of learning.

Appendix 2: Teacher Consent Form

Please sign the form below to indicate your willingness to take part in the study described above.

I, ____, have read the accompanying information letter and give my informed consent to participate in the research study, **The Impact of Teachers' Epistemic Beliefs on the Inclusion of Indigenous Perspectives in the Science Classroom**, conducted by Christa King.

I hereby agree to:

- Interview with Christa King about my beliefs about science knowledge and pedagogical actions, with responses being audio-recorded and transcribed

In agreeing to take part in this study, I understand that:

- I am under no obligation to participate
- Even after giving my consent to take part, I may discontinue without penalty at any time. I may withdraw information that was already collected by contacting Christa King within one month of the collection of that data.
- Information that I provide will be treated as confidential. Direct quotes from me may be used in research reports (i.e. thesis documents, presentation, and publications), but my name and other identifying information will be changed or omitted.
- Research reports will be used for academic and professional presentations (e.g. conferences, workshops) as well as academic and professional publications.

I understand that I am under no obligation to participate in this study and that I can withdraw from the study after which any information or data that directly link to me as an individual will be excluded from the study.

____
(print name)

____ ____________________
(signature) (date)

Appendix 3: Constructed Teaching Scenarios

Scenario 1.

A teacher gives a lesson on the difference between biotic and abiotic parts of the local ecosystem. Biotic is described as things that are living, while abiotic are termed as those which are non-living. A student raises his hand and asks about an indigenous perspective that all things contain a spirit and because of this, are interconnected. The teacher replies, distinguishing that perspective as a religious belief particular to a culture, while the definitions of biotic and abiotic are scientific and is therefore applicable in all circumstances. Gently, she tells the student that cultural and spiritual beliefs are not what are taught in a science classroom.

Scenario 2.

A teacher gives a lesson on the history of Western medicine. She gives the example of the development of pain relievers such as Aspirin or acetylsalicylic acid. She tells the students that Aboriginal people traditionally used willow bark for minor pain by either chewing it or brewing it into tea. The active ingredient in willow bark is salicylic acid, and while the Aboriginal people did not know it at the time, this was the forerunner for the synthetic compound acetylsalicylic acid, which is found in our modern-day Aspirin. Felix Hoffman first synthesized this compound in 1897 and was trademarked as Aspirin in 1899.

Scenario 3.

A teacher begins a discussion about the benefits and risks of human activity on the environment. He spends time going through the Western science understanding of the impact of humans on the environment, framing it through the Gaia hypothesis that all organisms interact with their abiotic surroundings in a synergistic relationship. Within this presentation, he is careful to remind students of the definition of science that has been developed throughout the semester to make sure that they remember what science is able to contribute as knowledge and the limitations it has as a way of thinking. Because this class has several indigenous students, the teacher encourages the students to share their perspectives on how all things in the universe interact. As a class, they discuss what insights this indigenous knowledge might offer to decisions made by governments and the general public. Time is spent comparing and contrasting these different worldviews and looking at how each can inform a more holistic understanding of the topic.

Scenario 4.

A teacher presents a lesson on pressure using ideas from indigenous science on snowshoes. In these series of lessons, students discuss the need for snowshoes for Aboriginal peoples based on different types of terrain and snow, considering factors such as snowfall, climate, and length of the winter. Students learn the traditional and current ways that snowshoes are made and how this contributes to concepts such as surface area, force, and pressure. Students learn to calculate pressure using the force exerted and surface area of the snowshoe. Snowshoes as a technology used by Aboriginal people is discussed in both Western and indigenous science perspectives, looking at how those two views of science complement and differ from each other. As part of this lesson, students also take a critical look at how knowledge is passed on in both views of science, discussing the benefits and concerns of each.

Appendix 4: Example Questions from Semi-Structured Interviews

Part 1:

How many years of experience do you have teaching science and what area do you primarily teach?

What's your educational background?

Part 2:

In your opinion, how do we come to know what scientific knowledge is?

How did you develop this idea? Where did it come from in your experience?

How has it changed over time?

Part 3:

If you were to give a lesson on the definition of science to your students, what would you tell them? Or how would you give the lesson?

Part 4:

In your response to the scenarios, you said ________ when asked which scenario you would most likely reflect what you do in the classroom and ________ when you asked which you would prefer to use. Can you elaborate on those two responses? Why is there a difference (*if there is one*)?

When might you choose to use something like this in your classroom? (*does it ever depend on <u>who</u> is in your class?*)

Part 5:

In scenarios 3 and 4, indigenous perspectives are included within the classroom in different ways. Is there a distinction for you? What impact do you think this has on using it in the class?

Are there any constraints that prevent you from teaching/incorporating different ideas into your classroom?

Part 6:

Throughout the course of this study, you have been asked about your views of science as knowledge and how that impacts your decisions in the classroom. Is this something new to you? I.e. have you thought about this before? Why or why not?

Have you ever had a moment when you were aware of how your beliefs about science as knowledge affected your pedagogical choices?

What did that look like? *Or if not*, why do you think you haven't been aware of that?

What drives the choices you make in your classroom?

Has this changed over the course of your career?

Appendix 5: High School Students' Scientific Epistemic Beliefs (SEBs) Survey (original)

Source (*where knowledge comes from*)

1. Everyone has to believe what scientists say.
2. In science, you have to believe what the science books say about stuff.
3. Whatever the teacher says in science class is true.
4. If you read something in a science book, you can be sure it is true.

Certainty (*how certain you are about the knowledge)*

1. All questions in science have one right answer.
2. The most important part of doing science is coming up with the right answer.
3. Scientists pretty much know everything about science; there is not much more to know.
4. Scientific knowledge is always true.
5. Once scientists have a result from an experiment, that is the only answer.

Development (*how knowledge is developed*)

1. Some ideas in science today are different than what scientists used to think.
2. The ideas in science books sometimes change.
3. There are some questions that even scientists cannot answer.

Justification (*how do we know what we know*)

1. Ideas about science experiments come from being curious and thinking about how things work.
2. In science, there can be more than one way for scientists to test their ideas.
3. One important part of science is doing experiments to come up with new ideas about how things work.
4. Good answers are based on evidence from many different experiments.

5. Ideas in science can come from your own questions and experiments.

Appendix 6: Survey Questions in Modified Survey (by dimension)

Source (*where knowledge comes from*)

1. Everyone should believe what scientists say.
2. When teaching science, the information in the textbook should always be taken as true.
3. There is only one definition of science as determined by the scientific community.
4. The explanations provided in textbooks about natural phenomena can be applied to every context.

Certainty (*how certain you are about the knowledge)*

1. All scientific questions have one right answer.
2. The most important part of teaching science is helping students come up with the right answer.
3. Scientists know nearly everything about natural phenomenon.
4. Scientific knowledge is always true.
5. Valid scientific knowledge comes from experimentation by scientists.

Development (*how knowledge is developed*)

1. Some scientific ideas today are different than what scientists used to think.
2. What is considered science is influenced by culture.
3. There are some questions that science cannot answer.
4. Scientific conclusions are always objective.

Justification (*how do we know what we know*)

1. Ideas about science come from being curious and thinking about how things work.
2. There is more than one way to test a scientific theory.

3. Scientific experiments have the same basic framework each time.

4. Good scientific explanations are based on evidence from many different experiments.

5. Ideas in science can come from questions and observations made in many different settings.

Appendix 7: Recruitment Letter

Dear Principal,

My name is Christa King and I am writing to ask for your assistance in the recruitment of science teachers to be part of a research study entitled **The Impact of Teachers' Epistemic Beliefs of Science on the Inclusion of Indigenous Perspectives in the Science Classroom**. This study is undertaken to fulfill the thesis requirements of my Masters degree in secondary science education at the University of Alberta. I am a teacher with the Calgary Catholic School District and have been approved by the district to conduct this research. Please see the approval letter attached to this email.

The purpose of this research is to look at the way teachers' beliefs around science knowledge impacts pedagogical actions for the inclusion of indigenous perspectives. Previous research has shown that teachers' personal beliefs about science as a domain of knowledge impacts their pedagogical choices of how to teach science, but a gap exists when looking at how these beliefs affect considering and including other perspectives in the science classroom. In Alberta, Aboriginal perspectives are a part of the Program of Studies, but there is little research into how these are actually being incorporated. Results from this research could be used to inform teacher education programs and curriculum planning.

Participation of teachers in this study is completely voluntary and they are under no obligation to participate. Full participation in the study would involve (a) answering a short online survey, and (b) if interested, interviewing with me about their beliefs about science knowledge and pedagogical actions, elaborating on responses from the survey for approximately 45 minutes. Should you being willing to pass along information to science teachers within your school, an email will be sent to you containing information about the study for teachers and a link for the online survey. Teachers who indicate within the survey their interest in being contacted for further participation in audio-recorded interviews will be emailed a consent form and information letter. The interview would be between the teacher and myself and will be scheduled at a time and place of mutual convenience and agreed upon by both parties. Even if teachers agree to participate, they are under no obligation to answer any specific questions.

Teachers will be able to opt out of the study, up until one month after the data has been collected, by informing me by phone or email that they no longer wish to participate. In the event that they no longer wish to be part of the study, any data collected will be removed from the data set. This will not have any adverse repercussions on their employment and no notification will be given to supervising teacher or administration.

Results from this study will appear in my final thesis and may also be presented at academic and professional conferences and could appear in academic and professional journals. Included within research reports may be direct quotes made by teachers, but names will not be used. In order to maintain confidentiality, privacy and anonymity, all identifying information will be omitted when results are made public. The proposal for this study has been reviewed for its compliance with ethical guidelines as established by the Research Ethics Board at the University of Alberta and will adhere to the University of Alberta Standards for the Protection of Human

Research Participants. For further information of these standards, please see http://www.reo.ualberta.ca/Human-Research-Ethics.aspx.

I will have primary access to data that will be stored digitally with a secure password on my personal computer or in a locked filing cabinet at my personal residence. I will be the only person to transcribe and analyze the audio-recorded interviews. During the transcription and data entry process, teachers will not be identified and following digitization of the data, all identification and names will be replaced with pseudonyms and codes. My supervisor, Dr. Gregory Thomas, will be the only other person to have access to the digitized, anonymous data. This data will be securely stored for a minimum of five years and will then be destroyed.

Two copies of the letter of consent will be provided, with one being signed and returned to myself and one kept for the teacher's personal records.

If you have any questions regarding this study, you may contact me at 403-796-7870 (christak@ualberta.ca) or my supervisor, Dr. Gregory Thomas at 780-492-5671 (gthomas1@ualberta.ca). If you have any questions or concerns about 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.

If you are able to assist in providing science teachers in your school with information and a survey link for this study, <u>please contact me by responding to this email as soon as possible</u>.

Thank you for your consideration of this request.

Sincerely,

Christa King Masters student (University of Alberta)

Appendix 8: List of Codes Used in Analyzing Interviews

1) Definition of science (sub-codes: focus on knowledge, focus on process, focus on communication, focus on history)
2) Epistemic belief of science (sub-codes: source of knowledge, certainty of knowledge, development of knowledge, justification of knowledge, value of knowledge)
3) Demographic influence (sub-codes: access issue, personal constraints to learning, influence of culture, influence of language, change in teaching practice)
4) Integration of concepts (sub-codes: challenges to integration, tokenize approach, pluralistic approach, multi-science approach, importance of integration, why Aboriginal?)
5) Perception of Aboriginal worldview (sub-codes: purpose of integration, understanding of Aboriginal worldview)
6) Program of Studies impact (sub-codes: current curricular content, presence of Aboriginal worldview, upcoming curricular change)
7) Professional development (sub-codes: lack of professional development opportunities, professional development potential, current professional development opportunity)
8) Teacher characteristic (sub-codes: personal development, personal interest)
9) Teacher development over time (sub-codes: impact of professional development, impact of experience, impact of collaboration)
10) Teaching beliefs (sub-codes: importance of relationships, role of the teacher)
11) Teaching constraint (sub-codes: time, diplomas, curricular content, extracurricular obligation)
12) Teaching strategy (sub-codes: teaching tool, relationship building, mechanics of teaching)

13) Metacognition (sub-codes: awareness of an epistemic belief, monitoring of an epistemic belief)