‘Canadian-grown’: Student perspectives about learning science in a culturally diverse classroom

by

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Abstract

As a result of science being viewed as universal and promoting Eurocentric values, science education has been suggested to be inaccessible for culturally and linguistically diverse students as measured by achievement gaps, poor standardized test results, and racial and ethnic disparities in science. Therefore, the literature suggests that culturally and linguistically diverse students will face barriers in their epistemological understanding of science. This qualitative case study sought to explore student perspectives of the implementation of science education in a culturally diverse classroom. Data collection focused on in-depth, semi-structured interviews with 13 student participants in a culturally diverse classroom, and twice weekly classroom observations for three months.

Students in this study defined science as the disciplines demarcated in school and universal in content. However, they also believed that science was prone to influence, particularly in the ways in which scientists interpreted results and arrived at decisions. While students had varied opinions on whether culture influenced science education, they did not feel that in their particular science class culture mattered as they all felt that they were 'Canadian-grown' – as in, students were all learning in the same classroom therefore they shared similar values and understanding with respect to learning science in this particular context. There was no evidence from observations within this study, from the students, their achievement, or their teacher to suggest that students encountered cultural challenges or barriers in accessing school science. However, the student participants held a range of diverse beliefs and values with respect to different topics within their science class but were never asked to incorporate their perspectives into their learning. These were potentially missed opportunities to make their science class more personally meaningful.

The findings from this research support recent concerns that incorporating culture and multiculturalism in science education in order to address achievement and access gaps to science may be based on hypothesized links. While incorporating culture and multiculturalism within science class is important, for example, to value diversity of perspective, as an understanding of the multicultural society in which students live, and to better address the Calls to Action in the Truth and Reconciliation Commission of Canada, the assumptions regarding student's inability to epistemologically access science education if culture is not included was not supported by the students in this study.

Preface

This thesis is an original work by Tracy Lynn Onuczko. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "Science education in culturally diverse classrooms", No. PRO00040921, July 31, 2013.

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Table of Contents

List of Tables

List of Figures

Chapter One: Introduction

Background

Canada in the 21st century is becoming increasingly culturally and linguistically diverse (Chan, 2006; He, Phillion, Chan, & Xu, 2008). Between 1986 and 2016, the newcomer or immigrant population increased from 15.6% to 21.9% of the total Canadian population (Statistics Canada, 2017). In addition to increasing levels of immigration, there has been a shift in the ethnic orientation of recent immigrants. The drop in European immigration to Canada from 1961 to 2012 was approximately 58%, while recent immigrants coming from Asia, including the Middle East, accounted for 61.8% of newcomers to Canada (Statistics Canada, 2016). In addition, for the first time in census-recording history, immigration from Africa ranked second ahead of Europe (Statistics Canada, 2017). In Alberta specifically, the percentage of new immigrants from 2001 to 2016 increased from 6.9% to 17.1%, with Calgary's immigrant population accounting for 29.4% of the total population and 23.8% in Edmonton (Statistics Canada, 2017). Increasing ethnic and cultural diversity in the Canadian and Albertan populations is resulting in Alberta schools becoming more diverse in terms of language, traditions, and culture (Alberta Education, 2009; Alberta's Commission on Learning, 2003; He, et al., 2008).

Schlein (2009) has argued that two central areas of focus in education are multiculturalism and diversity, as "schools are provided with the great responsibility of and opportunity for structuring successful academic environments for amplified numbers of underrepresented and newcomer students" (p. 22). However, teachers are often unprepared to address cultural diversity in schools due to a lack of experience with cultural diversity (Chan, 2006; Liston & Zeichner, 1996; Schlein, 2009). The majority of teachers in North America come from White, middle-class backgrounds and do not always have familiarity or experience with the multitude of cultural backgrounds or norms of the students in their classes (Liston & Zeichner, 1996). As Chan (2006) has suggested, “given the role of experience in shaping perceptions of curriculum, we can expect that teachers’ practices would be shaped by their own experiences of culture in their school curriculum” (p. 172). Given that many teachers have not had these types of cultural experiences, teachers are required to make curricular decisions for the diverse learners in their classes without the experience or knowledge of the diverse cultures of their students (Schlein, 2009). Even when teachers are committed to learning and about cultural diversity, classroom diversity presents a challenge, as the knowledge and skills that teachers require are lacking in teaching education programs and in teachers’ professional development (Bryan & Atwater, 2002; Calabrese Barton, 2000; Suriel & Atwater, 2012).

Science education, in particular, can be a complex location for discussions surrounding cultural diversity and education because, as researchers have argued, science is often viewed as universal and immune to the influence of cultural diversity (e.g. Carter, 2008; Lee, 2001; Siegel, 2002). Milne (2011) has argued that the canon of the scientific method was developed out of the Enlightenment and fosters the universal image of science by promoting one exacting and correct way of following a procedure for determining how we order phenomena. A universal epistemology in science determines “that the culture, gender, race, ethnicity, or sexual orientation of the knower is irrelevant to science knowledge” (Stanley & Brickhouse, 1994, p. 388). Traditional Western or Eurocentric science, in particular, has claimed to be objective and value-free, promoting universal truths (Carter, 2008; Siegel, 1997, 2002). The practices of science and how these practices are known have been determined by evaluation, discovery, and validation strategies of Eurocentric science. The values of Eurocentric science have been equated with scientific universalism, and this valuing has influenced science education in the West (Lee, 2001).

In Canada, this is best seen in the *Common Framework of Science Learning Outcomes: Pan-Canadian Protocol for Collaboration on School Curriculum* (CMEC, 1997), which represents the Council of Ministers of Education of Canada's (CMEC) aims for science education. Aikenhead (2006) has suggested that the vision of the Pan-Canadian science framework "assumes a particular cultural context or school science: canonical Western science content embedded in the predominant Euro-Canadian culture" (p. 388). The Pan-Canadian science framework, in addition, forms the basis for provincial and territorial science curricula. In Alberta, this can be seen in all science programs of study (e.g. Alberta Education, 2014) and in the Alberta Senior High science program vision in statements that identify science knowledge, such as "students focus on learning the big interconnecting ideas and principles. These ideas, or major themes, originate from science knowledge that transcends and unifies the natural science disciplines" (Alberta Education, 2006, ¶ 2).

Research Issue

There is a growing concern that science education represents Eurocentric values and epistemologies, resulting in inequitable access to school science due to differences between school science and students' worldviews, ethics and values, and views about appropriate pedagogical practices. Initiatives promoting 'science for all' have become a central area of focus in science education, as there has been growing global recognition that many students feel estranged from and unable to access school science (Cobern & Aikenhead, 1998; Lee, 2001; Gaskell, 2003). Research in science education and culturally and linguistically diverse students has led to questions about what is taught in science classes, how science is being taught, and what is counted as science (Carter, 2007; Lee, 2001). UNESCO (2009), for example, has recognised the need to adapt educational approaches to consider intercultural competency and culture-specific learning as a response to the discourse surrounding the universality of science and science education.

In contrast to the view of science as a universal endeavour, some researchers have framed science education and science itself as a “socially and culturally embedded” (Abd-El-Khalick, 2005, p. 17) discipline, as they are both part of, and affected by, cultural and social factors. Schools largely reflect White, Western, or Eurocentric interests, and this is highly pronounced in science curricula (Aikenhead & Jegede, 1999; UNESCO, 2009). Lee (2001) has suggested that it can be a challenge for teachers to provide equitable instructional and assessment practices for diverse students in science because connecting cultural norms with mainstream science can be problematic with respect to relevancy and meaning for students.

In response to growing cultural diversity and the Eurocentric focus of science education, researchers have called for the inclusion of culture in science education through efforts such as culturally relevant and responsive curricula and multicultural education (Calabrese Barton, 2000; Lee, 2001; Pomeroy, 1994). Culturally relevant and responsive science curricula, as Calabrese Barton (2000) has suggested, can reframe science so that diversity becomes a resource rather than a problematic issue. This may be achieved by asking questions about the nature of science, the implications for science education within diverse settings, and the relationship between science and society. In her view, a culturally relevant science curriculum would be a critical urban pedagogy that “must respond to the political and ethical consequences that science has in the world, and must be equally infused with analysis and critique as it is with production” (Fusco & Calabrese Barton, 2001, p. 343).

According to Hodson (1993), multicultural science education can mean a variety of different things to different people, and that the needs in different locations and schools can vary accordingly. Approaches to multicultural science education that are too narrow or prescriptive can lead to a strict focus on areas such as enrolment levels of traditionally underrepresented groups, divisive approaches (i.e. differentiated courses for different ethnic groups), or tokenistic additions to curricula (Hodson, 1993). Despite these potential problems, a significant amount of research promoting multicultural science education exists (Bryan & Atwater, 2002; Cobern & Loving, 2001; He, et al., 2008; Hodson, 1993; Snively & Corsiglia, 2001).

Research in science education and cultural diversity has focussed on broad topics, such as the place of different knowledge systems within schools (e.g. Aikenhead & Jegede, 1999; Carter, 2007; Parsons & Carlone, 2013; Snively & Corsiglia, 2001), and on more narrow topics, such as linguistic and vocabulary difficulties, multicultural approaches to teaching and learning, and specific ethnic and cultural groups of students and teachers (e.g. Aikenhead, 1997; Gao, 1998; He, et al., 2008; Iannacci, 2006; Luft, Bragg, & Peters, 1999). The perspectives and experiences of students remain strikingly absent from the discussion, particularly regarding culturally diverse classrooms.

Purpose and Research Questions

The purpose of this case study is to explore students' perspectives of the implementation of science education in a culturally diverse classroom. Curriculum implementation is thought about broadly within this study and includes the ways in which the science curriculum in Alberta is being put into practice, how schools and outside resources and pressures support or hinder implementation efforts, the ways in which students respond to the curriculum, and the interactions between all facets of the instructional environment. The main research questions guiding this study were formulated as follows:

1. How do students view science, science education, and culture within a culturally diverse classroom?
2. What are the perspectives and experiences of students as they interact with each other, their teachers, and the curriculum in a culturally diverse classroom?

Rationale and Significance

The rationale for this study was to address gaps in the literature pertaining to a lack of focus on students' perspectives on and experiences with the implementation of science education in culturally diverse classrooms. Research on multicultural science education has been based primarily on theoretical discussion papers (Krugly-Smolska, 2013), with little empirical research to support said theories within a science education context. The work that has been done has focussed on intervention approaches for low-achieving immigrant or English-language learners, the perspectives of teachers and teacher candidates, and issues related to language and literacy. The vast majority of these studies have been conducted in schools or classrooms with a majority of students from a particular racial or ethnic group. This case study presents a snapshot of the perspectives of students within a culturally diverse science classroom, focussing on what the students view as strengths, opportunities, and challenges. This is in opposition to more traditional research approaches that have looked at the implementation of a curriculum with a focus on a specific intervention or on a deficit model, in which difficulties are identified and recommendations are made to rectify these difficulties (Rogan & Grayson, 2003). The purpose of looking at strengths, opportunities, and challenges is to provide suggestions for curricular improvements and potential new ways of moving forward in educational research.

Research focus. Details regarding participant recruitment procedures and information about participants are presented in Chapter 3. It is, however, essential to outline at the beginning that all aspects of this study focus on examining growing cultural diversity as a result of the widening diversity of immigrant and newcomer populations in Canada. Research in the field does draw upon First Nations, Métis, and Inuit (FNMI) education research, which is discussed throughout this study. However, FNMI students and their worldviews remain outside of the scope of this study because (1) no students who self-identified as FNMI participated in this study; (2) FNMI are treated as distinctly different when discussing multiculturalism in schools; and; (3) from St. Denis (2011),

> Multiculturalism is dependent on colonial structures because it assumes the legitimacy of the current colonial Canadian government. As multiculturalism ignores ongoing colonialization, the result is a trivializing and erasing of Aboriginal sovereignty. Attempting to equate Aboriginal people with racialized minorities, multiculturalism erases the unique Indigenous/Aboriginal location of Aboriginal peoples (p. 311–312).

Connection to Topic

I came to this topic somewhat unexpectedly, but also because I was fortunate enough to be in the right place at the right time in order to say yes to a number of wonderful opportunities. As a classroom teacher in a K – 12 school, I have always been interested in the work of students and teachers in science classrooms. When I entered into the PhD program I had intended to continue my master's work, which looked at how non-Indigenous high school Biology teachers conceived of incorporating Indigenous perspectives in their classrooms (Blood, 2010; Onuczko & Barker, 2012b). As I continued working with a number of amazing people on different projects towards this goal, I was given the opportunity to work as a research assistant, an instructional leader, and as an intern in China, Norway, and Tanzania. While in China, I was a research assistant on a project that explored the cultural barriers faced by Canadian teachers in teaching the Alberta science curriculum in China to predominantly Chinese students. The results of this study indicated that the Canadian teachers faced cultural barriers with respect to the content they were teaching, the context of the classroom, and differing expectations around pedagogical approaches (Onuczko & Barker, 2012a, 2014). I started to become interested in how science education was being taken up by students and teachers in different areas of the world. I shifted my research goals and intended on looking at how the Alberta science curriculum was being taken up by international schools approved to teach the Alberta curriculum. When the scope, cost, and logistics of traveling the world to do this research became a bit too large, I decided that I did not need to travel the world. In fact, the diversity and demographics of the student body in Alberta was dramatically changing. Schools in Alberta are culturally diverse and the questions I had for students in particular, could be answered by staying right here.

Research assumptions. As a beginning researcher, the literature I read supported a position that there was cultural incongruence between science education, and teachers' and students' everyday worlds (see the literature review for details). Research projects I had participated in, particularly the one with Canadian teachers in China, further corroborated the view that there were cultural barriers in at least teaching science. My own teaching experience did not necessarily support this view, including when teaching in Norway and guest lecturing in science education in Tanzania. Outside of localized, contextualized differences, there did not seem to be cultural barriers that were particularly insurmountable. For example, while in Tanzania, I guest lectured a number of times in a Science Education Masters level course at a university. In my discussions with teachers, it consistently came up how similar our understandings about our students and science education was. However, I was particularly aware of my privileged position as a White teacher, whether teaching in Alberta or anywhere else. It was this awareness that made me default to the literature whenever forming an assumption about what this research might tell me. I assumed going into this research that I would find students who experienced cultural barriers in accessing and understanding school science.

Chapter Two: Literature Review

Introduction

This chapter provides a review of the literature within culture and science education research, outlines the gaps present in the literature, and describes the ways in which this study addresses those gaps. This chapter contains a discussion of how culture has been thought about within science and science education research, including multiculturalism, culturally relevant pedagogy, and a number of theories supporting or refuting culture within science education. The gaps in the literature are highlighted to provide a rationale for the investigation, and the methods employed for this study.

Culture of Science and Science Education

The work of anthropologists of education in the United States and Canada from the 1950s to the 1980s, can be summarised, according to Carlone, Johnson, and Eishenhart (2014), as "students from culturally nondominant (i.e. 'nonmainstream') groups often struggled in school because they did not know or share the values, beliefs, and activities established as the norm for schools by dominant group ideals" (p. 653). The idea that there was a cultural difference between the everyday worlds of students and schools opened up the possibility to science educators that perhaps there was a cultural incongruence between the values, beliefs, and attitudes of science and science education, and those of students (Carlone, et al., 2014). Moving forward, the ways in which science and science education have been understood have been influenced by whether one takes a universalist or cultural perspective with respect to science (e.g. Good, 1995; Loving, 1995; Matthews, 1994; Siegel, 2002; Stanley & Brickhouse, 1994). More recently, the debate between universalism and multiculturalism has shifted, and science education researchers have drawn on concepts of hybridity, third space, funds of knowledge, and figured worlds to discuss the ways in which students and teachers negotiate science classrooms (e.g. Basu & Calabrese Barton, 2007; Calabrese Barton et al., 2013; Holland, Lachicotte, Skinner, & Cain, 1998; Moje et al., 2004; Moll, Amanti, Neff, & Gonzalez, 1992).

Definitions of culture. Culture is a contested term within the literature. The most common definitions or understandings of culture within science education research come from psychological and anthropological perspectives (Parsons & Carlone, 2013). Specifically, culture is “a system of beliefs and values that influences how individuals perceive and interact with the world” (Parsons & Carlone, 2013, p. 2) recognising the dynamic practices of culture both in individuals and within groups. According to Banks and Banks (2007), culture is the values, concepts, and knowledge that are interpreted and shared within a group. Gay (2010) asserted that culture is multidimensional and under constant change. Time, setting, age, economics, social circumstances, and a variety of other factors influence culture; therefore, as much as culture is shared amongst groups, culture also extends differently to the individual.

Krugly-Smolska (1996) has identified “culture [as] one of those concepts that most of us seem to understand but for which we have difficulty providing a definition” (p. 22). This study takes a broad view of culture to include not just expressed behaviours, but also the beliefs and values that one holds. Included here is the idea that “members of ethnic groups [and by extension cultural groups] whether consciously or not, share some core cultural characteristics” (Gay, 2010, p. 10). However, as Wax (1993) notes, there is an inherent

> tension between the view that there is a social entity called *culture* characterized by a thematic unity and manifest as a holistic object that is distinctive in history and space, and the view that sees cultural traits, such as movies, transistor radios, bicycles, and the

appreciation of Mozart and surrealistic sculpture, as diffusing almost randomly over the face of Earth (p. 102, emphasis in the original).

Globalisation that is increased by mass communication, and stronger political, economic, and military relationships is suggested by Wax to be diminishing the educational use of using culture as a lens through which to look at education. However, culture continues to be used extensively in educational research. Therefore, this study acknowledges the tension around culture as problematized by Wax, while at the same time, acknowledging the use of culture as a dominant lens used in science education research.

Definitions of science. The *Oxford English Dictionary (OED)* defines science, in a broad sense, as knowing something directly or indirectly, specifically related to the state of knowing, or in a strict sense, "a branch of study which is concerned either with a connected body of demonstrated truths or with observed facts systematically classified and more or less colligated by being brought under general laws" (OED, 2012, ¶ 3). Modern definitions categorise science within specific disciplines and identify science with the systematic knowledge of the natural or physical world obtained through experimentation and observation (Blackburn, 2008). Science is also restricted to those branches of study that relate to the phenomena of the natural or physical world (OED, 2012). Regardless of the definition used, defining and delineating science from non-science can be problematic, which has led to the development of specific questions addressed by the philosophy of science, such as where the demarcation between science and non-science lies, what characterises good from bad explanations in science, where other enquiries such as history or sociology fit, and whether or not there is a universal science that transcends local contexts (Blackburn, 2008; Milne, 2011).

The period of the Enlightenment promoted European thought devoted to universal claims of reason and was dedicated to human progress through the advancement of the natural sciences (Blackburn, 2008). During the Enlightenment, major changes in science occurred, including the demarcation of disciplines, scientific institutionalisation, professionalisation, consistency of scientific practices and activities, such as hypothesis- and experiment-driven research (Silva & Moura, 2012), and a belief in the human ability to know ourselves and nature through strict, orderly laws (Bristow, 2011). One of the key tenets of the Enlightenment was the universal application of education in the progress of science (Coulby & Jones, 1996). As Coulby and Jones (1996) have suggested, "science was both a total explanation and a key to human betterment. The truths of nature and of the universe were seen to be increasingly comprehensible to systematic scientific investigation and explanation" (p. 172). While the ideals of the Enlightenment have been critiqued and denounced, they continue to be maintained, particularly in scientific and educational terms and circles (Coulby & Jones, 1996; Siegel, 2002). The application of universalism in science has had profound effects on science education, with researchers and scholars identifying that "the core epistemological debate that affects science education involves that between proponents of universal and multicultural views of science" (McKinley & Gan, 2014, p. 287).

Universalism. A universal epistemology in science determines "that the culture, gender, race, ethnicity, or sexual orientation of the knower is irrelevant to science knowledge" (Stanley & Brickhouse, 1994, p. 388). Traditional Western science, in particular, has claimed to be objective and value-free, promoting universal truths (Carter, 2008). Universalists assert that the truth claims of science are not directly affected by racial, class, or national differences and that science surpasses human differences (Matthews, 1994). Universalism in science strives for objectivity, understands the natural world as knowable, perceives modern Western science as superior to ethnic science, and includes realism or the idea that "there is a natural world that exists independently of us and our beliefs about it, which it is the business of science to explore, and of which it is the aim of science to produce knowledge" (Siegel, 2002, p. 808).

In a well-cited example used to explain science as a universal concept, Matthews (1994) has put forward the following analogy:

> Just as volcanic eruptions are indifferent to the race or sex of those in the vicinity, and lava kills whites, blacks, men, women, believers, nonbelievers equally, so also the science of lava flows will be the same for all. For the universalist, our science of volcanoes is assuredly a human construction with negotiated rules of evidence and justification, but it is the behavior of volcanoes that finally judges the adequacy of our volcanology, not the reverse (p. 182).

While Matthews acknowledges the potential influence of different contexts, scientific 'truth' has the potential to be known by all, and the adequacy of scientific activity and explanations determines what this truth is. Matthews has contended that mainstream science gives us better explanations than 'ethnic' science, as in his view, "no ethnic science is going to adequately explain how radios work, why the moon stays in orbit, [or] why hundreds of thousands of Africans are dying of AIDS" (Matthews, 1994, p. 193).

Modern Western science is considered universal and superior, according to Siegel (2002), as it has produced theories that are testable, predictive, and explanatory of the natural world, giving humans a deep understanding of the observed and unobserved features of the world. The adequacy of scientific explanations—as well as the superiority and universalism of Modern Western science—was and continues to be based on rationalism, as the Enlightenment propagated this particular ‘brand’ of science, which is considered to be true (Siegel, 1997). Cobern and Loving (2001) have argued that good explanations in science are universal and that, although there are competing explanations about natural phenomena in schools resulting from being located in multicultural communities, “what works best is still of interest to most” (p. 51). Western science is considered best in this regard. In support of their position, Cobern and Loving defined the Standard Account of science, delineating science from what they consider non-science. The Standard Account, according to Cobern and Loving, is broken up into the following three major categories, each with accompanying subcategories: (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).

Both Matthews (1994) and Siegel (1997) have acknowledged that science is positioned in a cultural context, by virtue of science being a human endeavour. However, the characteristics of science, namely the production of theories of the physical world, are better than those produced by other means (for example, through Indigenous or African ways of knowing). In other words, they argued that science is epistemologically better than other systems of understanding (Southerland, 2000).

Milne (2011) has proposed that the cannon of the scientific method was developed out of the Enlightenment and fosters the universal image of science by promoting one exacting and correct way of following a procedure for determining how we order phenomena. The practices of science and how these practices are known have been determined by the acceptance of strategies related to the evaluation, discovery, and validation of Eurocentric science. Coulby and Jones

(1996) have identified modern scientific knowledge as a component of the Enlightenment distinguished by white, Western knowledge, also referred to as Eurocentric science, relegating "the knowledge of other cultures to exoticism, superstition or folkways" (p. 173). Although Eurocentric science has been significantly influenced by diverse cultures, for example, from China, India, Africa and Middle East, "as a form of systematic knowledge [science] has become a global behemoth, isolated from the sites of local knowledge from which it emerged" (Milne, 2011, p. ix).

The values of Eurocentric science have been equated with scientific universalism, and this valuing has influenced science education in the West. For example, when using catch phrases such as 'science for all', "little space is given to acknowledging that Eurocentric science is an expression of European thought and one way of organizing phenomena . . . and communicates an acceptance of the notion that Eurocentric science is universal and monolithic" (Milne, 2011, p. 10). Hammond and Brandt (2004) further asserted that the practices of science developed within a "male dominated, Eurocentric, and middle-class context" (p. 651); therefore, the assumptions and ways of knowing in science are reflective of this particular context.

Multiculturalism. In a seminal and highly debated work, Stanley and Brickhouse (1994) contended that there could not be a universalist account of science, as the methods used to make decisions are based in communities with human dialogue and interpretation. However, while they argued for multicultural perspectives in science and suggested that narrow definitions of science are exclusionary, they did not "believe the sciences of various cultures should be given equal weight in the curriculum as Western science" (Stanley & Brickhouse, 1994, p. 395). Stanley and Brickhouse advocated for add-ons to Western science, as opposed to systemic changes in teaching and learning science (Loving, 1995).

Good (1995) responded to Stanley and Brickhouse by asking them and other critics of modern science to specify contributions from the so-called neglected sciences that would enhance understanding of the legitimate science taught in schools. Throughout this brief two-page critique, Good did not identify any discernible difference between science and science education, stating that taking “examples from medicine and agriculture as samples of neglected science from other cultures is a very weak response to the challenge” (p. 336), suggesting that they are not as relevant as physics, chemistry, biology, and geology for forming the foundation of school science. Loving (1995) has concurred with Good’s assertion that Stanley and Brickhouse (1994) did not adequately outline their plan for a multicultural classroom. In response, Stanley and Brickhouse (1995) submitted that their examples came from applied science, as they were attempting to “show the human consequences of a universalist position” (p. 338). Again, this response does not necessarily address the concerns brought forth by Good and Loving. The multicultural piece that Stanley and Brickhouse recommended does not fundamentally differ from what is taught as science in school; rather, they advocated for more superficial additions.

Lee (2001) has suggested that Western science is needed to participate in an information society and a global economy. Not providing opportunities to learn Western science therefore creates inequality. However, “the quality of educational experience suffers if Western science is imposed on students who do not share its system of meanings, symbols, and practices” (Lee, 2001, p. 499). Because of the explanatory power of science with respect to natural phenomena, science can be “invasive of other systems of meaning” (Cobern & Aikenhead, 1998, p. 50). In many cases, Western science may be foreign to students but not incomprehensible (Gaskell, 2003). In other words, it is not that students cannot access Western science but why would or should they if it means that they need to give something else up, such as their identity or culture.

Debate within education. UNESCO (2009) has recognised the need to adapt educational approaches that consider intercultural competency and culture-specific learning as a response to the discourse surrounding science and science education as universal. In Alberta science programs of study, this consideration of culture-specific learning has been presented in the incorporation of Aboriginal perspectives within science education (e.g. Alberta Education, 2014). While the front matter of the programs of study specifies the incorporation of Aboriginal perspectives, specific outcomes incorporating Aboriginal perspectives are not required portions of the programs and, instead, form potential examples that teachers may or may not use. In the mandatory science programs of study, no consideration is given to alternative perspectives in a meaningful way, other than through Eurocentric science. So, while science education is situated culturally, science programs of study in Alberta represent Eurocentric science, with the exception of the superficial addition of the inclusion of Aboriginal perspectives.[1]

Researchers and scholars have identified science education as inaccessible for many students, in particular, minority, and culturally and linguistically diverse students, resulting in achievement gaps, poor standardised test results, and racial and ethnic disparities in science (e.g.

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[1] Alberta is currently engaged in a six-year curriculum redesign process with a stronger focus on First Nations, Métis, and Inuit content and, among others, commitments to the Calls to Action from the Truth and Reconciliation Commission (Alberta Education, 2017b). However, what this commitment looks like in the Alberta programs of studies generally, and science education more specifically, remains to be seen.

Atwater, Lance, Woodard, & Hillsman Johnson, 2013; Lee, 2001; Meyer & Crawford, 2011; Pedretti & Nazire, 2011). However, in a comprehensive synthesis of research findings, primarily from the United States with respect to science education and diversity, Lee and Luykx (2006) found that factors such as home influences and family support correlated much more strongly with achievement than racial/ethnic or cultural background. According to Lee and Luykx, "these results suggest that it is the economic and educational marginalization associated with racial/ethnic minority status, rather than students' racial/ethnic or cultural background per se, that negatively affects minority students' science achievement" (p. 139).

The representation of science as exclusively Eurocentric has still been suggested to be problematic for students who may hold a distinctly different worldview, such as Indigenous populations in Canada (Aikenhead, 1996, 2006; Aikenhead & Jegede, 1999; Doig, 2003). However, problems may also arise even when the worldviews of students are similar with respect to science but different in terms of ethics, morals, and values, for example between North American, Middle Eastern, or Asian cultures.

According to Hodson (1993), there are powerful teaching opportunities present when teachers take into account the knowledge and experience that children's cultural backgrounds present, such as those around plant and animal knowledge, health practices, energy resources, dress, tools, and utensils. However, teachers often ignore this valuable teaching opportunity, and this extends into miscommunication regarding teaching practice and learning. Children from certain cultural groups may experience difficulties when attempting to adapt to the student-centred expectations that teachers and the school may have of them. As an example, parents may have difficulty supporting "learning styles that encourage children to adopt a critical and questioning stance" (Hodson, 1993, p. 692–693). Biology can also be a potentially problematic area with the potential for cultural insensitivity. Hodson has outlined that

> reference to experiments on human embryos may be deeply offensive to those from Islamic cultures; the use of eyes, hearts, and lungs in laboratory exercises, now common practice in many schools, may be offensive to Jewish and Muslim children if they are from a pig and to Hindu children if they are from a cow; storing human skulls and skeletons and preserving the bodies of dead animals in the laboratory may be offensive to Maori. Certain fundamentalist Christian groups share with Islam an opposition to the teaching of evolution. Parental attitudes toward sex education may cause problems in any school, but in a multicultural setting the problems may be insoluble short of "ethnic streaming" (p. 694).

In contrast to these differences, in a cross-cultural examination of how high school students from Jamaica, South Africa, Sweden, Taiwan, and the United States conceptualised and justified decisions within science, Zeidler, Herman, Ruzek, Linder, and Lin (2013) found that, while there were statistically significant differences in how students from different countries raised scientifically relevant questions, there was significant congruence in the ways that students across countries framed and justified their epistemological beliefs. Students from all countries, except Taiwan, produced common epistemological beliefs related to scientific knowledge in the dimensions of real-life applicability, evolving knowledge, and sources of their ability to learn. Taiwanese students scored significantly higher on dimensions of the structure of scientific knowledge, and the nature of knowing and learning. Zeidler et al., have made the case that these "differences in epistemological beliefs about science reflect less on the culturally unique identities in relation to scientific understanding and more on the relative emphasis with which students affix importance to science as an interrelated set of conceptual networks" (p. 277). In other words, the researchers suggested that students' ability to draw upon nature of science components when arriving at decisions is more reflective of the sophistication of their epistemological beliefs than with their cultural identity.

Cultural differences can potentially present challenges in approaches to teaching and learning and in the content taught within science education. However, as Krugly-Smolska (2013) has noted in a review of multicultural science education, the zealousness of Hodson and others in linking the causal factors of Western-oriented science curricula and the poor performance or lack of participation in science by ethnic minority students was, and still is, based on 'hypothesised links'. She has pointed out that "much of the early writing in multicultural science education is of the persuasive essay, discursive analysis type, if not outright polemical" (Krugly-Smolska, 2013, p. 24). The consequences of relying on this type of work is that theories become enacted in classrooms without research support.

Cultural hybridity, third space, funds of knowledge, and figured worlds. More recently, the debate between universalism and multiculturalism has been left at somewhat of a stalemate, with some science education researchers drawing on concepts of hybridity, third space, funds of knowledge, and figured worlds. The concepts of cultural hybridity and third space originated in postcolonial theory and, in particular, the work of Bhabha (2004), or from within educational research (Gutierrez, Rymes, & Larson, 1995). Moje et al. (2004) have described the third space as "a bridge, a navigational space, or a space for critical understandings of the relationship between science and students' 'everyday worlds'" (p. 54). Within a postcolonial context, "third space framings allow us to look for those spaces that allow for the transforming of power structures" (Carlone, Johnson, & Eisenhart, 2014, p. 664), whereas within educational research, third spaces have been characterised as the creation of learning spaces grown out of diversity. Within science education specifically, a common theme within third spaces is "the potential conflict between students' cultural experiences and background and what is taught in school science needs to be resolved before meaningful science learning can take place" (McKinley & Gan, 2014, p. 288).

Moll et al. (1992) have characterised funds of knowledge as the particular kinds of knowledge that people hold and bring to situations. For example, funds of knowledge have been used as a tool to capitalise on children's knowledge to organise classroom instruction (Moll et al., 1992). Funds of knowledge can be used to create engaging classroom activities and encourage engaging with community members while moving away from general terms such as culture. As Carlone, Johnson, and Eisenhart (2014) have stated, "the strength of the funds-of-knowledge approach is its focus on what students' communities and experiences can bring to the classroom to enrich the curriculum" (p. 656).

Figured worlds is a theory whereby "figured worlds are socially and culturally constructed realms of interpretation in which particular actors are recognized, certain acts judged significant, and specific trajectories and outcomes valued" (Holland et al., 1998, p. 52). Figured worlds can be drawn upon to describe how identities are developed within different situations. For example, Calabrese Barton et al. (2013) have used figured worlds to illustrate how middle-school girls with non-dominant backgrounds negotiate their possible futures in science.

While concepts around hybridity and third space were born out of cultural contexts, particularly those based on the work of Bhabha (2004), they—along with funds of knowledge and figured worlds—move past direct framings of culture, working to explain behaviours and how students come to develop their conceptions of their own identities.

Culture and Curriculum

In response to growing cultural diversity, the perceived Eurocentric focus of science education, and issues around students' ability to access science education in meaningful ways, researchers have called for the inclusion of culture in science education through efforts such as multicultural science education and culturally relevant and responsive science curricula (Atwater, 2010a; Calabrese Barton, 2000; Lee, 2001, 2005; Patchen & Cox-Petersen, 2008; Pomeroy, 1994; Suriel & Atwater, 2012). However, there is significant debate in the literature about exactly what each of these terms mean and what they might look like in practice (Calabrese Barton, 2000; Hodson, 1993).

Multicultural science education. Atwater (2010b) has defined multicultural science education as approaches and practices devoted to ensuring that "all students learn quality science so they can change the world around them" (p. 130). Irrespective of gender, race, ethnicity, social status, or cultural characteristics, all students should have equal opportunities in education (Banks, 1999). The processes and understanding of science within a multicultural science education context are socially, historically, and politically located processes with a pedagogy focussed on the classroom life and not simply teaching strategies (Calabrese Barton, 2000). Advocates of multicultural science education challenge the teaching methods and applications of science, as well as the underlying science content. At the same time, they believe that "it is important for all students to know and be able to do traditional science, since that is what schools and society measure" (Calabrese Barton, 2000, p. 800).

Southerland (2000) has separated multicultural science education into instructional multicultural science education and curricular multicultural science education. Both have the goal of a more respectful and sensitive approach to science education. However, instructional multicultural science education adapts instruction within the traditional definitions of science, whereas curricular multicultural science education suggests redefining the epistemology of science to equate it to other ways of understanding the physical world (Southerland, 2000).

The dominant interpretation of multiculturalism is around cultural pluralism, with the intention of recognising and promoting cultural and ethnic diversity (Hodson, 1993). Hodson (1993) has advocated the inclusion of three elements within multicultural science education, highlighting the importance of "education *of* diverse cultural groups, *through* a wide range of culturally impregnated experiences, *for* life in a multiracial and multiethnic society at both local and global levels" (p. 689, emphasis in the original).

While many researchers advocate for a multicultural science education, others, including many science teachers, do not believe multicultural education has a place within science education, as they believe in universal principles of science (Atwater, 2010a). In Calabrese Barton's (2000) study of how a service-learning approach might provide a way for pre-service science teachers to see how multicultural science education might look like in practice, many students initially held definitions of multicultural education as an add-on to existing curricula.

In their investigation of secondary science teacher's beliefs about multiculturalism and science education, Petty and Narayan (2012) found that all of the participants indicated that Western science was the only perspective they believed in. While all the participants believed in providing a high-quality education to all students and that multiculturalism was important in terms of the respectful treatment of students, they did not feel multiculturalism was important in science. In this study, only nine Caucasian science teachers participated; therefore, generalising these results to the general teaching population is not possible. However, it does provide interesting evidence to suggest that what teachers believe in regards to multiculturalism and science education could influence whether these pedagogies are concepts are taken up in science classrooms or not.

Researchers have promoted the benefits of multicultural science education. However, there is little research to specify “what multicultural science teaching and learning looks like in practice” (Calabrese Barton, 2000, p. 800). Banks (2010) has developed a curricular integration typology including four approaches for the integration of multicultural education in curriculum: the contribution, additive, transformative, and social action approaches. Banks model of curricular integration is valuable for understanding the “complex processes in which teachers engage as they create and develop multicultural curricula” (Milner, 2005, p. 396). In the contributions approach, science teachers would include the contributions of scientists from diverse ethnic and cultural backgrounds. The additive approach would incorporate “science content, concepts, themes, and perspectives, but it does so without changing the structure of the mainstream curriculum” (Atwater, 2010b, p. 106). The transformative approach changes the structure of the science curriculum by investigating content, concepts, and themes through different perspectives (Banks, 2010). In Alberta, the science programs of studies require teachers to incorporate Aboriginal perspectives (e.g. Alberta Education, 2014), indicating a move towards a transformative approach. However, the examples provided in the program are optional examples with tokenistic and superficial additions, suggesting more of an additive approach; furthermore, in practice, teachers have difficulty even integrating these examples (Onuczko & Barker, 2012). Finally, in the social action approach, students are required to make decisions and act on them. For example, students would evaluate an issue from multiple perspectives and then participate in a demonstration, a letter-writing campaign, or some other form of action in support of their position.

In an interview with Geneva Gay, a leading researcher in multicultural education, Atwater (2010a) asked what advice Gay had specific to multicultural approaches to science teaching. Gay stated that, at a minimum, teachers would include contributions to science from different ethnic, racial, and linguistic backgrounds, and that science education should be made relevant and meaningful to students from all culturally diverse backgrounds. In her view, the critical dimension of multicultural science education would be to make science meaningful and relevant for all students (Atwater, 2010a); also, it should not add to existing science content but instead reframe the process by which the content is taught (Banks, 2004). A multicultural science pedagogy, according to Atwater (2010b), is evident when

> teachers can give their students the opportunity to investigate who is articulating a science agenda, analyzing the current status of science, deciding the boundaries in defining membership in science, and even framing what empowerment really means in the practice of science teaching and learning. It is in their science classrooms that teachers get to decide what voices are heard, when they are heard, and under what circumstances they are heard (p. 104).

However, what practicing teachers are left with is to decide what—in a more tangible sense—this means for their classes, the students they teach, and the curricular requirements they must comply with.

Culturally relevant science education. Several researchers have supported the implementation of a culturally relevant pedagogy in science (Lee, 2003; Lee, Butler, & Tippins, 2007). Gay (2010) has defined culturally responsive teaching as

> using the cultural knowledge, prior experiences, frames of reference, and performance styles of ethnically diverse students to make learning encounters more relevant to and

> effective for them. It teaches to and through the strengths of these students. It is culturally validating and affirming (p. 29).

More so than in multicultural education, a culturally relevant pedagogy would identify power relations and address them by connecting the classroom and community (Patchen & Cox-Petersen, 2008). Teachers are required “to reflect upon students’ cultures and the ways privilege, oppression, and power influence learning outcomes and opportunities” (Bettez, Aguilar-Valdez, Carlone, & Cooper 2011, p. 944), considering the whole child, both as an individual and as a member of a cultural group. A culturally relevant pedagogy involves teachers who establish connectedness with their students, develop a community of learners by encouraging students to learn collaboratively, and structure fluid student–teacher relationships (Ladson-Billings, 1995).

As in multicultural education, there is a greater focus on critical discussion papers with few empirical studies of culturally responsive pedagogy (Patchen & Cox-Petersen, 2008). This has resulted in difficulty in determining what a culturally responsive classroom might look like in practice. Patchen and Cox-Petersen (2008) have presented a model for the connectedness between constructivist teaching practices and culturally responsive teaching; they have investigated how, in culturally diverse classrooms, culturally relevant practices can be informed and supported by constructivist practices. They have suggested that key constructivist themes of authority, achievement, and affiliation are particular areas of overlap within culturally responsive teaching. However, when looking at two successful constructivist science teachers, they found little evidence of culturally responsive teaching, even though both of the science teachers indicated the importance of recognising the background cultures of their students.

Although both multicultural science education and culturally responsive teaching are seen as a means to address issues associated with growing classroom cultural diversity, with few exceptions, neither has been explicated enough beyond theory in the science education literature to demonstrate what they might look like in a science classroom. This is especially evident in the science education literature on students from diverse cultural backgrounds, as the majority of the studies carried out have focussed on teachers working in areas with high proportions of either Hispanic or African-American students in the United States (August, Branum-Martin, Cardenas-Hagan, & Francis, 2009; Clark, Touchman, Martinez-Garza, Ramirez-Martin, & Drews, 2012; Eijck & Roth, 2011; Lee, 2005; Lee, Maerten-Rivera, Buxton, Penfield, & Secada, 2009).

Research Initiatives

Specific research initiatives looking at cultural diversity and science education have focussed on

1. intervention approaches for traditionally low-achieving immigrant or English-language learners;
2. teachers' perspectives in classrooms, especially with students who are not from the same cultural, racial, or ethnic background; and
3. language and literacy.

Intervention approaches. Several studies have applied interventions to the teaching or learning of science in culturally diverse schools. August et al., (2009) have assessed the effectiveness of Project QuEST (Quality English and Science Teaching), an intervention "designed to develop the science knowledge and academic language of middle grades English language learners studying science in their second language and their English-proficient classmates" (p. 345). The project involved instructional materials appropriately designed to take into account the language and culture of the students, as well as professional development supports for teachers on how to use the resources within their classes. The intervention took place in a school division where 98% of the students were Latino, with 42% being English-language learners. Achievement in science content based on post-tests was not significantly greater for the treatment group compared with the control group, although more gains were seen with vocabulary improvement. The authors speculated that project gains over three years would show significant improvement (August et al., 2009). This assumes, however, that the gains remain consistent over the course of three years, extrapolating the results far beyond the findings.

Clark et al., (2012), investigated an online science-learning environment where one group of students was given Spanish-language supports within the program. Immediately following the completion of the online tasks, no statistical differences were found between the group who had supports and the group who did not. However, there were some improvements seen on the delayed post-test results suggesting that long-term retention may be improved with greater language supports.

In a study by Parsons, Travis, and Simpson (2005), two teachers were given instruction and specific lesson plans on incorporating Black Cultural Ethos (BCE), a specific type of culturally relevant pedagogy focussed on aligning student preferences in teaching to improve achievement. The lessons were targeted to grade 8 students on force and electricity, and they incorporated several dimensions of BCE, including verve, movement, and communalism (for more information on BCE, see Parsons, 2000; Parsons et al., 2005). The results indicated that more students, whether African-American or not, experienced enhanced achievement with the BCE lessons. However, there was no description about what exactly occurred in each of the lessons; therefore, causality is difficult to ascertain. In another project, Parsons (2000) used BCE in the teaching of the water cycle. However, Krugly-Smolska (2013) has questioned the effectiveness of this activity for displaying Black cultural values as opposed to “making learning fun" (p. 26). In both of Parsons' studies, it is difficult to ascertain whether the interventions are effective because they incorporated African-American cultural frames of reference, or if they are effective because they are engaging students in meaningful learning activities targeted specifically to their age, activity level, or other factors. In other words, it is not apparent that there is a specific cultural dimension directly tied to either of these situations.

While not presented as an intervention as overtly as the previous studies, Suriel and Atwater (2012), "sought to understand (a) teacher's integration of multicultural curricula in science curriculum units, and (b) how personal experiences influenced the level of integration in light of Banks' typology[2] of ethnic content integration into school curricula" (p. 1287). This study was conducted with teachers who were completing a Master's degree in education with the authors, Suriel and Atwater, as course instructors. As part of one of the course assignments, students in the class designed science lessons with multicultural components and then implemented these lessons with students. The teachers were taking classes on multicultural education and then applying this learning to lesson plans. The authors found that participants who had experiences in which they experienced being the cultural 'other'—even when from the majority culture—and where the courses resulted in the participants moving outside of their comfort zones with the multicultural components achieved higher levels of Banks' typology.

Teacher perspectives. The majority of the studies that were not looking at interventions focussed on teachers' perspectives on cultural diversity and science education versus the perspectives of students or other members of the school community. Aikenhead and Otsuji

[2] Banks' (2010) typology was described earlier in this chapter and includes the contribution, additive, transformative, and social action approaches to teaching.

(2000) have looked at a cross-cultural comparison between Japanese and Canadian teachers' perspectives on the connection between their students' cultures and the culture of Western science. The Canadian teachers in the study were teaching primarily Aboriginal students, whereas the Japanese teachers were teaching Western science to Japanese students. In both cases, the teachers did not appear to be aware that students may have been experiencing cultural clashes in the science classroom.

The Japanese teachers in Aikenhead and Otsuji's (2000) study were more likely to see the values of the community reflected in scientists' work compared with the Canadian teachers. The Canadian teachers were also more likely to hold reductionist views of science. This was presented as being related to the more individualist nature of North American culture versus the more community-based and holistic cultural views held in Japanese culture. This conclusion is derived from the author's suggestion that the Japanese view of humankind's relationship with nature indicates a holistic view generally, whereas the separation of humankind from nature in the West is reductionist. Other than asserting this proposition, Aikenhead and Otsuji provide no other evidence to fully support their claim.

Lee, et al. (2009) have examined the perceptions of urban elementary school teachers' knowledge of science content, teaching practices, support for language development, and organisational supports and barriers to their teaching and learning practices in science. In the school district studied, which had a predominantly Hispanic student population, 221 teachers completed the questionnaire. Most teachers indicated they had never or only participated in one professional development session on student diversity, and teachers did not report using strategies to assist English-language learners in their classes with English-language development in science. This suggests that science teachers may not see the relevance within science in assisting their students with English-language development, even though language is a significant part of the culture of science that students are exposed to.

Johnson (2011) explored how two middle-school science teachers participating in culturally relevant pedagogy professional development program altered their conceptions and practices in the classroom in schools with primarily Hispanic students. The focus of this study was due to the huge increases in Hispanic students over 10 years from 5% to 70%. Both teachers in the study were relatively successful with incorporating culturally relevant pedagogy within their science classes as a result of the professional development. Although there may have been other factors that altered their practice, the teachers consistently identified the professional development, which occurred over a sustained three-year period, as key to their change.

One notable exception to the focus on the perspectives of teachers is Aikenhead (1997), who has investigated Canadian high school students' views regarding the impact of culture—specifically, education, values, religion, and politics—on how science was conducted. While there were slight differences between each of these individual factors in general, a minority of students either believed that cultural norms impacted science or that science was isolated from cultural norms; conversely, a majority of students "debated the degree to which cultural constraints can override a scientist's individuality" (Aikenhead, 1997, p. 419). Although students' perspectives were explored, the participants were divided into Anglophone (from across the country) and Francophone (from Quebec) students. This would appear to indicate that students whose first language was not English were excluded from the study, although this is never explicitly stated.

Language and literacy. Language can be problematic within science education due to diversity of mother tongue, the language of science (specialised terminology, use of everyday words in specific, restricted contexts, and style of written communication), the stylised language of classroom interactions in general, and the use of language-based activities to bring about learning (Hodson, 1993, p. 691). Learning science language is challenging, as the language of science "contains unique lexicon, semantics, and syntax" (Fang, 2006, p. 492) that allows for clear communication between scientists but adds a layer of complexity for students. The distinction between the social language that students use and the specific language of school science is challenging for all students, but it is especially challenging for English-language learners (Fang, 2006).

Research looking at language and science education has focussed on interventions to improve science learning and English-language development (e.g. August et al., 2009; Clark et al., 2012; Lee, 2005), and research has shown that teachers do not necessarily see the relevance of language development in their science classes (e.g. Lee et al., 2009).

As mentioned previously, August et al. (2009) and Clark et al. (2012) have both used interventions with Latino English-language learners studying science in English. August et al. have implemented a project with the goal of improving both science content and vocabulary, whereas Clark et al. have provided language supports in an online science environment. In both cases, post-test results were not statistically different compared with those of the control group. However, Clark et al. conducted delayed post-tests, in which students who had both English- and Spanish-language supports showed some improvement. This may indicate that language supports are important for long-term retention.

In a meta-analysis of English-language learners and science education, Lee (2005) found that future research needed to consider the "interrelated effects of language and culture on students' science learning" (p. 513), as previous studies have often left this connection out. In addition, Lee has suggested that English-language learners' cultural backgrounds are often ignored in the teaching and learning of science and that more research needs to be done in this area. Lee and Buxton (2013) have echoed this sentiment, suggesting that literature on funds of knowledge highlights the important resource that students' lived experiences may bring to the science classroom.

International contexts. Literature from international contexts provides examples of potential difficulties that students from outside of Canada or North America may face when immigrating. In particular, this literature can provide insight into how, even though the worldviews when approaching science may be similar, there can be cultural challenges with respect to teaching, learning, and content.

The ability to ask questions is frequently cited as an important feature in the science classroom. Dkeidek, Mamlok-Naaman, and Hofstein (2011) have examined differences between students of the Jewish and Arab sectors in Israel to assess the effect of culture on question-asking ability in a chemistry laboratory. The authors described Jewish culture as Western and individualistic, whereas they portrayed Arab culture as conservative and traditional. In this study, Arab students had more difficulty formulating research questions compared with their Jewish counterparts in inquiry-based chemistry labs. Dkeidek, Mamlok-Naaman, and Hofstein have argued that this result can be attributed to educational attitudes and habits based on cultural differences, as well as to the differences in the qualifications of science teachers in the two sectors. For example, while asking questions was encouraged by teachers in the Jewish contexts, respect for authority (in this case the teachers) was valued more by the Arab students; therefore, questioning the teacher may not have been considered appropriate. The significance of the multicultural context in which an initiative is to be implemented is highlighted as an area for further research in Dkeidek, Mamlok-Naaman, and Hoftein's study. Culture, therefore, may affect how students engage with differences in teaching strategies and learning.

Terminology used in science and language can be particularly problematic since cultural norms in language may be different across contexts (Erickson, 1986). Mori, Kojima, and Tadang (1976) have explored the effect of language on the ability to interpret concepts in science, specifically speed. In a comparison between Japanese and Thai students, Japanese students were confused twice as often about the concept of speed because *fast* and *early* in Japanese are pronounced the same; however, in Thai, their pronunciation is distinct. This suggests that the culturally applied connotations of words are even more important than the actual words themselves (Mori, Kojima, & Tadang, 1976).

In China, Gao (1998) noted that terminology is particularly important. *Forces*, for example, imply energy or power in Chinese daily life, and 'weight' is an equivalent term to an amount of a substance; therefore; teachers are required to explicitly differentiate the concepts of weight and amount. Gao also added that translation can be problematic, as the word for particle is *li zi*, which directly translates to 'tiny grains of solids', for example ; this can create misconceptions for students when thinking about, for example, molecules, atoms, or ions.

In a study of the metacognitive orientation in science classrooms of students from Confucian heritage cultures (CHC) and non-Confucian heritage cultures (international students), Thomas (2006) found that the influence of culture on the learning environments became important during the investigation. Within both classroom environments, the focus was on discourse related to content as opposed to metacognitive approaches to teaching and learning. However, differences were found in terms of the type of support and encouragement provided by teachers and considerations of appropriate cognitive activities. Memorisation was reported by the

CHC students as the focus of their classroom activities, which strongly relates to traditional CHC values in education. The international students “spoke more of activities and general request[s] to think” (Thomas, 2006, p. 103) that are predominant within science education in the West; however, Thomas questioned the intent of such reforms for science education. Thomas concluded by suggesting that excluding cultural factors in the development of metacognition would be inappropriate within science learning environments.

Although these are but a few examples, the international literature suggests that there are differences in how students come to understand science. This provides further evidence that it is important in a place such as Canada, with high populations of newcomer students and parents, to explore how science is being implemented and whether this is meeting the needs of all of the students in the class, regardless of cultural background.

Gaps

Canada is becoming increasingly, and arguably already, culturally and linguistically diverse (Chan, 2006; He, et al., 2008). As a result of this diversity and Canada’s commitment to multiculturalism (Canadian Multiculturalism Act, 1988), researchers have argued that two central areas of focus in education are multiculturalism and diversity, as “schools are provided with the great responsibility of and opportunity for structuring successful academic environments for amplified numbers of underrepresented and newcomer students” (Schlein, 2009, p. 22). With the push for ‘science for all’ in the early to mid-1990s, researchers “highlighted the fact that, in North America at least, school performance and achievement in science are not equally distributed, with many students of color, indigenous students, and young women not interested and not participating in science” (Carlone, Johnson, & Eishenhart, 2014, p. 652). More contemporary research has continued to show that minority students, as well as culturally and linguistically diverse students, experience achievement gaps, poor standardised test results, and racial and ethnic disparity in science (e.g. Atwater, et al., 2013; Lee, 2001; Meyer & Crawford, 2011; Pedretti & Nazire, 2011). However, this same work focusses on specific locations and demographic populations, and it does not include information about how these same individuals were performing in other school subjects. In a comprehensive synthesis of research findings, primarily from the United States with respect to science education and diversity, Lee and Luykx (2006) found that factors such as home influences and family support correlated much more strongly with achievement than racial/ethnic or cultural background did. Lee and Luykx indicated that "these results suggest that it is the economic and educational marginalisation associated with racial/ethnic minority status, rather than students' racial/ethnic or cultural background per se, that negatively affects minority students' science achievement" (p. 139).

Despite this, researchers continue to call for integration of culture, through multicultural science education and culturally relevant science education, as a means of addressing achievement gaps and unequal participation in science. Work in culture and science education has primarily been focussed on theoretical discussion papers (Krugly-Smolska, 2013). In comparison, little empirical research has been done within the area of culture and science education. Of the research that has been done, there have been three primary focal areas, including

1. intervention approaches for low-achieving immigrant or English-language learners;
2. the perspectives of teachers and teacher candidates; and
3. specific work around language and literacy.

Lee and Luykx (2006), in their comprehensive analysis of science education and diversity, identified that the majority of the research studies that do exist are small-scale and descriptive, and "there are only a small number of intervention-based studies" (p. 147).

The majority of the multicultural science education and culturally relevant science education literature examines how White teachers might begin to work with students of colour (Bettez et al., 2011). In these situations, the students in question represent high proportions of one ethnic or cultural group, particularly Hispanic and African-American student populations in the United States (August et al., 2009; Clark et al., 2012; Eijck & Roth, 2011; Lee, 2005; Lee et al., 2009). One notable exception is Milner's (2005) study looking at an African-American teacher's curriculum development and teaching. However, as in the other studies where the teacher was not of the same cultural background as the students, the teacher in Milner's study was teaching in a suburban school with mostly White students.

Lee (2005) has indicated that literature reviews tend to focus on science education amongst African-American, Asian-American, Hispanic, and Native-American students, but not often in diverse settings. While there is some evidence from international contexts that illustrate potential challenges for culturally diverse students in science education, none of these situations reflects the ethnic or cultural make-up of Canada or Alberta. The default, therefore, is to look towards the United States. The Canadian Multiculturalism Act (1988) promotes multiculturalism as reflecting a "fundamental characteristic of the Canadian heritage and identity" (¶ 3) and encourages individuals to "preserve, enhance and share their cultural heritage" (¶ 3). The encouragement and promotion of diversity is embedded within the laws of Canadian society. The United States, on the other hand, does not have a national policy with respect to multiculturalism (Ungerleider, 2007). Johnson and Joshee (2007) have highlighted that, while much can be learned by examining and comparing multicultural educational policies in Canada and the United States, encouraging dialogue to further understand policy, they strongly suggest that "multicultural education is part of a larger complex of policies and programs meant to address social and cultural inequality" (p. 6). Both the smaller multicultural education policies and the broader complex of policies of Canada and the United States are inherently different. This implies that the application of results from culturally diverse classrooms in the United States to Canada may not be appropriate.

Previous work in the literature is based on the well-established theoretical assumption that students in science classrooms have borders that need to be crossed and that students from non-Western cultures require more assistance than others (Aikenhead, 1996, 2001; Cobern & Aikenhead, 1998; Costa, 1995). While there is good support for border crossing, particularly at an individual level, the border-crossing concept has become a pervasive assumption in the majority of the research looking at students in classrooms. Cultural differences can potentially present challenges in approaches to teaching and learning and in the content taught within science education.

What is lacking in the research is a study that is not tied up in the theoretical assumptions linking causal factors of Western-oriented science curricula to the poor performance or lack of participation in science by ethnic minority students that Krugly-Smolska (2013) warned about. This research addresses a number of gaps in the literature, and it took place within a culturally diverse classroom—one that is not heavily dominated by a particular ethnic or cultural group but by a mixture of students from different ethnic and/or cultural groups, as represented by the changing newcomer demographics. This study focusses on student perspectives, particularly their attitudes, beliefs, and values, as well as their interactions with the teacher and the curriculum, to better understand the work happening within the classroom. This study gives a voice to students about their experiences within a culturally diverse class and about how they understand science, science education, and culture, in a field that is dominated by theoretical assumptions, in which students are rarely spoken to.

Chapter Three: Methodology

Introduction

The purpose of this case study was to explore student perspectives of the implementation of science education in a culturally diverse classroom by utilising a qualitative case study methodology within a constructivist paradigm. In order to explore these student perspectives, the following questions were used to guide the investigation:

1. How do student's view science, science education, and culture within a culturally diverse classroom?
2. What are the perspectives and experiences of students as they interact with each other, their teachers, and the curriculum in a culturally diverse classroom?

There are gaps in the literature with respect to student perspectives within culturally diverse classrooms and how they understand science, science education, and culture, devoid of the theoretical assumptions that have been adopted throughout the entire field of research, even when conceived of in particular contexts. It was anticipated that focussing on student perspectives within a culturally diverse classroom would assist in identifying areas of congruence or not with existing research, and ascertaining areas of the current curriculum that allow for the possibility of meaningful cultural engagement.

This chapter outlines the research approach taken and describes in detail how a case study was conceived of as the methodology for this study. Then, the research design, including the research questions, study propositions, units of analysis, connections between data and propositions, and the data analysis techniques, are discussed. Finally, the ethical considerations, limitations, and delimitations of this study are reviewed.

Research Approach

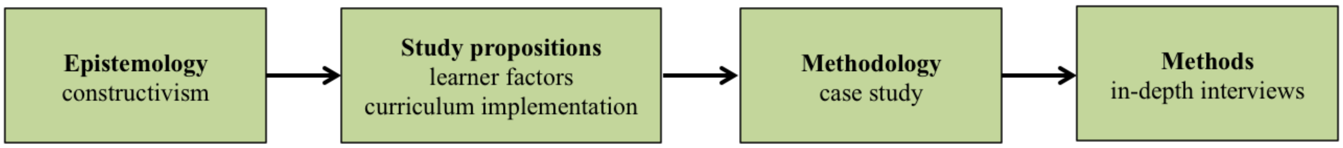

Figure 1. Overview of the research approach.

A research paradigm includes one's assumptions and beliefs about how the world works, and it is the framework that guides how the researcher approaches the research. A constructivist paradigm, according to Guba and Lincoln (2005), ontologically assumes that reality is socially constructed and subjective, containing multiple points of view; epistemologically, however, this paradigm accepts knowledge as containing subjective meanings focussing on situational details. This study focuses on the varied perspectives of the students in a culturally diverse classroom, with a belief that, in a singular instance, different students may have understood the event or situation quite differently from one another based on the complex interactions of the various influential factors.

Kothari (2004) has defined research methodology as a way to "systematically solve the research problem. . . . In it we study the various steps that are generally adopted by a researcher in studying his research problem along with the logic behind them" (p. 8). In other words, the methodology is more than just the research methods but also the logic and explanation behind the methods being used within the study. van Manen (1990/1997) has suggested that

> 'methodology' refers to the philosophic framework, the fundamental assumptions, and characteristics of a human science perspective. It includes the general orientation to life, the view of knowledge, and the sense of what it means to be human which is associated with or implied by a certain research method. We might say that the methodology is the theory behind the method, including the study of what method one should follow and

why. (p. 28)

Miles and Huberman (1994) have identified some common features of qualitative research, including the fact that qualitative research usually involves sustained contact with a "typically 'banal' or normal [situation], reflective of the everyday life of individuals, groups, societies, and organizations" (p. 6). In addition, the researcher's main goal is to present a holistic understanding of the context under investigation, specifically by illuminating the ways in which the individuals within the context manage, understand, and behave in their everyday situation. Yin (2010) has pointed out that the practices of a qualitative methodology involve flexible as opposed to rigid designs, the collection of field-based data, including evidence capturing the context and the perspectives of the participants, an analysis of non-numerical data, and an interpretation of findings. In addition, there are five features of a qualitative methodology proposed by Yin, which reflect much of what Miles and Huberman identified, including

- studying the subjective meanings of people within a real-life context;
- representing the participants' perspectives;
- examining the surrounding context;
- providing insights that may help to explain social behaviour; and
- using multiple sources of evidence.

Although there is no one formal qualitative research methodology (Yin, 2010), consideration of the above five features in conjunction with a strong research design produces the strong reliability and validity that good research requires. A qualitative methodology is appropriate when there is a problem or issue to be explored, a complex understanding of the issue is needed, the participants cannot be separated from the setting or context they are in, and/or when quantitative measures do not fit, such as when looking at the interaction amongst people (Creswell, 2007).

A qualitative research approach was used in this study, as the school setting defined the participants in this study as students. Altering the setting would invariably redefine the identification of the participants as students. The investigation was focussed on a complex phenomenon with a multitude of variables, in particular, the perspectives of the participants about an unfamiliar topic (culture and science) within a familiar setting (a science classroom). As a result of the connection to setting and the complexity of the phenomenon, qualitative research was the preferred and more logical approach. The qualitative research methodology used in this study was particularly appropriate within a constructivist paradigm, as qualitative research is "a means for exploring and understanding the meaning individuals or groups ascribe to a social or human problem" (Creswell, 2009, p. 4) and presents a complex view of the world (Firestone, 1987). Qualitative research produces a description for the reader outlining what the experience would convey, and it attempts to provide an understanding of the complex interrelationships within the area of study (Stake, 1995).

Case Study

There is current debate within the literature surrounding whether a case study can be characterised as a method, methodology, or research design (Hamilton & Corbett-Whittier, 2013). Gerring (2004) has noted that, although case studies are increasingly popular in a number of disciplines, practitioners have "difficulty articulating what it is that they are doing, methodologically speaking" (p. 341). The lack of guidelines directing case study research is described by Meyer (2001) as both a strength and a weakness. As Meyer has articulated, the lack of consistency directing research has led to poorly designed case studies. However, because there is not a regimented process, design and data collection can be tailored to the specific research questions. When considering case studies within the context of methodology, being explicit about emphasising methodological considerations is necessary when conducting ‘good’ case study research (Meyer, 2001; Yin, 2014). This section first defines case studies within the context of this study and then explicitly addresses specific methodological considerations as per Meyer (see also, Baxter & Jack, 2008; Hamilton & Corbett-Whittier, 2013; Patton, 1990; Yin, 2014).

Case studies have been used extensively in the social sciences. However, there has been little agreement on one specific definition (Gerring, 2007; Hamilton & Corbett-Whittier, 2013; Merriam, 1988). In general, case study definitions involve “the study of an issue explored through one or more cases within a bounded system (i.e., a setting, a context)” (Creswell, 2007, p. 73). As Merriam (1998) stated, “a case study design is employed to gain an in-depth understanding of the situation and meaning for those involved. The interest is in process rather than outcomes, in context rather than a specific variable, in discovery rather than confirmation” (p. 19).

Case study approaches have long been used in a variety of disciplines, such as psychology, medicine, law, political science, anthropology, and sociology (Creswell, 2007; Hamilton & Corbett-Whittier, 2013). Several researchers within the field of educational research have been instrumental in espousing case study research as a viable means with which to conduct research. Researchers in the 1970s tended to view case studies essentially as ethnography (Hamilton & Corbett-Whittier, 2013). However, Stenhouse (1979) challenged this view by asserting that, in opposition to ethnographic research, case study researchers almost always have familiarity with the context and situations being investigated and draw on theories related to education. Case studies also tend to be more intensive analyses of single situations, organisations, and so forth, within a particular place and at a particular time compared with other forms of qualitative research (Hancock & Algozzine, 2006). Since this time, Robert Yin, Sharan Merriam, and Robert Stake have all produced highly cited texts for conducting case studies (Hamilton & Corbett-Whittier, 2013; Hancock & Algozzine, 2006; Merriam, 1988, 1998; Stake, 1995, 2006; Yin, 2014).

This study drew primarily from Robert Yin and Robert Stake's work in case study research designs largely because they both situated their work in a constructivist paradigm, as is the case with this study (Baxter & Jack, 2008). As described earlier, in a constructivist paradigm, individuals develop subjective meanings, which are varied and multiple, of their experiences (Creswell, 2007). The goal of the research is "to look for the complexity of views rather than narrow the meanings into a few categories or ideas" (Creswell, 2007, p. 20). Meanings are formed through interactions with others that are socially and historically negotiated (Creswell, 2007). The focus for researchers is on the processes of interactions and the contexts in which people are embedded.

Yin (2014) has most recently proposed a two-fold definition for case studies, including the scope and the features of a case study. The scope identifies a case study as an empirical inquiry investigating a complex phenomenon within a situated context, where the boundary between the phenomenon and the context are not always clear. The portion of the case study definition dealing with scope assists researchers in differentiating between a case study and other methods or methodologies, such as ethnography, histories, or experiments. For example, "an experiment. . . deliberately separates a phenomenon from its context, attending only to the phenomenon of interest and only as represented by a few variables" (Yin, 2014, p.16). The features of a case study deal with multiple sources of evidence for triangulation, as there are more variables in a case study than an interested case or a single data point. Data collection and analysis in case studies, therefore, benefit from the prior development of theoretical propositions (Yin, 2014). Yin has suggested that "the second part of the definition of case studies arises because phenomenon and context are not always sharply distinguishable in real-world situations. Therefore, other methodological characteristics become relevant as the *features of a case study*" (Yin, 2014, p. 17, emphasis in the original).

Yin (2014) has proposed that case studies are the preferred research method when (a) there is a *how* or *why* research question, (b) the researcher does not have control over the relevant behaviours, and (c) when one is examining a contemporary event. A case study methodology was appropriate for this study, as primary and supporting research questions were formulated as 'how' questions supporting the explanatory nature of the study. In addition, this study investigated a contemporary situation (students' perspectives on the implementation of science education) in a real-life context (the culturally diverse science classroom) with no intention of intervention or control of what is occurring.

Both Stake (1995) and Yin (2014) have offered overlapping definitions for different types of case studies. Stake differentiated case studies as intrinsic or instrumental, where intrinsic case studies are studied because the case itself is of interest and represents a particularity. An instrumental case study is used to understand something beyond the specific case itself. Collective case studies are a multi-case design where each case is instrumental to understanding the phenomenon (Stake, 1995). Yin identified three case study types: explanatory, exploratory, and descriptive. Explanatory case studies are used to provide answers to questions with presumed causal links (Baxter & Jack, 2008; Yin, 2014), whereas the purpose of exploratory case studies is to identify research questions or procedures requiring further study. Descriptive case studies are used to describe a phenomenon within its real-world context (Yin, 2014). Multiple-case research studies, which may be explanatory, exploratory, or descriptive, are conducted between more than one case to draw similarities or differences within and between cases (Yin, 2014). In multiple-case study research, cases must be carefully decided upon so that the researcher can theoretically predict similarities or differences between cases. This study is a single instrumental case study that was open to including exploratory, explanatory, and descriptive elements. The single case was chosen because of its regularity and representation of a diverse classroom.

A common challenge for case study researchers is determining what the case or unit of analysis is (Baxter & Jack, 2008; Creswell, 2007; Merriam, 1988; Stake, 1995; Yin, 2014). Merriam (1988) has pointed out that the unit of analysis or case can be an individual, a program, a group, or an event, whereas Stake (2006) has noted that "a case is a noun, a thing, an entity; it is seldom a verb, a participle, a functioning" (p. 1). Even when the main focus is on a particular phenomenon or experience, the case that is chosen should be a particular entity. In addition, placing boundaries on the case being studied is an important feature in combatting a common problem in case study research when the question being asked is too broad or there are too many objectives being studied (Baxter & Jack, 2008; Stake 1995; Yin, 2014). Binding a case may be achieved by time and place (Creswell, 2009), time and activity (Stake, 1995), and/or definition and context (Miles & Huberman, 1994). Briefly, the case or unit of analysis in this study consists of a culturally diverse science classroom, and this is expanded upon in the research design. The case was bounded by place, in a specific school and in a specific classroom environment, and by time, from a few weeks after the beginning of a new semester (February) until a few weeks from the completion of the school semester (May).

One of the greatest concerns regarding case studies has been their lack of rigor (Meyer, 2001; Yin, 2014). Because there are very few specific guidelines for how to conduct case studies, the researcher is free to choose from a number of design and data collection procedures to address the research questions. However, this loose design has led to a number of poorly developed case studies (Meyer, 2001). In order to address the loose design limitation of case study research, detailed descriptions and accounts of the design decisions and data collection procedures are described in the research design. According to Meyer (2001) and Yin (2014), the issue of lack of rigor can be mitigated by following systematic procedures and by detailing these procedures.

Case studies have also been faulted as not being able to provide generalisations (Flybjerg, 2006; Yin, 2014). Stake (2006) has argued that the "power of a case study is its attention to the local situation, not in how it represents other cases in general" (p. 8). In addition, as Yin (2014) has contended, "case studies, like experiments, are generalizable to theoretical propositions and not to populations or universes" (p. 21). In other words, case studies are not able to generalise to whole populations; however, in their local contexts, case studies are able to provide information that may be of use in other similar populations. So, while the results might not have generalisability to all culturally diverse science classrooms in Canada and may not represent the views of all students in these classrooms, the results obtained might have important implications for how other research is designed, in the questions that are asked of participants, or in the assumptions that researchers make when approaching culturally diverse science classrooms, for example.

Finally, Yin (2014) highlighted that there has been a renewed interest in educational research on ‘true experiments’ that try to establish causal relationships; something which case studies are unlikely to do, as there is not a specific intervention being applied and then studied. Given the complex nature of classrooms, direct cause-and-effect relationships are difficult to establish, and in this way, case studies can provide important understandings that complement ‘true experiments’ (Yin, 2014).

Research Design

Meyer (2001) has argued that the strength in case studies lies in addressing present phenomena in real-life contexts. However, when considering case studies within the context of methodology, the researcher must be more explicit about the methodological considerations. Specifically, if researchers are to claim they are using a case study research design, they must be clear with respect to the selection of cases (single or multiple, sampling, and the unit of analysis), sampling time (including entry, length of time, and number of data collections), setting boundaries on the study, and the “selection of and choices regarding data collection procedures” (Meyer, 2001, p. 332). Yin (2014) has outlined five aspects of the research design particularly important in case study design that are used to explicitly emphasise the methodological and design decisions taken in developing this study. The five aspects are as follows: the research questions, the study propositions, the unit(s) of analysis, the connection between the data and the propositions (data collection procedures), and the data analysis techniques.

Research questions. The main purpose of this case study is to explore student perspectives of the implementation of science education in a culturally diverse classroom. The questions used to guide this investigation include the following:

1. How do students view science, science education, and culture within a culturally diverse classroom?

2. What are the perspectives and experiences of students as they interact with each other, their teacher, and the curriculum within a culturally diverse classroom?

A case study is particularly appropriate for the research questions in this study, as they deal with "operational links needing to be traced over time, rather than mere frequencies or incidence" (Yin, 2014, p. 10). There are a vast number of factors involved in a school and a classroom, including the people, the curriculum, the resources, and so forth, with no direct, singular cause-and-effect relationship to each other. Therefore, the ways in which students view the links between the factors and how they influence one another are crucial. As a result, a case study is able to more wholly answer the research questions in this study.

Study propositions. Propositions direct the researcher's attentions toward the aspects that should be examined within the study. In case study research, there is a danger of looking at everything and not narrowing down to focus on the particular, or to simply look at the particular and not come back to the whole (Stake, 2006). By stating propositions, the researcher is guided towards balancing between focussing on the particular whilst still considering the whole. As Yin (2014) has indicated, the research questions may not sufficiently address exactly what it is that the researcher should be studying. By stating propositions, the research is pointed towards something in particular that should be studied and that helps to guide data analysis.

The two main propositions guiding this study are as follows.

1. Learner factors, including attitudes, beliefs, and values are correlated with student behaviours or actions in classrooms and beyond (Koballa, 1988).
2. Curriculum implementation exists within a hierarchical structure (Banathy, 1991) and can be explored in terms of the interactions between the curriculum-as-plan and the curriculum-as-lived (Aoki, 2005).

While specific study propositions that correspond to particular research questions were proposed (see Table 1), the study was left open to other possibilities.

Study proposition	Research question
Learner factors	1
Curriculum implementation	2

Table 1. Study propositions and associated research questions.

Learner factors. Learner factors involve things such as academic performance, attendance, language proficiency and attainment, perspectives—which include attitudes, beliefs, and values—and behaviours about school and school science, and familial or cultural commitments. These factors, compounded with the potential cultural disconnect between school science and home, reflect the complexity of education for culturally diverse students (He, et al., 2008; Osborne & Collins, 2001). Language and culture are key issues related to student identity and schooling. Students mediate curriculum policy by coming to school with different backgrounds (Marsh, 2004), and the research to date has tended not to explore students' experiences in culturally diverse science classrooms. In the limited research focussing on student perspectives on the role and value of science curriculum, students have expressed "a number of discontents about current practice" (Osborne and Collins, 2001, p. 460), particularly around the messaging of the importance of science and yet the lack of relevant and contemporary content.

Students' attitudes, beliefs, and values with respect to science, science education, and culture within this study are important because, when probed in particular ways, they have been shown to be correlated with behaviour or action (Koballa, 1988). Osborne, Simon, and Collins (2003), in summarising several researchers' work, have noted that "behaviour may be influenced by the fact that attitudes *other* than the ones under consideration may be more strongly held;

motivation to behave in another way may be stronger than the motivation associated with the expressed attitude" (p. 1054, emphasis in the original). Attitudes towards a specific action to be performed (e.g. attitudes about doing science or about how students believe they can or cannot incorporate culture in scientific decision-making) are more powerful predictors of behaviour than simply ones attitudes about a particular concept (Ajzen & Fishbein, 1980; Osborne et al., 2003).

Koballa (1988) has differentiated between attitudes, beliefs, and values as necessary for interpreting findings. Attitudes are defined as "favorable or unfavorable feelings toward objects, persons, groups, or any other identifiable aspects of our environment" (Koballa, 1988, p. 117). Beliefs associate a characteristic to an object, such as in the statement that 'science (object) is difficult (characteristic)'. While attitudes are only evaluative, beliefs can range from descriptive to evaluative, and they can be held with different levels of strength (Koballa, 1988). Values tend to be broader than attitudes or beliefs and develop from cultural, subcultural, and personal experiences. The values that students hold are particularly important when considering the learning experience, as values play a critical role in mediating attitudes; while possible to change over time, values tend to be stable and persistent (Koballa, 1988). A model of how each of these concepts are related to behaviour has been proposed by Fishbein and Ajzen (1975; Ajzen & Fishbein, 1980), where attitudes towards an object, which are mediated by values, are determined by beliefs about the object, and in turn, influence a person's behaviour toward the object.

Ryan and Aikenhead (1992) have made the case that "students' images of science will certainly color their views on its epistemology, and vice versa. For example, epistemology will differ greatly between students who see science as an encyclopedia of facts about the world and those who see science as a facet of Western culture" (p. 562). In this study, students' views of science, science education, and culture are all, therefore, important terms to unpack.

Curriculum implementation. Curriculum has been defined in many different ways, narrowly focussing on curricular materials and more broadly to include “any and all educational phenomena” (Egan, 1978/2003, p. 16). Defining curriculum is a difficult task, as “many writers advocate their own preferred definition of curriculum, which emphasizes other meanings or connotations” (Marsh, 2004, p. 2). This study takes a broad view advocating that a curriculum is more than just the governmental programs of study. The school curriculum or specific course curriculum includes the education system as a whole that can only be looked at fully in relation to the other parts. So, while the definition is not as broad as that of Egan (1978/2003), who defines curriculum as “the study of any and all educational phenomena” (p. 16), curriculum in this study’s context is understood to include the formal program of study and the relationships between those factors that impact the instructional environment.

Curriculum has been further sub-divided by different individuals into, amongst other things, the formal/informal curriculum and the planned/hidden curriculum. The formal curriculum is usually mandated by an outside government ministry (in Alberta, these are programs of study) that may or may not include planned instructional pieces, and it is also called the manifest, planned, or intended curriculum (Erickson et al., 2008). The informal or hidden curriculum includes the implicit aspects of the curriculum, such as what is being done in the classroom that demonstrates the kinds of knowledge that are valued (Erickson et al., 2008). Aoki (2005) has described the curriculum-as-plan as the curriculum one is asked to teach, with its “origins outside the classroom” (p. 159), and the curriculum-as-lived as the situated world that is experienced by teachers and students. For the purposes of this study, the curriculum-as-plan and curriculum-as-lived are used to indicate the differences between the formalised science program of studies and how students in classrooms take up the program of studies, respectively.

Curriculum implementation and enactment are terms used both interchangeably and distinctly in the literature. As a distinct term, curriculum implementation has been described as the initial introduction or innovation of a curriculum within a school or system or as the ongoing work of implementing an existing curriculum (Fullan, 2008; Marsh, 2004). On the other hand, curriculum enactment has been defined by Ball and Cohen (1996) as “the jointly constructed [curriculum] by teachers, students, and materials in particular contexts” (p. 7) with teachers placed at the center. Other researchers have also spoken of curriculum enactment as being strongly related to the teacher and made little reference to the actions or reactions of the students and other factors (Bouck, 2008).

Houle (2008), who has defined curriculum enactment as including elements of both the taught curriculum (focussing on the teacher) and the experienced curriculum (what the students experience while being taught), is one exception to the teacher-driven focus of curriculum enactment. In contrast, Snyder, Bolin, and Zumwalt (1992) have argued that curriculum enactment describes the continual process of implementation, focussing on the experiences of teachers and students.

What exactly one means by curriculum implementation or enactment is still largely defined by individual researchers; sometimes they mean the same thing, and sometimes they do not. Although either term could be used within this study, enactment implies action on the part of someone or something, usually the teacher, outside of the focus of this study. Given the dispute over terminology, this particular study uses the term curriculum implementation broadly to refer to the ways in which the curriculum is operationalised as a whole, focussing on the ways in which the students understand or respond to the curriculum.

In researching educational organisations, Banathy (1991) proposed four levels of educational organisation, including the

1. institutional or governance,
2. administrative,
3. instructional, and
4. learning-experience levels.

In Alberta, the institutional level includes government, the ministry of education, school boards, and central offices; the administrative level involves administrators at individual schools; the instructional level includes teachers, resources, the curriculum, and other things that facilitate learning; finally, the learning-experience level directly involves the students. Figure 2 contextualises Banathy's levels to the Alberta context. The unit of analysis for this research is at the learning-experience level or, more specifically, within the science classroom.

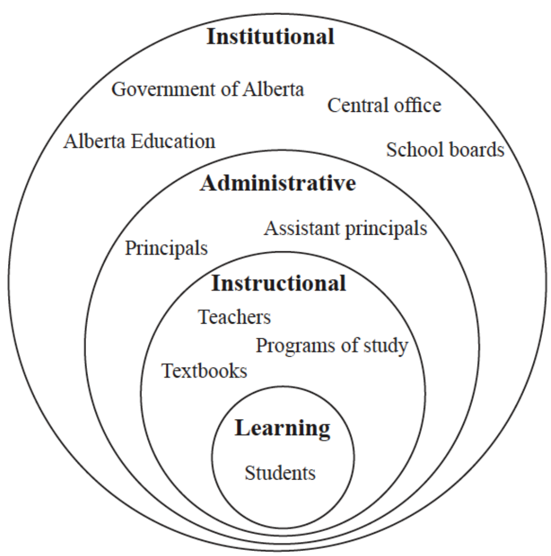

Figure 2. Levels of educational organisation in Alberta (based on Banathy, 1991).

Marsh (2004) has described the "classroom environment [as] an integral part of the learning process and no teacher or student can be unaffected by it" (p. 125), as it influences the types of interactions that the students and teachers will have with each other and can signal particular teaching and learning practices.

*Curriculum-as-plan***.** The curriculum-as-plan is the program that a teacher is expected to teach (Aoki, 2005). Aoki (2005) has elaborated on the curriculum-as-plan as "the works of curriculum planners, usually selected teachers from the field, under the direction of some ministry official often designated as the curriculum director of a subject" (p. 160). In Alberta, the curriculum-as-plan includes the programs of study produced by Alberta Education, the education ministry in Alberta, which stipulate the mission, vision, and goals of the science curriculum (e.g. Alberta Education, 2014). In addition, the programs of study specify, for each grade and subject, the objectives or outcomes that students are expected to accomplish throughout the course. At the time of writing, Alberta is engaging in the process of a curriculum redevelopment. Alberta Education's (2017a) website, which is dedicated to communicating about curriculum development to the public, clearly states that "Alberta Education determines 'what' students need to learn in provincial curriculum, [but] teachers use their professional judgment to determine 'how' students achieve the learning outcomes in the provincial curriculum". In this way, science education in Alberta is structured and mandated by the ministry. However, the ways in which teachers and students take up these concepts is not mandated and may be approached differently in different classrooms.

Curriculum-as-lived. The curriculum-as-lived is the situated world that is experienced by the teachers and students. According to Aoki (2005), the curriculum-as-lived is the place where teachers interact with students, who are all unique human beings. According to Aoki, the students' "uniqueness disappears into the shadow when they are spoken of in the prosaically abstract language of the external curriculum planners who are, in a sense, condemned to plan for faceless people, students shorn of their uniqueness" (p. 160). As a result, teachers are required to translate the curriculum for the actual students in their classes. Pinto (2005) contended that, either consciously or unconsciously, teachers take new curriculum proposals and interpret, categorise, and select which of those they will take on and which they will not. While a number of researchers have discussed the pivotal role that teachers play in the implementation of curriculum (e.g. Fishman & Krajcik, 2003; Fullan, 2007; Pinto, 2005; Snyder, Bolin, & Zumwalt, 1992), research into student's experiences is limited.

Erickson et al. (2008) pointed out that, since 1990, there has been an increase in the amount of attention being paid to students' experience of school. However, in comparison to the total field of educational research, students' experiences still receive little emphasis. Students' subjective experiences and perspectives about the curriculum and their interactions with their teachers are as important as they are individual and varied from one person to another (Erickson et al., 2008). Students' voices are vital to developing an understanding of classrooms (Crawford, 2000).

The unit(s) of analysis. The unit of analysis in this case study is a culturally diverse classroom. There is debate amongst case study researchers about how exactly to define the case under investigation (Gerring, 2007; Merriam, 1988; Stake, 2006; Yin, 2014) and, more specifically, whether the case within a study is or can be an individual, group, phenomenon, event, and so forth. Stake (2006) for example, argued that "even when our main focus in on a phenomenon that is a function, such as 'training', we choose cases that are entities" (p. 2) because entities can be easier to define and delimit. Yin (2014) has contended than any of the aforementioned things may form a case study. However, as Stake has alluded to, it is essential to clearly define the case under investigation and place necessary boundaries around the case. Merriam (1988) has identified that "the focus of research in a case study is on *one* unit of analysis. There may be numerous events, participants, or phases of a process subsumed under the unit" (emphasis in original, p. 46). The case or unit of analysis in this study is the culturally diverse science classroom, with students as participants.

Selection of the case. The primary goal in choosing the case for this study was to select a school and classroom that were considered culturally diverse and that was instrumental in nature (see Chapter 4 for a detailed description of the case and the participants). After receiving ethics approval for this study from the university and the research ethics boards[3] in two school divisions, intermediaries known to the researcher were approached about distributing letters to teachers located in schools with culturally diverse student populations. Science teachers were required to be certified teachers teaching at a public or Catholic school in Alberta with at least three years of teaching experience. This selection reduced the initial participant pool and helped to focus on representative classrooms in Alberta. Teachers who were interested in having their classes participate in the study contacted me directly. Once a teacher was selected, an introduction letter was given to the administrators of the school, who contacted me directly to give permission to conduct the study as per the requirements of the ethics approval given by the school division. Students in the classrooms I made observations in were introduced to the study prior to beginning of the observation sessions. Students who were interested in participating approached me for an introduction letter, a student assent form, and a parental consent form for student participation. Students and parents interested in the study contacted me directly.

A variety of student participants were sought according to their generational status (born in Canada, first or second generation, as defined by Statistics Canada, 2011). Acculturation into

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[3] See Ethical considerations for a discussion about the process of gaining ethics approval.

the majority culture has been shown to increase after the second generation, and stronger ethnic identity is seen with people who are first and second generation (Perez & Padilla, 2000; Rosenthal & Feldman, 1992; Zhou, 1997). Therefore, students who are first or second generation were predicted to be more likely to face issues associated with cultural diversity in the science classroom than other students.

Ultimately, 13 students across two grade 10 classes taught by the same teacher were selected as participants. Stake (2006) highlighted that "the case has an inside and an outside. Certain components lie within the system, within the boundaries of the case; certain features lie outside. A few of the outside features help define the contexts or environment of the case" (p. 3). The student participants comprised the inside of the case. In addition, informal conversations were held with the teacher and two administrators, both of whom had involvement with the science department in the school, throughout the study when additional context was needed. For example, verification that the school and the classroom were culturally diverse was confirmed during these conversations.

Sampling time. Data collection began with initial conversations between myself and the teacher the first week in February 2014 and ended with final interviews with the student participants in the middle of May 2014. This particular time period was selected because it was the beginning of a new semester for students and a more logical entry point into the classroom. Approximately three months were chosen, as the participating school division preferred that research not be conducted in schools during the months of May and June due to preparations for final exams. This period of time was an appropriate length since the majority of instructional time was devoted to classroom work and not specifically to final exam preparation.

Data collection procedures. The focus of the data collection procedures involved multiple case study interviews with the participants (Yin, 2014). In addition, discussions with staff members as well as classroom observations—including student–teacher interactions, student behaviours, classroom conduct, and classroom materials and resources—were held in order to provide additional context and clarity to the interview data.

Interviews. Two audiotaped, semi-structured interviews were performed with students (see Appendix A for the interview schedule). Kvale and Brinkmann (2009) have described an interview as "a conversation that has a structure and a purpose. It goes beyond the spontaneous exchange of views in everyday conversations, and becomes a careful questioning and listening approach with the purpose of obtaining thoroughly tested knowledge" (p. 3). Interviews were necessary because the behaviour, thoughts, or feelings of the participants could not always be observed, and in some cases, past events that could not be duplicated were discussed (Merriam, 1988; Yin, 2014). The semi-structured interviews had pre-determined questions that were developed to inform the research questions guiding this study. However, the format of the interview differed from participant to participant in response to the interviewees' responses, with questions being added or omitted as necessary (Merriam, 1988; Robson, 2002). These types of interviews recognise that each participant has a unique perspective of the events, as opposed to more survey type interviews, in which participants are given pre-determined choices (Merriam, 1988).

Interviews with the participants occurred halfway through the observation period and once towards the completion of the observations. The first interview asked questions about participants' attitudes and beliefs about whether they felt there were cultural challenges or considerations in science education, and whether they felt these were being addressed or not. In addition, students were asked about whether or not the science taught in schools was congruent with their home/community life. These interviews were approximately 30 minutes to one hour in length, audiotaped, and later transcribed verbatim. The second round of interviews was conducted to re-visit some of the questions discussed in the first interview to confirm views or to allow students to expand on their answers. In addition, students were asked questions about what other students had stated, and they were asked what their views were on different instances that occurred in the classroom; these were noted during classroom observations. See Appendix B for an example of the interview protocols.

One of the challenges with interviewing the participants was that they were being asked questions that they may not have encountered previously or ever even thought about. Some questions from the first interview were repeated in subsequent interviews to allow participants additional time to consider the questions, and to add to or eliminate from their previous answers. To help provide context for students around the types of questions that students may not have had any experience with, during the last interview with the participants, a technique employed by Burke (2013) for eliciting participant commentary was used. In this technique, a bank of statements is presented to participants, and they are asked to sort them. As they are sorting, participants are asked to discuss their reasons for categorising the statements as they did. According to Burke, these "statements provided foci around which participants could organise the expression of their opinions by first making the decision whether to agree or disagree with each statement presented" (p. 6).

For this study, students were asked to sort statements (see Appendix C for the statements used in the sorting activity) first into whether they believed they were scientific or non-scientific. After they did this and provided rationales for their choices, students were given the option to re-sort their statements, with a third category of both scientific and non-scientific categories being added. Seven statements were chosen to reduce the complexity of the task, and all statements were selected from scenarios either from the students' required textbooks (Gue et al., 2004), which they were referred to numerous times during class, or from the outcomes in the Science 10 Program of Studies (Alberta Education, 2014). The statements focussed on historical developments, decision-making, and science–technology–society elements. The statement-sorting activity allowed for richer and more meaningful discussion, helped the participants to frame their opinions, provided greater insight into potential behaviours, and allowed for a triangulation of other interview data. Statements made within this context were compared to previous statements made to verify or refute other interview data and to expand certain discussions with students. For example, if a student sorted the statement on ancient Greek thinkers using logic and not experimental investigation as a scientific statement but had earlier stated that science only included experimental investigation, discussions circled back to these questions. In some instances, when students were unable to account for the discrepancies, this data was not used in the analysis, as it could not be substantiated.

Other sources of data. Discussions with other staff members were conducted in order to provide additional context to the school and classroom environment. For example, discussions with staff corroborated the culturally diverse nature of the school, and student achievement was verified with the teacher.

Classroom observations occurred two days per week per classroom over a three-month time period, and field notes were generated to identify interactions between students, between the students and the teacher, and to more broadly understand the day-to-day operation of the classroom. Yin (2014) has pointed out that observational evidence can be crucial for case studies when trying to understand the actual uses of something, such as for a curriculum, as is the case for this study. Merriam (1988) has noted that "as an outsider an observer will notice things that have become routine to the participants themselves, things which may lead to understanding the context" (p. 88). In contrast to interviewing, which can rely on recalling details, observation allows behaviours to be recorded as they occur (Merriam, 1988). In this study, the observation data served to provide context to the environment and to support or refute interview data.

Data analysis. Yin (2014) has contended that "the analysis of case study evidence is one of the least developed aspects of doing case studies" (p. 133) and advocated the consideration of analytic approaches during the data collection protocol phase of case study research.

Upon completion of an interview, audiotaped recordings were sent to a professional transcription company. Transcripts were returned in three days. All transcripts were reviewed with the audio recordings, and edits were made for accuracy. Transcripts were then analysed by applying an initial set of pre-determined codes to the data. These initial codes were developed using the study propositions as a guide and "related to the research questions, concepts, and themes" (Robson, 2002, p. 477). This first-level coding attached labels to large groups of words or statements from the student interviews (Miles & Huberman, 1994). As this process continued, notes were made about possibly including additional codes, deleting codes, or further refining existing codes. These possibilities were then compared to the research questions and design, and the codebook was further refined (Yin, 2014). Data was then reanalysed with the refined codebook. Two additional iterations of the refinement process occurred. Ultimately, the first-level coding allowed for large-scale coding, and the second-level coding further divided the first-level codes into smaller themes or patterns. The final code list, with descriptions and additional notes or quotes, is present in Appendix D.

To ensure consistency in coding, statements made by individual participants were compared. Inconsistent statements were either discarded or explicitly identified. Finally, the data were compared and contrasted with the existing literature for alignment or disagreement.

Triangulation. Stake (2006) has advocated triangulation of the data in which "triangulation is mostly a process of repetitious data gathering and critical review of what is being said" (p. 34). Yin (2014) has encouraged the use of multiple sources of evidence in order to corroborate the same findings. In order to accomplish triangulation within this study, comparisons were made between student responses in interviews to the behaviours they displayed in class or their work, as well as using multiple student perspectives around a particular event. For example, when students discussed how they behaved in science classes, their statements were compared with observational notes taken in class. Or, when discussing a particular event, such as Culture Sharing day, multiple students' perspectives were compared against each other. In some instances, when a participant's distinctive perspective was sought, triangulation was achieved by questioning the student on different occasions and in different ways. For example, students were asked their perspectives about what science was and what science was not in both interviews, and they were also asked to participate in a sorting activity that gathered information about their perspectives on what science was and was not. Unless explicitly identified, only convergent evidence was described in the analysis. Yin (2014) has argued that, when multiple sources of evidence cannot be gathered, for example, when asking about a participant's subjective experience, questioning a participant at multiple times serves on its own as multiple sources.

Validity and reliability. Creswell (2009) has defined qualitative reliability as consistency of approach. In order to do this, Creswell (2009) and Yin (2014) have recommended documenting as many steps of the procedure as possible, as well as other reliability procedures, including cross-checking codes, checking transcripts, writing definitions of codes, and constantly comparing data with those definitions of the codes. For this investigation, transcripts were rigorously checked and definitions of codes were cross-checked with the researcher's supervisor to ensure reliability.

Qualitative validity "means that the researcher checks for the accuracy of the findings" (Creswell, 2009, p. 190) by using multiple strategies to enhance the researcher's ability to evaluate the precision of findings. For this investigation, member checking was done to ensure that the interpretations from the interview data are accurate. Participants were provided with the transcripts of their interviews and the original emerging data to verify what they had said or to add or eliminate any statements.

One possible threat to the validity of my findings was my assumptions going into this research were that students experienced cultural barriers accessing and learning school science. To add credibility to the findings, detailed descriptions of the case and context—including descriptions of the school and classroom, neighbourhood demographics, and participant profile—were compiled. In addition, peer debriefing with my supervisor occurred. Peer debriefing involves "an interpretation beyond the researcher and invested in another person" (Creswell, 2009, p. 192), which increases the validity of the account.

A criticism of qualitative research is that validity and reliability are more difficult to achieve than in quantitative research (Creswell, 2009; Stake, 1995; Yin, 2014). By ensuring that set procedures are followed during data analysis, the reliability and validity of findings can be increased.

Ethical Considerations

To ensure all ethical considerations were accurately assessed, this study was reviewed by the University of Alberta Research Ethics Board and by the Cooperative Activities Program (CAP). Once ethics approval was granted by both, one school division gave permission to approach intermediaries known to the researcher, while another division gave permission to contact a particular school where an intermediary was known. In alignment with the policies set out by CAP at the time of the research, I contacted the appropriate intermediaries and interested teachers contacted me directly. In addition, to ensure compliance with the requirements of the Research Ethics Board, this study also adhered to the University of Alberta Standards for the Protection of Human Research Participants. I have also participated in research ethics training as part of the University of Alberta graduate program. While the steps mentioned above satisfied the requirements for ethics approval, as suggested by Atkins and Wallace (2012), "an ethical approach should pervade the whole of your study" (p. 30). Therefore, ethical approaches were applied and considered throughout all aspects of this study. These considerations are noted in the accompanying text for each piece.

Anonymity, confidentiality, and privacy were maintained by using pseudonyms for the participants, and specifics about the school or its location were anonymised as much as possible. Informed consent was obtained by informing all participants of the research project in an information letter and providing them with a consent form to sign indicating their willingness to participate in interviews, observations, and the collection of artefacts. Students under the age of majority were also required to have their parents sign the consent form. Participants were able to opt out of the study at any time during the interview process and up to one month after data collection without penalty of any kind. Audio-recordings of interviews, transcriptions, and data are kept in a secure location on a password-protected, encrypted computer. Any non-digital data is locked in a secure filing cabinet. After a period of five years, the data will be destroyed.

Limitation and Delimitations

The limitations of this study are that the classrooms, teachers, and ultimately, students who participated were, in part, determined by the willingness of the school division and the principal to participate. Within the design of the study, we only approached principals and teachers in areas with higher cultural diversity or were directed by the school division towards schools that they had deemed to have higher cultural diversity. However, my purposeful sampling was limited to these criteria. As with any case study, generalisations are not possible. However, the purpose of case study research is not to generalise (Stake, 2006; Yin, 2014), as "the power of case study [research] is its attention to the local situation, not in how it represents other cases in general" (Stake, 2006, p. 8). This study was able to identify different factors and specify the conditions under which they may be of use in other situations.

This study was delimited by both the time and sampling methods. Only a single case study was conducted, as I was the only researcher. Due to time constraints and limited resources, interactions with participants and observations only occurred over a roughly three-month period. While this did allow for a comprehensive snapshot of what was happening in the classroom environment, this cannot fully capture the current reality in the learning environment over the long term.

Chapter Four: Findings and Analysis

Introduction

This chapter begins with a detailed description of the school where this study took place. Demographic information about each participant and a description of a typical day are included in order to provide the 'thick and rich descriptions' that case studies require. The findings and analysis are organised by theme and include (1) perspectives about science, (2) science education experiences, (3) understanding of culture, and (4) curriculum implementation. Within this last theme, a short vignette is presented on a stem cell lesson in order to explore this particular theme more deeply.

Description of Case and Context

This study was conducted in a high school located just on the outskirts of the downtown area of a large city in Alberta, Canada. Approximately 1,800 students from grades 10–12 were enrolled in the school, which offers comprehensive programming for students. In addition to core academic programming, the school had a wide range of optional programming for students, including the International Baccalaureate (IB) program, multiple second language offerings, French immersion, music, art, drama, career and technology studies, and a full special education program. A large majority of the student population attended from a very particular catchment area with specific junior high schools feeding into the school. However, there were also students who came to the school specifically for some of the optional programming, in particular the IB program. Initially, the school was chosen because of the researcher's familiarity with the culturally diverse nature of the school and the student population in general. Although schools or school boards do not provide demographic data regarding a student's generational status, neighbourhood data indicated that the surrounding neighbourhood was culturally diverse. All of the participants in this study and the participating school division confirmed, in their opinion, that the school was culturally diverse.

The unit of analysis for this case study is the science classroom, and the grade level and course chosen for this study was Science 10. In order to graduate with a high school diploma in Alberta, all students must take at least 10 credits in science (Alberta Education, 2017c). Science 10 is a five-credit course and is the foundational course in grade 10 for students to pursue more general science courses (Science 20 and 30) or specialise in biology, chemistry, and/or physics throughout high school.

In this particular case, the teacher taught two Science 10 classes: one Science 10 class with students who had enrolled in IB (Science 10 IB), and one Science 10 class with students who had just completed Science 14 (Science 10 Prep). The IB Diploma Program is a two-year program targeted at students aged 16–19 (International Baccalaureate Organisation, 2017); therefore, it does not formally begin in Alberta high schools until grade 11. Students enrolled in IB are still required to complete all the requirements of Alberta Education for a high school diploma. As such, the Alberta Science 10 Program of Studies is used for all students enrolled in Science 10, whether taking IB or not.

Participant demographics. The majority of the student participants in this study (9 out of 13, or 69%) were born in Canada and, even more specifically, within the city in which this study took place. However, the majority of the participants' parents were born outside of Canada (69%). Four students came to Canada as immigrants—two of the students had obtained Canadian citizenship and were therefore first generation, whereas the other two were unsure of their official citizenship status. Five of the participants were second generation, and in all of these cases, both of their parents were born abroad. The remaining four participants and both of their parents were born in Canada. The student participants also spoke a variety of languages, with languages other than English being spoken at home and at school. All but two of the participants were 15 years old, with two being 16 years old. Appendix E provides a brief description of the student participant demographic information. All participant names are pseudonyms either chosen by the participants or chosen by the researcher with the participants' consent.

Cindy. Of all the student participants, Cindy was the most recent newcomer to Canada. She was 15 years old and had come to Canada four years prior from Taiwan. Her mother and father were from Vietnam and Taiwan, respectively. Cindy spoke Mandarin and Cantonese at home and was quick to point out in our interviews that she struggled with English language arts and the English language in general. She struggled in school, with the exception of Mandarin class, and had a grade of approximately 50% in science prep. Her achievement was less than this in English and social studies. Cindy was focussed on her social interactions with peers while in school, which was corroborated both by her statements during interviews and her behaviours in class, including passing notes during instruction and consistently talking to her group of three friends—not about science—during work time. Cindy experienced difficulty involving her parents in her schoolwork, as she struggled with how to translate the information for them. Cindy wanted to participate in the study, as she felt it would help her to practice her English.

Ryan. Ryan was 15 years old and born in Canada. Both of her parents were born in Vietnam and had been in Canada for approximately 40 years. Her father was a radiologist, and her mother was a nurse. She came to the high school from outside of the area because of the Mandarin program at the school and was enrolled in IB. She had approximately 85% in Science 10 IB at the times of her interviews. Ryan spoke Cantonese, Mandarin, and English, and she was learning Korean. She also participated in Lion Dance, piano, and cross-country running, and she had begun training for weightlifting. Ryan and her family were heavily involved in their church and participated in several extended missionary trips, primarily in different areas of Asia. She regularly discussed the importance of familial beliefs regarding science and religion in her responses. Ryan wanted to participate in the study because she thought it would be a good experience to see how research happened when you were not in a lab.

Tam. Tam was a self-declared non-science person. While she thought science class was 'okay', she did not see herself ever going into a science field as a career. Tam was 15 years old and born in Canada. Both of her parents were born in Hong Kong and had come to Canada approximately 30 years prior, but they had met in Canada. Her father was a pharmacist, and her mother was a medical researcher. Tam's family spoke Cantonese at home, but Tam always responded in English. She was taking Mandarin at a beginner level. Despite not being a science person, Tam had approximately 90% in Science 10 IB during the interviews. Tam was very involved in dance and her church. She had some of the most sophisticated views about science, religion, and the interaction between the two. After the first interview, she found a book in her English classroom that was a religious perspective on Darwinism and evolution. She identified that the book was very religiously biased but that, in spots, it made good points, for example, about the bias in Haeckel's drawings in most textbooks. She had begun to read *On the Origin of Species* as a counterpoint and was interested in any resources I could suggest for her to look at about science and religion. She genuinely wanted to know how specific individuals and not groups perceived the conflict between science and religion. Tam agreed to participate in the interviews because she thought the topic of the research sounded 'weird' and did not understand why this was a science question.

Martin. Martin was 15 years old, born in Canada, and lived with his Aunt. He could only trace his family back to Canada and did not know where they were from before. Martin spoke only English. He was working with a tutor to improve his grades and was attempting to get a part-time job. Martin was in Science 10 prep and had a score of approximately 55%. Martin did not think that his cultural background—although he did not feel he had one—played any role in his life. He wanted to be a pilot and felt that taking science might be important for his career, but he did not really like science class. Martin was hoping that participating in the study would count towards some school volunteerism hours he had to acquire.

Seth. Seth was 15 years old and was born in Scotland. He moved from Scotland to Canada with his parents in 2008. Seth was involved in football and in instrumental band. He did not believe that his background was necessarily important to discuss with people. However, he did feel it was important to talk about his prior learning disability. He was unsure of what this was but described his need for hands-on learning. He was fine with sharing this with the class and the teacher, although he did not have an individualised program plan. He had approximately 35% in Science 10 prep, and according to his teacher, had just passed Science 14. In general, Seth struggled in most of his school subjects, with the exception of instrumental music, where he had higher achievement, and physical education, where he excelled. Seth agreed to participate in the study because he thought the topic sounded ‘neat’. Seth frequently asked me if he was giving good answers. I was careful to repeatedly ask and rephrase questions to ensure I was getting his actual perspective and not just what he thought I wanted to hear.

Hua. Hua was 15 years old and born in Harbin, China. She had immigrated to Canada with her parents 11 years prior. She was fully enrolled IB and was taking Mandarin in school. Mandarin was her first language and the language she spoke at home. Hua was involved in swimming and was taking courses to become a water safety instructor. She felt it was really important for people to know her and others' backgrounds, as she believed this strongly influenced the values people held and how one might communicate or interact with people. Hua's parents were interested in her pursuing something in the medical field, but she was not really interested in biology, in particular, at all. However, she did indicate that she was interested in pursuing something in science. Hua had approximately 85% in Science 10 IB. She agreed to participate in this study because I asked for volunteers.

Tala and Jennifer. Tala and Jennifer were extremely good friends and participated in their interviews together. They wanted to participate in the study but were nervous about being alone. Tala and Jennifer shared many school related interests and values, such as the courses they took, their involvement in cheerleading, and their desire to do well in school and go to university. Although they interviewed together, they did share different perspectives about different things. Tala was 15 years old and was born in the Philippines. Both of her parents were from the Philippines, and they had come to Canada five years prior. Tala spoke Filipino but, according to her, not fluently. Tala had approximately 60% in Science 10 Prep. Jennifer was 16 years old and was born in Canada. Both of her parents were born in Canada, and she only spoke English. Jennifer had approximately 75% in Science 10 Prep. Jennifer and Tala sat together during class, away from most of the other students, and remained focussed during class, in direct contrast to most of the other students in Science 10 Prep.

Claire. Claire was 16 years old, and both of her parents were born in Canada. She lived primarily with her father and saw her mother every second weekend. She believed her background had a mix of German, Scottish, and British. Claire only spoke English fluently but was learning Spanish as part of her IB program. Claire was interested in pursuing a career in medicine. She had approximately 85% in Science 10 IB. Claire was very focussed in class. Her friends were not in IB, so while in class, she interacted with her classmates only during labs or group work. She indicated that, as a result of not seeing either of her parents very often, she rarely spoke to them about school other than grades. They had other things to talk about. Claire also had a part-time job to assist with family finances. Claire agreed to participate in this study because she wanted to pursue any opportunities that were presented to them during class, including helping me with my research study.

Cheng. Cheng was 15 years old and born in Canada. His parents had immigrated to Canada from Guangzhou, China, approximately 20 years prior. He spoke some Mandarin and some Cantonese. He spoke mostly English with his parents at home. Cheng was in partial IB but did not take English IB. He had approximately 85% in Science 10 IB. Cheng was interested in computer science but not science class. He indicated that his parents strongly valued English, science, and math class because these were important subjects for him to get into engineering or medicine. Cheng had very short answers and had difficulty answering some of the questions in the interviews. He required a significant amount of wait time between questions and answers, and he frequently had to rephrase the questions. Cheng did not know why he agreed to participate in the study, and I was very careful to use only the responses he gave that were strongly corroborated.

Zack. Zack was 15 years old and born in Canada. Both of his parents had met in Guangzhou, China. He was not sure when they had immigrated to Canada. He was fluent in English, Mandarin, Cantonese, and Taishanese, a Cantonese dialect. He was in full IB and had approximately 90% in Science 10 IB. It was important for his parents that Zack be a well-rounded person, not just perform well in school, and he agreed to participate in the interviews because he thought his parents would like it. As a result of his motives, I was again careful to use only those responses that were repeatedly corroborated with supporting information.

Ayana. Ayana was 15 years old and born in Canada. She had four younger siblings. Her parents were both born in Ethiopia and had come to Canada approximately 20 years prior. They met in Canada. Ayana spoke Harari fluently, and her family spoke a mix of both at home. Her father drove a taxi, and her mother stayed home. Ayana was in full IB and was in beginning Mandarin. She had approximately 85% in Science 10 IB. She was very involved in her 'cultural community', which included 'African Muslims'. Ayana indicated that the community placed very high expectations on the children to perform well in school. She agreed to participate in the study, as she was interested in how science and culture might be related.

Lenny. Lenny was 15 years old and born in Canada. Both of his parents were born in Canada, although his mother lived in the United States of America for a number of years. Lenny had just dropped from the full IB program to a partial IB program as all he was interested in taking was IB biology and IB Spanish. He had just started learning Spanish that semester. Lenny had approximately 85% in Science 10 IB. He was interested in pursuing university but was unsure about what he wanted to take. Lenny was interested in participating in this study because he was curious about what I could possibly ask.

Typical day. Each class was typically structured around the following schedule:

1. Homework from the class before was checked for completion. Time was given to complete the homework, as most students rarely had it finished. The teacher then went through each question.

2. New material was presented didactically to the class. Each lecture included PowerPoint lectures, and the students had unit booklets with fill-in-the-blank notes. Occasionally, there would be a short video or video segment.
3. Finally, some class time was given to work on assigned homework, which came either from the textbook or from the teachers' resource manual that accompanied the student textbook.

There were a few times when the class deviated from this basic structure. Two laboratories for Science 10IB were observed—one on velocity and one on chemical reactions—and one laboratory for Science 10 prep, which was a microscope lab. There was also a debate on stem cells observed in Science 10IB, which also occurred in Science 10 prep but on a day during which observations did not take place.

Perspectives about Science

The participants' perspectives, including their attitudes, beliefs, and values about science, were important in attempting to understand the ways in which they understood science within a culturally diverse classroom. In relation to the framework, attitudes, beliefs, and values about science form an important link in how students may shape the learning environment by their behaviours or actions. Three sub-themes emerged regarding participants' perspectives about science: definitions, influences, and science-as-process.

Definitions. Participants in this study defined science as 1) specific disciplines, and in particular, the scientific disciplines demarcated in school; 2) as explanations of the world and how and why things work; and 3) as universal in content. Responses were categorised as definitions when participants were describing what science was or was not, and the ways in which participants demarcated science from other subjects as ways of knowing or understanding the world.

Discipline-based. The majority of the participants identified specific disciplines when defining science. In particular, the disciplines mentioned included the specific topics and courses within the school program. For example, most participants discussed science as involving biology, chemistry, and physics. Tam (interview 1) suggested that in science '*you do your chemistry, and you do your physics, and you do your biology. That's kind of all areas of science, isn't there? There's not much left in science'*. Prior to the first interview with students in the Science 10 prep class, the chemistry and physics unit had been covered. When Jennifer was asked about what science was, she used chemistry and physics descriptions in her definition. By the second interview, the biology unit was taking place, and Jennifer (interview 2) wanted '*to add bio, because I don't think I put that in for this one'*.

When students were asked what their favourite and least favourite things were about science, all participants based their answers on the specific scientific disciplines that comprise 'science' in school. In addition, the perceived usefulness of a discipline was included as part of the students' reasoning for why a particular discipline was more or less favoured. For example, Ryan (interview 1) identified biology as her most favourite thing about science and chemistry as her least favourite. Although the Science 10 IB class had not covered the chemistry unit by the first interview, Ryan (interview 1) suggested that she did not like it because '*I just don't think chem does a lot'*. Students in this study, with respect to their most and least favourite aspects of science, rarely mentioned things other than sub-disciplines, such as investigation or specific processes, and most of the students identified their only engagement with science as taking place within a school setting.

In conversations, the teacher also specifically mentioned biology, chemistry, and physics, and demarcated science from non-science as not belonging to one of the other core disciplines in school, for example, mathematics or social studies. Deniz (2011), Eberle (2008), and Mansour (2008) have all suggested that students' beliefs about science (and in particular the nature of science) may be influenced directly or indirectly by the ways in which teachers, in part, define science. The correlation between usefulness and interest in a science discipline is echoed in Osbourne and Collins' (2001) study of students' views on the role and value of the science curriculum. They found that, for all students—those who had science career aspirations and those who did not—the usefulness of a particular sub-discipline to the students' lives was correlated with their interest in the sub-discipline specifically, and science more generally. Given the ways in which the teacher defined science and the ways in which the students described their own interests in science, it is not surprising the students defined science as particular school disciplines. However, it does suggest that students' notions of what science is might be influenced and, more specifically, limited by how schools are specifically demarcating the disciplines of science.

Explanatory. In addition to the specific disciplines mentioned, when probed, the majority of the participants (93%) defined science as a way of finding out how and why things work. For example, Zack (interview 1) defined science as '*how you learn about the world and how it works'*.

Some participants described the explanatory nature of science as the most important component of science. For example, when asked whether or not historical developments, in particular the scientists themselves, were important in understanding science, Martin (interview 2) stated,

> *I don't think so because . . . I mean, I get that they should get credit for it but I think that should be part of being social. I mean, science is about understanding how things work, and I don't see why who made an invention is important for that.*

Five of the student participants went on to suggest that the explanatory power of science was the most important component because of its applicability to daily life. For example, Ryan (interview 1) suggested that

> *knowing how the lights work in your house and if you ever have a light go out you would know the simple stuff, why a light went out and what you could do to fix it. And for biology you can kind of know what happens in your body, so then you can know, 'Oh, why do I have a stomach ache?' or 'Why are some people different from others?'*

Universality. On the whole, participants expressed science content as being universal. As Tam (interview 2) indicated, '*I think science is now, right or wrong, universally accepted everywhere, so everyone just kind of learns the same science'*. Hua (interview 2) extended the idea that science content was universal by suggesting that science was like a book you simply follow. However, she also felt '*people practice [science] differently. Same with art. They can interpret it differently'*.

The definition of science content as universal expressed by the participants is in line with how both Matthews (1994) and Siegel (1997, 2002), amongst others, have positioned science content. Both Matthews and Siegel have asserted that, while science is positioned within a cultural context—and as the participants agree, prone to interpretive influence—modern science is still universal.

Hua (interview 2) provided a specific example to illustrate the universality of science. She stated that '*sugar is sugar and salt is salt. It's not like sugar can be salt*'. Most of the participants, when discussing the universality of science, provided very simplistic factual examples and statements, such as salt and sugar. Even though students were learning or had learned about more complex topics, such as stem cells, they tended to default to very simplistic examples from their science classes when discussing science content.

Influences. All of the participants discussed cultural, religious, political, and personal influences on the way science was done; how people, scientists, and the general public, approached science; or the way that science was interpreted. However, these influences were almost exclusively discussed within the context of scientific interpretation and the approaches taken by scientists to arrive at decisions.

Although the participants saw science content as universal, they understood scientific interpretation as prone to influence. When discussing scientific interpretation, Martin (interview 1) suggested that, previously, '*people would use theories they developed with their religion to explain things that happen with science'.* When asked why scientists come up with different theories even when looking at the same evidence, Lenny (interview 2) said the scientists '*see what they want to see to some extent [and that] culture, ethnicity, origin, ancestral beliefs*' were all things that could influence them. With respect to why two scientists might get different results, Tala (interview 1) provided the following analogy: '*Like, if you were to interview someone else in the school, it'd be different answers too. . . . [People have] different perspectives*.'

When discussing how scientists may approach problems, Ayana (interview 2) specifically suggested,

> *what [the scientists] grew up with, like the people around them, influenced their decisions and just what they've learned. Like, someone might learn, like in math you learn different methods if you choose a different method, like if you choose method one, you still can get the same answer if you chose method two, so you can still use, you can have the same answer but you're using different methods.*

The students acknowledged that scientists could approach problems differently, leading to different interpretations, in some cases even being influenced by biases, personal or otherwise. When asking a group of scientists why different conclusions about the extinction of dinosaurs could come from the same set of data, Wong and Hodson (2009) found that scientists described the need for imagination and creativity in science. The different perspectives that each individual holds, from the scientist's perspective, were bound by training, experience, and to a lesser extent, background. In contrast, the students in this study felt that background was an important aspect in terms of the ways in which scientists interpret results.

Other factors that were seen to influence science included governmental support and economics. Ryan (interview 1) stated that government support was helpful '*if scientists want to develop something new or do research on something*', specifically because governments provide financial support and connections to other countries. Tala and Jennifer both thought science might be impacted by the politics of a particular location. Specifically, '*poor places in the world—they probably don't have enough money to do really big science experiments and stuff that will benefit the world*' (Jennifer, interview 1).

In some cases, the student participants described factors, such as personal beliefs and interactions, as superseding scientific belief as opposed to just influencing them. Cheng (interview 1) identified that

> *some places value religion more than science, so it's different. So, yeah, like, in other places, people learn about how God created the world and then here we learn about big bang theory, and we have more open choice on what we should believe in here. In other countries, you're only supposed to believe in one religion.*

While participants were aware that the culture, religion, background, and so forth, of an individual could influence how scientific interpretation and approaches to scientific problems happens, this was not evident in their definitions of science. There was a significant disconnect between how students defined science narrowly as specific sub-disciplines, factually as providing explanations for how the world works, and universal in content, and at the same time, prone to influence. The student participants also believed that a scientist's personal perspective or opinion was just as likely to influence science as larger societal influences, such as religion or politics. In addition, the extent to which the influence of the myriad of decisions that scientists make regarding their results was largely ignored or de-emphasised as being important to the process of science. In what Knorr-Cetina (1983) has called the, 'decision-impregnated nature of inquiry', the activities of science are directed by the available tools but also by the decisions that scientists make at all levels, which are made against particular decision criteria. While the students in this study generally believed that science and scientists could be influenced by factors such as religion or politics, the extent to which this influence affected a scientist's particular decision criteria was not considered.

Processes of science. In their exploration of the authentic practices of 13 well-established research scientists, Wong and Hodson (2009) identified two major themes encompassing areas of misunderstanding for learners with respect to science: a) methods of scientific investigation, and b) role and status of scientific knowledge, which mirrored how the participants in this study described the process of science. The participants' descriptions of methods of scientific investigation focussed on experimentation, logical arguments, and observation, whereas their descriptions of the role and status of scientific knowledge focussed on the use of theories and the ability of science to determine the 'truth'.

Methods of scientific investigation. The methods of scientific investigation described by the participants included their beliefs about experimentation, logical arguments, and the process of observation, particularly compared with other disciplines of inquiry. Most of the participants described the importance of experimentation as part of the scientific process. This is not surprising "given the high status of 'experiments' in the rhetoric of school science education" (Wong & Hodson, 2009). However, as interviews with the scientists in Wong and Hodson's (2009) study indicate, many scientists do not conduct experiments, and those that do, rely on remarkably flexible approaches compared with the scientific method taught in schools.

When discussing whether or not a government's decision to focus on the utilisation of nuclear energy was scientific or non-scientific, Martin (interview 2) indicated that he believed this decision was

> *scientific because, I mean, when they decided to focus on nuclear energy, they probably conducted experiments so they could know it was the best choice. . . . A big part of science is making inferences and then experiments to prove them.*

Martin assumed the government had engaged with scientists on this issue, and then he further assumed that experimentation must have been done. In a large scale study assessing 10,800 high school graduates' beliefs about science–technology–society, Fleming (1987) asked whose authority should be used in decision-making about what types of energy Canada should use in the future. Fleming found that 71% of students espoused a belief, to a greater or lesser degree, that scientists and engineers were experts with the unique knowledge necessary for this type of decision-making. While 48% of the students supported a democratic model of decision-making, only 29% of the responses suggested that scientists or engineers should not have more power in decision-making on these issues. In subsequent follow-up questions with Martin, as with the graduates in Fleming's study, he expressed the belief that scientists were the authority. Therefore, the government must have consulted them.

When discussing the development of treatments for diseases, Jennifer (interview 2) believed that this must be scientific because '*they must have been, like, doing tests to see if [the* *disease treatment] was true, and then they're probably just going to test it on somebody. So, I think, yeah, it's scientific*'. As with Martin, Jennifer also assumed that the scientists had been doing tests or experiments, even though the statement provided no such evidence. Experimentation was assumed by most of the participants to be part of science and how scientists approached problems or arrived at decisions.

Other participants suggested that the lack of experimentation could point towards something being non-scientific. When asked whether ancient Greek thinkers were being scientific when they theorised that the universe was composed of tiny particles called atoms, Tala (interview 2) indicated '*actually I'm not sure, it might be both because it says that it's not using experimental investigations*', while Jennifer (interview 2) strongly believed that it would be non-scientific because they did not use experiments.

Observations were viewed as important to the process of scientific investigation by several of the participants. Ryan (interview 2) suggested something could be scientific if '*it's based on [scientists'] observation and their monitoring*', whereas Lenny identified that explanations for phenomena were the result of observations. However, many of the participants suggested that simply observing something was not enough to consider it a scientific process. Ayana (interview 2), for example, believed that '*the studying of viruses and microscopes was all scientific, but then just looking at it [under the microscope], I don't think that's scientific*'.

To a lesser degree than experimentation or observation, logical argumentation and thinking were seen by some of the participants as important to the scientific process. Zack (interview 2) suggested that '*you have to use logic in science*' in combination with experimentation, and Tala (interview 2) indicated that thinking exercises like developing hypotheses was still scientific, even in the absence of experimentation. Tam (interview 2) believed that logical thinking could be scientific '*because that is how our whole evolution theory is based on now, right? It's just like people logically thinking out evolution should have been this way*'.

Claire believed that at certain points in time, logic was enough to consider something scientific. For example, when asked about ancient Greek thinkers, Claire (interview 2) shared the following opinion.

> *Okay, at the time, if I was way back then, I'd be like, 'Oh, yeah, scientific, let's go'. But they were dealing with their own reason, and their own opinions, and their own observations with not proper experimental investigations. . . . Because there was a lot of reason behind it and what they're own, what they thought was logic, they gave it a pretty good shot, but we have better experiments now to correct them.*

While Claire believed that logic alone was at one point satisfactory, '*proper experimental investigation*' was needed now in order to prove something correct. The sentiment that certain methods, logical or otherwise, might have been enough at one point was echoed by Hua (interview 2), who suggested that the knowledge of willow bark's pain-relieving properties being passed down from generation to generation was non-scientific '*because it's been passed down—like it's an old method, I would say. Like, scientific, I would be thinking, like people created this in a lab*'. In this case, the observation that willow bark worked was not enough anymore to consider it scientific.

Participants in this study had limited understanding of the possible approaches that scientists use, believing to a large degree that experimentation was necessary for something to be considered scientific. In contrast, several scientists in Wong and Hodson's (2009) study indicated that much science occurs without experimentation, and even when experimentation is done that

> scientific investigations in which data are obtained first [before forming a hypothesis] and then interesting problems are identified by 'data mining' have become much more

> common in recent years. This feature of contemporary practice runs counter to a common textbook assumption that science follows a rigid stepwise procedure, beginning with the formulation of a hypothesis (118–119).

Given how pervasive references to a universal, step-by-step scientific method, including conducting an experiment, is within science classrooms (Windschitl, Thompson, & Braaten, 2008), the students' perspective about what counts as scientific makes sense.

Role and status of scientific knowledge. The participants discussed the role and status of scientific knowledge by the use of theories within science and the ability of science to determine the truth. While Reiss (2004) disagreed with the notion that truth emerges from scientific inquiry independent of the cultural contexts surrounding the discoveries, he has acknowledged that many people see science as the way to truth.

*Laws, theories, and models***.** The majority of participants discussed theory in science, but notably, only one participant mentioned the word 'hypothesis', and only one mentioned 'laws'. None of the participants described models in science. In general, they believed that theories were best guesses at the time and that they were subject to belief because they could be proven to be incorrect. In general, students did not differentiate between scientific theories and the everyday use of the word theory.

For example, Hua (interview 2) believed that science was still discovering new things, '*so it's like a theory. It's not always true. But [a theory] can lead onto discovering true things*'. Tam (interview 2) felt that when scientists were interpreting results, they could be '*scientific or they could have just been really crazy, and they just suddenly one day decided they wanted that kind of theory, and they were like "Okay, let's go with it*"'. In both cases, the processes associated with this 'thinking' around the development of theories, particularly the support for theories as a result of repeated experimentation and general consensus amongst the scientific community, were not described by the participants nor understood when the students were probed further. Theoretical speculation in science in more everyday usage was echoed, to some extent, by the scientists in Wong and Hodson's (2009) study but in the sense that it was impossible to have absolute objectivity in science. All scientist participants acknowledged the "impact of their own personal biases on the experimental outcomes as a consequence of observation and interpretation of data being heavily impregnated with theoretical assumptions" (Wong & Hodson, 2009, p. 119).

One of the student participants, Zack displayed a greater understanding that scientific theory was different than the everyday usage of theory. When discussing whether science gives us the truth, Zack (interview 1) stated, '*We aren't 100% sure of things, and maybe that one day we'll find a different theory that will surpass all of the ones that we have thought of so far*'. Zack differentiated between guesses and theories, including that we come to find theories by thought experiments, observations, and so forth. In many instances, participants used the concept of a 'theory' to describe a number of different things; in particular, they conflated the concept 'theory' with 'hypothesis'. Students' inability to distinguish between theories, laws, hypotheses, facts, and evidence has been previously reported (Parker, Krockover, Lasher-Trapp, & Eichinger, 2008). This conflation of terminology by the majority of the student participants is consistent with findings from Eastwell (2012) and Lawson (2010), who have suggested that students do not readily understand such terms, either from a definitional perspective or when enacted during scientific activities. The consequence of this conflation is that students have difficulty with scientific reasoning, argumentation, and discovery, which are critical to understanding the nature of science.

Proof. Most of the participants believed that science provides or works towards providing the truth, even if people believed something else. Claire (interview 2) believed that science was different from other forms of inquiry because

> *you have to prove something. It is not all belief like in philosophy and with science; most of it you can see it right in front of you. If you follow everything and you understand everything, normally, it makes sense.*

For the participants, proof in science meant that there was repetition in findings, based on facts and observation, as opposed to their lack of understanding that support for theories is also the result of repeated experimentation. Ryan believed that something was true when there was 'enough' proof and that this proof required repetition. She stated that enough proof happened at '*the point where, whatever you do, it still goes back to the, to the same point, so whatever you do still ends up the same way*'. While Tam (interview 2) was more specific and identified that enough proof happened when there was '*something that [scientists] experiment many, many times and it comes out the same every time*'.

For the participants, science was able to provide 'truths' because the evidence generated was based on facts and, in some cases, supported by observation. Previous studies (e.g. Chai et al., 2010) have shown that students consistently acknowledge that scientists are able to discover an objective truth. The participants in this study repeatedly compared science with other forms of inquiry, believing that science provided evidence. For Claire (interview 1), '*science really depends on what you can see, and you know if you have to kind of see it to prove it*'. Ryan (interview 2) corroborated this observational viewpoint and suggested that being able to see viruses with electron microscopes means that it has been proven. However, as outlined earlier, observations were not always considered scientific 'enough' by the participants.

Most of the participants indicated that just because something worked did not mean that it had been scientifically proven. When asked whether the knowledge of willow bark being used to treat headaches being passed down from generation to generation was scientific or non-scientific, most of the participants suggested that the fact that it worked did not necessarily mean it was scientific. Specifically, the mechanism or action of the willow bark may be scientific in the sense that it worked. However, the passing on of the knowledge may not be scientific if the people did not know how it worked. Martin (interview 2) indicated that the statement was both scientific and non-scientific '*because it works, but they're not using it because they understand how it works; they just know that it does*'. Jennifer (interview 2) thought this was

> *non-scientific because, if it's passed down, then it's probably not been tested, in my opinion, because somebody just tried it and it worked for them once, so they probably thought it was true and just passed it down. And then, nobody else tested because they thought it was true.*

However, Claire (interview 2) thought '*that it is scientific because the method is scientific, how the chemicals react and what not, but I just don't think it being passed down—they don't realise it has science behind it. It works because of science*'.

Tam indicated that blood-letting could be scientific or not depending on who you were talking to. Tam (interview 2) suggested that '*it works, but when you ask a science person they are like you are cray [slang for crazy], none of this is real. But, to Chinese people it works, so I guess it is kind of both*'. While not specific to blood-letting, Duan et al. (2013) discussed cultural differences within Chinese medicine and genetics practice, specifically the fact that satisfactory diagnosis differs in China because scientific reductionism is not integral to the traditional Chinese worldview. If, for example, people can be treated by traditional Chinese medicine, they are less likely to seek out other kinds of medical science (Duan, et al., 2013). van Eijck and Roth (2013) have pointed out that the multiculturalism versus universalism debate in science (summarised in brief in the literature review) is deadlocked, in part, around the "poor distinction between 'truth' and usefulness as measures for the validity of knowledge" (p. 58). In general, Tam's perspectives were more sophisticated and displayed a greater awareness of the existence of different worldviews, as evidenced, in part, by her awareness of how different groups of people may view something.

Even though most of the participants felt that science either provided or worked to provide the 'truth', they also believed that science was not always correct. For example, when asked whether science always provides the truth, Lenny (interview 2) thought that

> *Eventually, it probably does. But, for example, Aristotle said that there are only four elements, earth, fire, water and air, and they believed that for, like, 2,000 years, and he ended up being way off. So, maybe at the time it could be totally wrong, but eventually, as technology improves and stuff, we eventually find out what's actually going on, so it's probably true but not like immediately. It's over a long time it finally gives us the truth.*

Ryan (interview 2) also believed that '*there have been mistakes in the history. . . . There's been mistakes people have made so, if it's not already proven, then it's not, technically, it is not true*'.

Martin (interview 2) believed that science was different from other forms of inquiry because it provided some truths. However, he also acknowledged that this was not always the case, particularly because science had been wrong before.

Tam was able to provide a specific example from her textbook where science did not provide the truth. Specifically, she pointed to the model of the atom in her book, and said, '*They even show you the old theories, and they weren't correct, right? And at that time, they thought it was correct, but it wasn't. So, science doesn't always have to be right*'.

Most of the participants expressed a general lack of understanding of the ways in which scientific processes were part of science and emphasised 'ready-made-science' (Latour, 1987) in the classroom as opposed to 'science in the making' (Wong & Hodson, 2010). In her discussion of scientific culture and the science classroom, Krugly-Smolska (1996) indicated that

> many science teachers still believe that science is a body of facts and theories produced by science and that these can be transmitted to students. These are the same teachers that, unaware and unquestioningly, transmit the culture of science with all its myths (p. 28).

Deniz (2011), Eberle (2008), and Mansour (2009) support this position and go on to suggest that teachers may then influence their students' beliefs, either directly or indirectly. In general, observations from the class highlighted that science was presented as something that had already happened as opposed to science in progress, which was reflected in the ways in which the students discussed their narrow understandings of scientific processes. Students also indicated that the presentation of science as something that had already happened was not unusual in their school experience, which perhaps explains some of the disconnect in their perspectives between the scientific process and science.

Science Education Perspectives

In the same way that the participants' perspectives—including their attitudes, beliefs, and values about science—were important in attempting to understand the ways in which they understood science within a culturally diverse classroom, so too were the participants' perspectives about science education. Sub-themes that emerged regarding participants' science education perspectives include reasons for school science, science learning, cultural influences, and contextual beliefs and values.

Reasons for school science. The participants all agreed that science was a subject taught in school for future prospects, including further studies and careers, and for general knowledge and understanding. When probed further, most of the student participants' answers were either specific to them personally or applied to particular subsets of students and not necessarily applicable to the whole student population.

Future prospects. Several of the students indicated they believed that one of the intentions of school science was to help prepare students for further studies and for a future career. Tala (interview 1) stated that she believed that the science courses students taken in school were important because '*when we go to university, maybe we want to take it up as a course*'. Lenny (interview 1) specifically identified that he was going to further pursue biology in high school, as he was planning on taking biology courses in university.

When asked why science was learned in school, Cindy, Seth, Hua directly recognised science as important for a career; most of the other participants alluded to this indirectly. Hua (interview 1) identified personally with taking science in school '*because a lot of jobs nowadays, you need to have science, like doctor or health or even just engineering and stuff like that. So, if I take science, it can help me later on*'. Jennifer (interview 1) believed that science was '*important for me because when I'm older I want to be working with people in like disabilities and like that. So, I think biology would be good because it studies the body, right?*'

Tam identified that school science was important if you were planning on going into a 'sciency' field, such as the medical field, or if you wanted to be an environmentalist; or, if you weren't sure what you wanted to do, then you might take science to keep your options open. However, for her personally, she did not see the relevance of school science other than for 'knowing stuff', as she was not planning on going into a science-related career field. She did not see herself as a 'science person'. The students' perspectives regarding school science as necessary for future prospects is in line with previous studies that have shown that students choose science to meet university prerequisites and to eventually attain career goals (Osborne & Collins, 2001; Palmer, Burke, & Aubusson, 2017).

General knowledge. All but one participant suggested that the reason why science was learned in school was related to the development of foundational knowledge or understanding. In some instances, participants described more general or broad ideas about developing foundational knowledge. However, in other cases, participants described more specific kinds of knowledge. In Alberta, science programs of study are "guided by the vision that all students have the opportunity to develop scientific literacy" (Alberta Education, 2014, p. 1), with the goal of helping students to develop knowledge about science and technology to solve problems, critically address science-related issues from different perspectives, and to provide a foundation for further study and occupations.

Broad. In a broad sense, participants indicated that science was learned in school to build a 'foundation' and to help them be more open-minded. For example, Ryan (interview 1) suggested that '*school in general is to make you kind of build a foundation in every aspect . . . in science, because we need to know why things happen*'. Seth (interview 1) simply suggested that science was learned in school to '*not be simpleminded about everything*'.

Other participants discussed the applicability of science to everyday lives. Cheng (interview 1) suggested that science was learned in school in order to apply concepts to everyday life, whereas Zack assumed that school science was meant to improve and make lives easier. Martin (interview 1) believed that '*if we have a background in science and if we see . . . if we see something we don't understand, then we can infer about how it works if we learn something that has to do with it*'. Hua (interview 1) discussed how the applicability of science in school could add to a person's foundational knowledge. She believed science was learned in school

> *because science comes handy every day. Maybe you don't know it, but you come in contact with it, so if we don't know anything about science, I feel like a lot of times you wouldn't understand why things happen, because in science you talk about really simple things, like why things fall, and then with that, it's sort of a common sense. It can add to your common sense*.

*Specific***.** Some of the participants identified specific things within science when describing why they thought science was learned in school. Jennifer (interview 1) believed that safety aspects of science were important suggesting that '*if you didn't learn science and you didn't know all of the concepts of what symbols mean what and you accidentally drink something poisonous, then science is there to show you not to do that*'. Hua (interview 2) specifically pointed to learning WHMIS (Workplace Hazardous Materials Information System) as an important reason to learn science in school. Ryan (interview 1) felt that the basic information in science was important for everyone to learn. In particular, she believed that

> *the things you learn in science, you can apply it to your daily life. Like knowing how the lights work in your house, and if you ever have a light go out you would know like the simple stuff: why a light went out and what you could do to fix it. And like, for biology, you can kind of know what happens in your body, so then you can know, 'Oh, why do I have a stomach ache?' or 'Why are some people different from others?'*

Other students connected the topics they were currently studying in science to answer why science was important to learn in school. Lenny (interview 1), for example, suggested that we learned science

> *to give us a better understanding of the world. Because, like, before I started taking science, I had no idea I was made up of a bunch of cells. I thought I was just some thing. And then, I didn't know how a rocket worked. I didn't know how a ball had potential energy when you held it like this. I didn't know a lot of things before I took science. And that gives me a better understanding of, like, everything, and like, yeah, I think it's pretty important.*

Claire (interview 1) identified specific aspects of each of the disciplines they had covered in class to that point, suggesting that biology was important in understanding how our bodies work, whereas chemistry was important in order to communicate more globally, specifically around

WHMIS designations and chemical compounds, such as carbon dioxide as CO_2 and water as H_2O. In their study of pupils' views of the role and value of the science curriculum, Osborne and Collins (2001) found that students emphasised that learning science was important, and just as in this study, that "scientific knowledge offered a point of entry into the discussion" (p. 447) as opposed to using scientific knowledge in engaging in scientific issues.

Science learning. The majority of the students in this study identified science in school as being related to the content within each sub-discipline of science, a pervasive view held by students in other studies (Osborne & Collins, 2001). Beyond the particular content identified by the participants as science, specifically biology, chemistry, and physics, they also identified specific practices related to the learning of science. Participants identified the ways that they learned science, primarily through memorising and 'understanding', as well as the practices of 'the good science student'.

Learning science. Several of the students described memorisation as a core part of learning science. Ayana stated that she had a difficult time with the memorisation portion of science. In order for her to learn, Ayana (interview 1) would

> *have to, like, go home and actually write it down a few times to remember it. I don't remember things right away. But, when I do remember them, I remember them for a long time 'cause I remember, like, learning about trees in grade 6 still.*

Cheng (interview 1) suggested that, in order to learn science, '*you just have to remember the people who discovered the things and what the stuff does, and then for physics, you have to apply a lot of equations to find the answer*'. For Cheng, remembering the 'stuff' was the easy part, but the application was much more difficult. Tam (interview 1) reiterated this view and said that for her, memorisation was the easy part; the things that could not simply be memorised—in her case the movement of tidal winds under specific conditions—were more difficult. Students in

Osborne and Collins' (2001) study of students' views of school science frequently equated science with memorisation of a body of facts. This was also correlated strongly with students' dislike of science, in contrast to the views expressed by the students in this study.

Hua (interview 1) suggested that, when learning science, she would study by a process of '*memorising and then do questions to practice it*'. However, Hua also indicated that, if there were parts of the lesson she did not understand, she would talk about it with her friends. Unlike any of the other participants, Hua discussed a social element to learning science. Studying science for the other participants was an isolated endeavour.

Other participants differentiated between memorising and 'understanding' when learning science. As Tam (interview 1) stated,

> *Anyone can memorise it. . . . We just did plants, right? So, like, you know xylem is going up; you know phloem's going down. So, you actually know these things. But, like, people that really get it, like, actually understands what's happening or, like, they can actually go deeper and understand it.*

In further probes, 'knowing' something was equated with memorising. Seth (interview 1) also suggested that people who were better at science than others likely understood the scientific process at a level where they could ask themselves questions.

Very few of the participants connected their own personal interest in science with any of the science-learning processes they described. When asked what parts of science the participants liked best, they were very likely to respond with particular topics or units, similar to the students in Osborne and Collins' (2001) study. Very few participants, even with prodding, would respond with the kinds of things they did in science classes. There were a few exceptions to this. Jennifer (interview 1) indicated that

> *the parts I like about science are the experiment stuff because that's easier for me to learn and take in the knowledge, like seeing exactly what's happening instead of just hearing about it.*

The ability to see what was happening was important to Claire (interview 1) as well, who explained that

> *one of the easier things that I find to learn about is something that I can see right in front of me and that doesn't take a lot of theory and a lot of thinking to understand why it works. I find biology very easy to learn because you can dissect something and see exactly how it's working in action. I find physics a little bit harder, and theories, and the idea of gravity and velocity, and how when you're dropping two different items and it can be two different weights. I find it all very confusing and a little bit harder to wrap my head around. So, the stuff that I can see right in front of me and know about every day—that I find a lot more easier to understand.*

The students in the study by Osborne and Collins (2001) expressed an interest in practical work, as it provided opportunities for autonomy and because it was seen as more fun than a memorisation task. While many participants in this study expressed an interest in science, it appeared that they saw this particular science class as a means to an end. It was for something else (i.e. future studies, careers, etc.). Therefore, the method or process by which they completed the course did not appear to be as important to the students.

The good science student. Participants identified the important traits of a good science student, including their actions, their grades, and participation levels inside and outside of a science classroom. Claire (interview 1) indicated that her '*vision of a great science student is someone who comes to the first day of chemistry with a periodic table written on their shirt. That is my vision of a really great science student*'. However, she also saw herself as a good science student, even though she did not wear or own a shirt with the periodic table written on it. She felt she had a keen interest in science but really wanted to move forward and start applying her science learning.

Ayana (interview 1) identified more specific actions, including to pay attention, '*not talk to other students during lectures . . ., and write down the notes*'. Seth (interview 1) suggested that good science students would understand the science concepts being talked about but would then do practical actions, such as '*handing in their homework, maybe doing extra work for the teacher . . . just improve their mark*'. Cheng (interview 1) offered the idea that good science students would read the textbook, whereas Jennifer thought they would listen and study. Hua (interview 1) immediately identified that marks would contribute to being a good science student. However, she also felt that participation '*during your spare time, if you help out at science institutes, I guess, or participate in science fairs—I think that would contribute to a better science student*'. Hua echoed Claire, who believed she was a good science student and yet did not perform some of the actions she used to describe good science students. Both Hua and Claire appeared to be describing what they thought I or another teacher might believe is a good science student, and not necessarily what they personally believed.

Lenny (interview 1) thought that

> *it's probably easier to be a better student in a subject if you like what you're learning, [and] a good science student would probably be paying attention and not like just daydreaming or sleeping or talking to their friend or something. But, they'd probably participate in all the class discussions and stuff like that, too.*

These were all behaviours that Lenny displayed when they were studying biology, a topic he admittedly enjoyed, but were absent or completely opposite when they were in the physics unit, one he readily admitted to disliking. Interestingly, Lenny's achievement in both units was similar, and his teacher did not feel as though he approached the units differently. In this sense, Lenny was playing 'Fatima's rules', a phrase named after a participant in Larson's (1995) study of student learning. These rules are part of the 'game' of school and include rote memorisation and going through the motions of learning. Aikenhead (2006) has stated that "playing Fatima's rules, rather than achieving meaningful learning, constitutes a significant *learned curriculum* for students and a ubiquitous *hidden curriculum* in school science" (p. 28, emphasis in the original).

Aikenhead went on to suggest that students play Fatima's rules as a coping strategy when they are attempting to resist assimilation into the culture of science.

While all of the participants readily admitted to playing Fatima's rules, none of the students acknowledged feeling as though they were resisting cultural assimilation. If anything, the students played them because they did not enjoy a particular unit of study or because they did not want to get into trouble with the teacher during work time. Several students indicated that if they just pretended to work, 'wrote stuff down', and asked questions on occasion, the teacher would leave them alone, and they could just talk to their friends. Observations in the class corroborated the students' perspectives.

Cultural influences on science education. The participants in this study varied in their opinions on whether culture influenced science education. Most of the participants felt that science was taught the same everywhere, particularly the content. In addition, they felt science did not need to be taught or learned differently, a view shared by teachers and teacher candidates in a number of other studies (Atwater, 2010a; Calabrese Barton, 2000; Petty & Narayan, 2012). However, a few participants in this study felt that some aspects of diversity may have an impact on what was taught and that student background may be important when teaching science. In contrast to much of the literature (e.g. Chan, 2006; Cobern & Aikenhead, 1998; Lee, 2001; Gaskell, 2003), the student participants in this study did not indicate feeling either welcomed or estranged from school science or that integration of culture was necessary for them to develop an epistemological understanding of science.

'Canadian-grown'. Tam did not believe that culture impacted science education, as she felt that most people in her science class were 'Canadian-grown'. To Tam (interview 1), this meant that

> *even though people have different ethnic backgrounds, most people are still just, like, Canadian kind of brought up; [background] doesn't really affect much. And, even if it does, I think people usually don't speak up about, like, the differences.*

Tam felt that people learned the same science content everywhere, so there really would not or should not be a problem. She went on to suggest that her two classmates from China did not discuss any difficulties or differences in what they were learning; therefore, her impression that people learned the same things in science was validated. She did think that where you came from might impact how you learn. However, Tam did feel that the teacher had a large impact on how people learned science, a view that students in other studies have also indicated (see Osborne et al., 2003; Tytler & Osborne, 2012). For example, she described that, at first, she had to adapt to her current science teacher's teaching because, from grades 7–9, she had a different teacher who taught very differently. This was described as way more stressful and difficult than having a teacher who did not understand her Chinese background.

Although there was a large amount of cultural diversity present in the school, the idea that students were really just 'Canadian-grown' was reiterated by Seth (interview 1) who thought that

> *beliefs and cultural diversity doesn't really affect our education that much. It's just overall [people are] going to learn in a way that people would teach them in a way I suppose? It's just like they're going to learn it no matter what.*

For Seth, irrespective of background, people would learn however they were taught, and the fact they were all in the same class was more impactful than the cultural diversity present within the class. To him, science was a body of knowledge that was transmitted from teacher to student.

Both Claire and Hua suggested that, even though people had different 'cultures', this did not impact what happened in the classroom. Hua (interview 1) specifically differentiated between home culture and school culture when she stated that '*a lot of people are born here, and although they have different values, like, at home because they're from different cultures, but* *like, when we're in the classroom, we sort of see it the same similar ways*'. Claire (interview 1) also acknowledged that

> *even though we all are different and we all come from different places and we all live very different lives, we all are in the same classroom learning the exact same material, all considered students, and I don't think that that affects my learning. Maybe somebody has to ask a few extra questions, but that has nothing to do with who they are as a person or where they come from at all.*

In some cases, cultural diversity was seen to potentially have an impact on learning science. However, these differences were superficial and certainly not specific to science education[4]. For example, Claire (interview 1) followed up, stating that diversity should not affect other people's learning in the class, and she gave the example that '*it shouldn't matter what this person is wearing to class, if it's a hijab or whatnot; it shouldn't affect your learning at all, and I don't think it does in this classroom*'.

None of the participants in this study ever indicated that the approach to science in the classroom was epistemologically problematic or that they—or to the best of their knowledge, their classmates and friends—had difficulties engaging with science as a result of the conflict between science and culture.

Impact of diversity. In contrast, some participants felt that certain aspects of diversity might impact science education. Ryan suggested that people from other countries might learn science differently because specific aspects of science might be more important in different places. For example, in a tropical place

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[4] See the sub-section 'Understanding culture in this chapter for a discussion about how students view culture. In summary, students viewed culture very superficially and often viewed themselves as acultural.

> *they would need to know more about climate changes and all that, and I think it would be taught differently because, if it was taught in their own way, they would understand it better than reading a textbook published in Canada because more of it would be related to the things that happen in Canada and the technology in Canada, whereas if they were in a country that technology isn't as developed or as advanced as Canada's, they wouldn't really understand our concepts and stuff* (Ryan, interview 1).

However, she did not believe that people needed to learn science differently but instead felt that particular content may resonate more or less with people depending on location and background. Ryan (interview 1) further expressed the opinion that an individual's background was important for teachers working in a culturally diverse class because knowing the places and backgrounds of students would assist a teacher to know

> *how to help them understand better and that you're not just helping a specific group of people because sometimes when you teach them the material, it might not help the other group of different people coming from a different background.*

Providing meaningful examples that resonated with the cultural backgrounds of the students was seen as important, but Ryan also indicated that using generationally applicable examples was equally as important.

Several students indicated that students from different places might learn explanations for phenomena other than science. Zack (interview 1) felt that people may learn different things in science because '*some places . . . don't really value science, they just rely on religion or creation or something to explain the things that are happening around the world, so I guess, maybe some places don't have the same teaching*'. Lenny also felt that, in some places, students might learn different things as a result of certain belief systems. He provided the following example:

> *Well, I have a couple of Muslim friends, and when we did a space unit, they didn't really like it 'cause they said it went against sort of their beliefs maybe a little bit. Somehow, I don't know, but to them it did. So, I think if they were in their home countries they'd probably learn different stuff than what we learn. They'd probably learn, like, if it's like a really religious country, they'd probably learn that God did it or something, I don't know. And then, yeah, I think it has an impact on, like, what you learn depends on where you are in the world, so yeah* (Lenny, interview 1).

However, even though Zack and Lenny felt that students may learn something different in science classes elsewhere, because all students in their particular science classes were learning the same things, cultural diversity did not impact what was happening in their science classroom.

Beliefs and values in context. Several of the student participants suggested that, in school science, you were required to learn the 'correct answer' for the exam. However, you were free to believe what you wanted outside of this environment. All of the participants still indicated that it was important to learn the scientific perspective, regardless of one's actual beliefs. Ayana, (interview 1) believed that science class provided the opportunity to learn different things. For example, she said that '*you should know what you don't want to know and want to know or learn more about and not learn more about, just have bits of information about it*', but she believed that students still had the choice to believe what they wanted. Ryan (interview 1) also felt that, even if students did not share a particular scientific perspective, it was important to learn '*because then you would know what others think and knowing two sides is better than just knowing one, and be biased, and just saying all of your stuff without knowing the other side of everyone thinks*'.

Tam (interview 1) was a self-described creationist. When asked whether learning things that went opposite to her belief system posed a problem for her, she responded as shown in the following transcript.

> *Respondent: Not really. Well, I just of go along with it, I guess. Like, 'cause they always . . . what was . . . big bang was, like, grade 8 science, probably. And then when they teach it you just, kind of, go along with it 'cause, I don't know . . ., it doesn't really affect me that much.*
>
> *Interviewer: Do you think it's important for you to learn those scientific [perspectives]?*
> *Respondent: Yeah, yeah, yeah. Well, 'cause it's like the generally accepted thing, right? So you just learn it and you accept what they believe. And then, you have what you personally believe, and that's whatever . . . Yeah, I'm learning what they believe and just,*

kind of, let them believe that. And I'll believe what I believe.

Interviewer: Okay.

Respondent: But I still learn it because it's going to be on the test and you got to know it.

While Zack acknowledged you could have your own beliefs, in science class, there was no real point in discussing these beliefs because in science class you had to learn the scientific perspectives. Zack (interview 1) explained that

> *like, in a test, if it's a multiple choice kind of thing and then you kind of just think of some random answer, you can't just randomly think that, 'Oh, I'd just rather think something. . . .' I don't know how to explain it but like, if you had like, if he asked you where, what is, where did, like what is heat or something? And then, you just say it's like magic because you think it's like, it's your religion or something? And then you can't really put that down because it's not on the curriculum.*

Roth and Alexander (1997) have written that "when there is a conflict between their scientific and religious knowledge, students have difficulties learning the subject matter of their curriculum" (p. 126). However, they believe that this conflict can be overcome if one has a mediating device, such as language, to discuss and differentiate science and religion. Despite the fact that many of the student participants expressed during the interviews they held belief systems that were considered in opposition to some of the scientific content presented in their classes, they did not feel that this hindered their progress, understanding, or achievement in science classes. In some cases, students simply learned what they need to know for the test and then dismissed the scientific ideas in relation to their own lives. In other instances, students learned what they needed to know for the test and saw this learning as an opportunity to learn the other side. There was not an opportunity to discuss these beliefs and values in class; therefore, it is not surprising that, given the persistence of values in people's lives, the students did not integrate, change, or reflect on their own personal beliefs and values in relation to what they had learned. However, they also did not see it as an impediment to learning science.

Understanding of Culture

The participants discussed culture in terms of traditions, values, and beliefs. In general, the students seemed unsure about what culture actually was and, in particular, what their own culture was. However, they were confident in identifying that there was cultural diversity present within their school. When they talked about cultural diversity though, they almost exclusively referenced racial and ethnic differences. The participants identified different ways in which the school promoted and/or provided supports for cultural diversity, although the promotion and supports tended towards surface aspects of culture, such as language, food, and dress.

Definition. The participants in the study defined culture broadly, typically including a person's background, beliefs, values, and traditions, amongst other things, such as common food, dress, and in some cases, religion. Although all of the participants were able to eventually define culture, most of them were not confident in their answers. More often than not, they appeared somewhat confused by why the question of culture was being asked in relation to a science class, even though they were aware of the research questions being asked in this study. All of the student participants, at one point or another during the study, asked why culture was important to ask. As Tam (interview 1) stated, '*That's a social studies question*'.

Broadly. Most of the participants included a person's background, beliefs, values, and traditions as part of their definition of culture. However, their descriptions tended towards large generalities. Zack (interview 1) suggested that culture is '*the values and beliefs that were passed down towards you*'. Lenny (interview 1) summarised the majority of the participants' definitions, suggesting that culture is the '*beliefs, values, where you're from, traditions, language, basically a combination of all that is what culture is really*'. Ryan (interview 1) also suggested that culture is '*your perspective on the world, and as you grow up, it's your friends, your family, and the* *media, and just everything, like, you're surrounded with that influences and kind of builds that perspective*'.

Beyond these broad general statements, the participants each identified additional elements associated with culture. Several of the participants included food and dress. Seth (interview 1) for example, stated that, because he was Scottish, people thought is culture was wearing kilts and eating haggis. Only one participant, Cindy, specifically identified race as a defining feature of culture. However, the participants almost exclusively linked country of origin as a central component of culture.

In several cases, it was difficult to ascertain how much the student participants really understood what culture was, as there were inconsistencies in their interviews. Ayana (interview 1) suggested that background, including ethnicity, could be part of culture. However, where a person lived could also contribute to their culture a view illustrated in the following exchange.

> *Ayana: If you were born in Africa but you lived in Italy for, like, half your life, then I guess you're also a bit Italian, so.*
>
> *Interviewer: What would make someone Italian or Canadian?*
>
> *Ayana: Citizenship (laughs). . . . Living there for a while and, like, knowing the culture and, like, the language and, like, how things work. Like, if you were to move there, would you be like an outsider? Or, like, would you look like a tourist or you actually can fit in and seem like one of them?*
>
> *Interviewer: And what would fitting in be, do you think? Like, what would you need to do to fit in maybe?*
>
> *Ayana: Speak the same language. I don't know—accents, like, food you eat.*

Because she had indicated earlier in the interview that values and beliefs were associated with culture, I asked her if everyone would believe or value the same things. She suggested that '*you could value different things because there's different religions, so that could influence it, too*'.

Although she had identified that a core aspect of culture included consistent values and beliefs, she said that they were not essential in defining culture.

Only one participant explicitly discussed that there could be diversity within a culture and that an individual could be part of more than one cultural group. Hua (interview 1) indicated that culture was

> *a group of people with the same values, similar values. Um, diversity inside of culture happens too. . . . because a culture, they have similar values, but then there's always something that is different; they can view the culture differently. Like, some people take this culture this way, and other people take it the other way.*

Hua (interview 1) described her cultural group as 'Chinese' and suggested that '*a lot of people in this culture have really similar values. Like, if I talk to my friends about it, our parents say the same thing, and they expect the same thing from us*'. However, she also indicated that there were generational differences between her peer groups and their parents. She believed that her parents formed a cultural group, and her Chinese friends formed another cultural group because they understood what it was like to have the expectations of Chinese parents but not grow up or currently live in China. Hua explained that she could be part of a friend's cultural group, a Chinese cultural group, or a Canadian cultural group depending on the circumstances. Hua (interview 1) gave the following example.

> *I'm Chinese; they're [her friends] all Chinese, but we're also, like, all of them, most of them are born in Canada. So, we share a lot of the same values and, like, when we're in Chinese class and we're talking with our Chinese teacher, we disagree on some stuff, so then you can see the [generational] differences there.*

Personal. When describing their own cultures, participants tended to describe more superficial aspects associated with food, clothing, and traditional practices. However, the participants also saw themselves as acultural. Lenny (interview 1) indicated that he knew his '*culture's different from someone in, say, China because they eat way different foods than we do* *here. When I'm eating a burger, they're eating rice with some kind of chicken sauce and chicken*'. Ayana (interview 1) indicated that, in her culture, there was different clothing and good food. However, she also discussed the strong cultural community created in her current city related to the decline of the population of people in Ethiopia that she identified as part of her cultural group.

Acultural. Many of the participants suggested that they did not have any culture. Jennifer and Tala both indicated that they did not have a culture and yet both identified values as being a part of one's culture. When probed further about whether or not they held values, they each identified different things. Tala, for example, described her family's strong value of completing a post-secondary education. Jennifer (interview 1) said that she chose her friends based upon shared values. For example, she stated,

> *I don't like the kind of people who throw away their lives, I guess, by just not paying attention in class and stuff and just talking the whole time and doing bad things. I don't like being friends with people like that because I don't want to have bad influences on my life.*

Jennifer also indicated she was '*French and kind of some Native*' but that, because she did not '*do any traditions*', she did not have a culture.

Martin (interview 1) stated that he knew nothing about his culture and that '*I don't have an accent or anything so no one, no one I interact with really has any inclination to think I was born anywhere but here. So, no, [my culture] never really comes up*'. When describing his own culture, Lenny (interview 1) stated,

> *I honestly don't think, I don't really know what, like, culture is. I was just born and then I just lived a normal life, and we didn't do anything weird; it was just normal. But, I guess, to compare it to someone, like, somewhere else, like, what I do would look kind of weird compared to what they do. But to me, it's just normal, and I don't really know what my culture is. 'Cause my parents lived here, I live here, and we don't really do anything from where we're from.*

The student participants in this study, whether they believed they had a culture or not, continually connected country of origin to culture.

Cultural diversity. Very few student participants directly/specifically identified race or ethnicity when describing culture. However, most of the participants, when asked about cultural diversity in the school, specifically identified race and/or ethnicity as a key determinant of cultural diversity. While a few other factors were noted (e.g. clothing, language, or friendship groups), the vast majority of these factors were based around race or ethnicity.

Racial and ethnic background. Cindy (interview 1) indicated that there was cultural diversity because people did not racially look like one another. Tam (interview 1) thought that '*you can obviously see [the diversity]. There's Asian people, and there's African people, and there's Caucasian people*'. Ayana (interview 1) was worried about sounding racist when asked what cultural groups she felt were in the school but identified '*Africans, I guess, [and] there's Asians; there's people from east India. There's people who live here originally. There's Europeans. There's probably Italians, Germans, all kinds of people*'. Lenny (interview 1) described a situation in his social studies class,

> *When my teacher asked us to raise our hand if we weren't born in Canada, only four people in my class didn't raise their hands. The rest were born in China, or Hong Kong, or something like that. They were all Asian. So, yeah, I guess we do 'cause we have one African person in our class, actually probably two, and then we have a lot of Asians, and then we have a couple White people. And then, I notice we don't really have any like Mexican or Latino people in our class really that much, but you see them around the school. We have a lot of different people in our school, like, you can't look in the hall when it's busy and just see one—I don't want to say a skin colour.*

The invisibility and circumvention of race and ethnicity that the students in this study described has been identified by Parsons (2014) as problematic in research in science education, as "ethnicity [and race] is important in how it may infiltrate ontology, what aspects of reality are perceivable, and how this perceptive reality is interpreted and acted upon; epistemology, what counts as valid knowledge and how it is known; and learning, how knowledge is engaged" (p. 175). Students in this study clearly saw that there was racial and ethnic diversity around them. However, they were very uncomfortable describing other students by their race or ethnicity.

When Halualani (2008) studied multicultural university students' sense of intercultural contexts, the participants described "that being near or within such diversity presupposes that they interact with different cultures all the time and that they are not racist or prejudiced" (p. 13). The participants also felt that there was so much diversity around them that they simply 'forgot' it existed. The student participants in this study described diversity in the ways that the participants in Halualani did, but they also tended to circumvent or felt badly about talking about race and ethnicity.

Immigration. While not expressly discussing race and ethnicity, Martin (interview 1) suggested '*that it would just be hard to be in a country with so many people who immigrated here in a school with so many people and not have cultural diversity*'. Ayana (interview 1) described this in more detail and included some of the diversity that resulted from immigration. In addition to her comments about race, she also felt the school was culturally diverse

> *because there's all kinds of, like, religions here, all kinds of races and people are, like, from all over the world. Not everyone was born here in this school. And, like, people might have just immigrated here; it's not just people who have lived here for a while, or you don't have to be a citizen to go here.*

Cultural groups. Some of the participants also described cultural diversity as related to the different groups of people they saw. In some cases, though, these were groups that consisted primarily of people who were of the same race or ethnicity. This was not always the case. Ryan (interview 1) indicated that some of the cultural diversity in their school came from the offering of special needs programs. She felt that the special needs group at the school formed a diverse cultural group because they had a distinct curriculum/program that focussed in on values of being 'nice'. While Seth (interview 1) thought '*skin colour could be one*' indicator of culturally diverse groups, he also identified how athletes, irrespective of skin colour, tended to form their own groups. Like Ryan, he felt that the athletes could be considered a cultural group because of their shared values around sports and teamwork. Peer groups were seen by most of the participants as forms of cultural groups, whether based on academics, religion, ethnicity, athletics, and so forth.

The students were mixed in their opinions about whether the groups they saw were ethnically/racially heterogeneous. For example, Claire (interview 1) felt that '*when I do walk around the halls, I do notice that certain ethnic people, I guess, hang out with certain ethnic people*', while Lenny (interview 1) indicated that '*you don't see just White people in a group, or you don't see just Asian people in a group really that often. So, it's pretty diverse, I guess*'. Seth (interview 2) thought groups

> *mix[ed] together because I see a lot of kids hang out with each other. Like, I hang out with Muslim kids, I hang out with like African, and all that type of thing. It honestly doesn't really matter. We're all kids'.*

My observations in the school, corroborated by informal discussions with other staff members, is that there was diversity in terms of how the students grouped themselves. For example, outside of classes, there were large groups of athletes who grouped together, and these groups tended to be racially diverse. Academic students, outside of classes, tended to group in more homogenous ethnic groups, although not exclusively, and there was almost always some ethnic diversity. Outside of these two groups of students, outside of classes, many other students were grouped by ethnicity or, in some cases, by country of origin.

Cultural bias. The student participants held cultural biases that were represented when they applied stereotypical traits or characteristics, in some cases towards themselves and their parents, during discussions around cultural diversity. In general, these cultural biases tended to be related to somewhat superficial things: clothing, food, and in one case, parking practices. However, the students were also very aware of not wanting to come across as racist. Therefore, they may have only been comfortable sharing their more superficial cultural biases.

Tam described different places as having different cultures, such as differences in the ways people from one major city to the next might park or how the Chinatowns in different cities might compare. In terms of people, Tam felt that those from Hong Kong and Korea were very different from one another because they dressed differently from each other; specifically, people from Korea all dressed the same, whereas people in Hong Kong dressed '*random looking*'. In addition, one of the cultural differences was that people in Korea would bow, but they did not do this in Hong Kong. Tala (interview 1) pointed out that New Zealand and China were different from both the Philippines and Canada because '*New Zealand has a lot of sheep. Do you know they have more sheep than people? And in China, we ate outside. Like, the restaurant was outside and just had like a roof, like a cement roof*'.

Lenny (interview 1) described differences between himself and his friend who was from India and was Muslim. His friend had a huge accent and was the one to point out to Lenny that Lenny said 'eh' often. His friend also ate different things because he was vegetarian; also, because he was Muslim; he prayed a lot. Although they had differences, which Lenny attributed primarily to his friend's religion, he also felt they shared many of the same values around education, career goals, and family.

School supports and promotion of cultural diversity. All of the participants suggested that the school did things to support and/or promote cultural diversity in the school. Supports ranged from formal and informal programming and activities to the participants' general feelings that the school was a supportive place.

The school provided several formal support programs and people, including English as a second language support classes and tutors, multi-faith Friday prayers, and an Aboriginal liaison who connected with Aboriginal students. Conversations with administrators suggest that the school began offering these programs and supports in response to the growing diversity of their student population. In addition, the school held a Chinese graduation for the students who completed the Chinese bilingual program and the school encouraged Aboriginal students to participate in the school district's Aboriginal graduation ceremony. The participants indicated that the number and variety of languages the school offered in formal programming signalled support for cultural diversity, in addition to the several associated clubs. At the time of the study, the school offered the following language programs: Chinese (Mandarin) at beginner and advanced levels, French as a second language and French immersion, Spanish as a second language, and American Sign Language. All of the student participants in the IB program were taking a language, which was a requirement of their program. Cindy was the only student in the Science 10 prep class who was taking a language. Because she was still relatively new to Canada, Cindy was taking Chinese (Mandarin) as an easy course for her to pass.

All of the participants talked about the school's promotion of Culture Sharing Day[5] as an important indicator of the support for cultural diversity. Hua (interview 2) described the event as a '*cultural day. And then they would sell foods from different countries and different performances*'. Student groups were invited to participate by selling foods from their cultures,

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[5] Name changed to support anonymity of the school and participants.

and some of the language clubs put on a number of performances, including Chinese dragon dancing and petite line dancers. The event was promoted by the school as a means to promote tolerance and understanding, and while Culture Sharing Day was a fun experience for the students and staff, there was no sharing of culture beyond talking about the good food and the cool dancing and dress. Little evidence existed to suggest that Culture Sharing Day achieved the lofty goal of promoting understanding and tolerance.

In addition to the different formal and informal programs and activities, all of the participants described a school ethos that supported cultural diversity. For example, Ryan (interview 2) indicated that the school '*does a really good job of promoting cultural diversity in the school. Just from what I hear from my friends from other schools, I feel like [the school] does a lot*'. Ayana (interview 2) felt that the school supported cultural diversity because '*everyone can come here if they want to come here. It's not like you can't come if you're a certain race or anything or if you're a certain religion. Anyone can come here*'. However, beyond allowing anyone to go to the school, she did not feel as though the school did anything specific to promote cultural diversity.

Although there were specific events targeted towards promoting cultural diversity, and most of the student participants felt that there were other indirect influences on the school's ethos that supported cultural diversity, all of these were directed at Banks' (2010) lowest multicultural approaches: the contributions approach and the additive approach. The school offered and the students participated in a celebration of different cultures through food, dress, and language. However, this was all done outside of the mainstream curriculum, and—at least in the classes I was in—none of these permeated into the classroom.

Curriculum Implementation

Most of the participants identified that no overt connection between culture and science had ever occurred in any of their science classes. In general, they felt that there was an explicit separation of culture and science in their classes. However, most students identified and described different topics (e.g. evolution, stem cells, categorising something as scientific or not, etc.) they had taken or were learning in school science that could have a cultural connection. Given the overwhelming perspective that culture should and did not matter for the students in their science classes, the ways in which the students took up culture was very limited. However, what emerged through the interviews with the participants were several opportunities to engage in different science topics that could include sociocultural elements and discussions around nature of science.

Curriculum-as-plan. The curriculum-as-plan, as mandated by Alberta Education (2014), is the Science 10 Program of Studies. There was no evidence that any portion of the program of studies, including the outcomes, had been communicated to students. They understood that Science 10 students in other classes generally learned the same things, but the students had never been asked and had never considered how the 'curriculum' they were learning in school came to be. Students' understanding of the mandated program was limited to guesses about how 'they' (curriculum planners) decided on what to include in the science program. Participants felt that curriculum planners must have chosen the 'major' or 'popular' topics in science or topics the planners had heard about before.

Tam's perspective was particularly interesting. At the time of the interviews, Tam had just finished reading a book countering Darwinism and was just beginning to read *On the Origin* *of Species*. She used this example to suggest what the curriculum planners and textbook writers were doing.

> *So, the part of the book that is countering Darwinism is countering the things they teach people in school. Because the author . . . he basically . . . he used to be Christian. Then, in high school, he became atheist due to Darwinism, and then he went back to Christianity later after countering Darwinism. And the main things he brought up how a lot of the textbooks they will specifically show images so you learn a specific way. And they won't tell you exactly what else happened in the experiment, and they will also tamper with the images and slightly change them so you really have a specific kind of view of whatever you are learning* (Tam, interview 2).

While she also felt that the popular or major topics were chosen for science class, she specifically identified that she believed learning about scientific developments in science was the curriculum planners' and textbook writers' attempt to prove science to students even when there was, in her opinion, evidence to the contrary. Despite Tam believing that the curriculum was written as part of a scientific conspiracy, she did not feel that this was a problem for her and that she could just learn whatever she was expected to. Again, like many of the students, she was comfortable learning what she had to in class but felt free to believe what she wanted. With the exception of students guessing how it had been decided what to include program of study, the students were very unaware of curriculum-as-plan.

Curriculum-as-lived. While the students had more to say about the ways in which science was taken up in their science class compared with their understanding of the curriculum-as-plan, students generally felt science class was something that was done to them. The students did not see value in incorporating culture in science class, and they did not feel as though their teachers had ever included cultural elements in science. However, what became apparent during the interviews was that there were places where the students showed a willingness to discuss culture alongside the science topics they were covering.

Connection between culture and science. The majority of the participants did not value a connection between culture and science, particularly school science. Tala (interview 2) indicated that she believed that those responsible for developing school science specifically attempted to separate science and culture and that including culture and religion in science classes was not important. Lenny (interview 2) also felt there was no value in talking about cultural diversity in science class, specifically suggesting that discussions around culture should be left for social studies. In his earlier interview, Lenny (interview 1) had indicated that lessons in science did not change based on culture; rather, he said, they changed more based on who the teacher was. Other students, such as Hua, Jennifer, Ayana, Cindy, and Martin, simply stated '*no*' when asked whether culture had ever been included in their science classes or if they felt that it was important to include culture within science classes.

Although the majority did not see or value a connection between culture and science, several students identified different topics that could have some cultural connection, in particular when discussing whether there could be potential tension points for them personally with respect to certain topics. Ryan (interview1), for example, reported experiencing some tension between her science class and her religious beliefs, '*especially topics about how the world began and all that, but it's not really talked about much in schools. Like it's not like the classroom's split into two and there are two sides and they're arguing*'. Tam (interview 1) also identified topics around creationism and the beginning of the world as potential tension points but personally saw them as connection points. She stated,

> *Personally, I think they connect, but some people could see them as tensions, like, the whole like big bang thing versus God doing things. Well, I don't know, maybe God did create the world through the big bang. I don't know. So I, like, think they connect* (Tam, interview 1).

Martin (interview 1) also mentioned potential tensions around people's belief in religion and science class. However, just as with all of the participants, he felt that they were allowed to believe what they wanted as long as they knew what they needed to for the test. Ayana (interview 1) discussed the Quran as central to her belief system, in particular, identifying where in the Quran one could actually find different theories about math and science. However, in her second interview, she also indicated that, although someone could bring in religious or cultural beliefs into science, especially around conversations about decision-making, she would just avoid participating in the discussions, as she did not think the discussions were even important to have in school.

Case vignette—stem cells. The science teacher in this study suggested that stem cells represented a controversial topic within science class. She believed that this topic included cultural elements and perspectives and was therefore a good topic through which to engage students in classroom discussions. Her perspective that stem cells represented a 'controversial' topic has been supported by numerous researchers, including Fonseca, Costa, Lencastre, & Tavares (2012) and Van Rooy (1993). The teacher's perspective on stem cells was that politics or government was in the middle of a balancing act, attempting to make scientists happy on one hand, and on the other hand, the general population, who hold cultural and religious beliefs (personal communication, 17 April 2014).

In general, units and lessons were developed by the teacher to align with the textbook entitled *Science Focus 10: Science, Technology, Society* (Gue et. al, 2004). The teacher indicated that she used the textbook in her planning and did not specifically identify focussing on the outcomes in the program of studies. However, with respect to stem cells, she did mention that the IB curriculum did specifically relate to stem cells. For both the IB and the prep class, the students received a notes package that mirrored the textbook topics. Stem cells are presented in the textbook under section ‘7.2 Cells and Technology’ (Gue et al., 2004) and in the notes package that the students received (see Figure 3 for the notes the students received on the topic).

Stem Cells

- What if we could grow body parts or organs to replace damaged ones?
- Stem cells are “blank slate” cells that have not decided what type of cell they will produce and they can become any cell in your body
- Normal cells can only produce more of themselves
- The Debate Around Stems Cell…

Figure 3. Verbatim excerpt of notes from notes package (instructional date: 24 April 2014).

The actual lesson on stem cells for both the IB and the prep class was very similar[6]. However, the assessment was different in scope and purpose. The teacher first used the notes to explain what stem cells were, particularly animal stem cells and not plant stem cells, and some of the controversies associated specifically with the use of animal stem cells. In the IB class, the students then talked in small groups about what they thought, specifically if using them was a good or bad thing. Both classes then watched a 15-minute video about stem cells, and the IB class had two readings on stem cells. One of the readings included information from the textbook, including the main text on page 274 and a reading tied to a textbook investigation on page 275 (Gue et al., 2004). The students in the IB class were then required to put together a

[6] The IB class had just completed the lesson on stem cells prior to my arrival at the school. I was present for the lesson on stem cells with the prep class. As such, this description is based upon my observations for the prep class and from personal communication with the teacher on 14 April 2014, when she described the lesson.

project on what they had learned about stem cells. One student created a cartoon, one created a poster, some created power point presentations, and others wrote mini-essays. The project was graded, and the focus was on information gathering, with only a brief mention about the controversies. For the IB class, the teacher indicated that the students were discussing their personal beliefs. However, for the assignment the students were only required to acknowledge that there were differing points of view (personal communication, 17 April 2014).

The students in the prep class participated in a debate in which they were either for or against stem cells. Students had 10 minutes to discuss their perspective and to nominate a speaker. Then, four groups each spent one to two minutes presenting their groups' perspectives. The students used points brought up in the video and in the lesson—specifically, that there were some groups of people who had religious and moral objections to the use of stem cells—but they did not expand on what these objections might be. None of the student groups discussed personal perspectives. This was ungraded, and most of the students were not on-topic when they were given time to discuss their perspectives. Observation notes indicate that most students were talking about unrelated social things.

Student perspectives. In contrast to the lack of personal perspectives that students brought to the discussions around stem cells during class, they mentioned a variety of perspectives during the interviews. Students specifically reported that, with issues related to controversial topics, such as global climate change, evolution, or stem cells, personal perspectives often outweigh scientific consensus. The vast majority of students agreed with using animal stem cells under certain circumstances, such as only using adult stem cells or only using embryonic stem cells if the person was going to have an abortion anyways. Three students had a very difficult time remembering details from the stem cell lesson.

Of the 10 remaining students, half felt that their personal opinion on whether to use stem cells was based on scientific reasoning, while the other half felt that their reasoning for using stem cells or not in some cases was based on non-scientific reasons. All of the students who felt that their opinions were based on scientific reasoning were in favour of using stem cells, whereas those who used other perspectives were either in favour of using stem cells with certain conditions or were not in favour of using stem cells. In all cases, the students had very definitive opinions, which is in direct contrast to what they displayed during class. However, the students were also asked a number of direct questions during the interviews that were not discussed in class.

Tam, Martin, Seth, and Tala all believed that stem cells should be used and that their decision was based on a scientific rationale. During the interviews, Tam's opinion about stem cells was initially based entirely on what she remembered doing for her project, and she listed some pros and cons. In discussing the controversies surrounding the use of embryonic stem cells during her interview, Tam (interview 2) expanded the pro/con list and instead talked about what her opinion.

> *Well, you can still get umbilical stem cells … you can use those I guess, and it is still the same purpose. I think you should still continue stem cell research and I think also—people that want to abort your babies—I'm not saying I subscribe to people aborting; I don't think it is good. But some people really don't have anything, any other option, and they are going to abort, well, you may as well donate your stem cells. That is not a good thing to say I know. Abortion is a big issue kind of thing, but just saying. . . . So, if you are going to do it, you may as well donate your stem cells.*

Martin stated he believed that even with the controversies associated with using embryonic stem cells, the decision to use them should be scientific. Martin (interview 2) felt that

> *if you're going to have an abortion, then it's just a given the remains are used for stem cells because I just don't see why you wouldn't. Like, if you're okay with having an abortion, why wouldn't you be okay with it helping other people?*

Tala more specifically identified that her opinion to use stem cells was scientific because she felt that if stem cells could help people, it was important to ask questions and then continue on with experimentation. However, when asked specifically about embryonic stem cells, Tala (interview 2) hesitated and said that it was okay to use them, but it might '*mean that they're [scientists] encouraging miscarriages and abortions and killing unborn babies*'.

As long as people were not aborting embryos to extract the cells, then she was okay with it. Even though Tala believed her opinion was based on a scientific rationale, this particular conversation highlights how the influence of social and environmental contexts in science, and some of the attitude outcomes in the program of studies (e.g. Alberta Education, 2014, pg 5–6) could be better addressed, as opposed to more didactic methods.

Ryan, Hua, Jennifer, Lenny, and Claire all believed that stem cells could be used in certain circumstances and that their decision was based either partially or completely on non-scientific rationales. Ryan (interview 2) believed that stem cell research should continue. However, she strongly believed that consent from the individual or the parent was essential. When asked if her perspective came from what she knew scientifically about stem cells, Ryan (interview 2) stated,

> *All I scientifically know about stem cells is it can help replace or help people who need it. But I believe that, if you just take something without permission, then I feel that is really not right, and I feel like taking a cell out of someone's body—if it is not through consent then it's kind of, it's almost kind of, in my opinion . . . taking a part of someone in a way.*

Ryan's lack of what she felt was scientific knowledge about stem cells was particularly interesting, as she was a high achieving student who did well on this project, which was focussed on the knowledge component of stem cells. Her project did not include anything about her own perspective but instead provided yet another pro/con list.

Ryan struggled to articulate her personal perspective and was even surprised when she was initially asked what her opinion was. Although Ryan self-identified as highly religious, she never discussed stem cells in relation to her religion, even though religious perspectives were briefly mentioned by the teacher in class. One possibility for this is because most of the students understood that they could believe what they wanted but had to put the correct answer on the test. Some of the students, Ryan included, were less open to sharing things with me at first or were surprised throughout our interviews that I was interested in their real opinions because I was a 'teacher'.

Hua (interview 2) also believed that it was okay to use stem cells and identified her reasoning as based on '*personal stuff*', and she suggested that it might be because not everyone, her included, thinks scientifically. Hua also did not believe that people could really hold both scientific and non-scientific beliefs about a topic as an individual, as evidenced when she was asked to sort topics as scientific or non-scientific.

In contrast to the other students, Ayana did not believe that stem cells should be used, in particular if it harmed an individual or was done without permission. She did not believe that her perspective was scientific, instead, she said it was based on the values and ethics she was taught mainly in her religion classes outside of school. Ayana held strong beliefs that abortion was wrong and that using embryonic stem cells was taking advantage of aborted babies. Ayana was the only student who self-identified as religious and discussed religious values and ethics with respect to the topic. Her project on stem cells did not discuss this religious perspective, even though it was important to her.

Tam, Ryan, and Ayana, in particular, identified as religious. However, the ways in which they approached the relationship between science and their religious beliefs was different and was highlighted by the way they approached discussing stem cells. In a study of the ways in which English (British) secondary school students viewed the relationship between science and religion, Taber, Billingsley, Riga, and Newdick (2011) found five broad stances that students took, ranging from giving religion precedence to choosing science over religion, and multiple stances in between. The students in this study did not subscribe to the extreme positions. Ayana was "open to science supporting faith: recognising some problem relating science and religion, but taking the view that ultimately these can be reconciled, with science supporting a faith position" (Taber et al., 2011, p. 1006). This was apparent in the way she talked about science supporting the Quran and in her belief that aborting babies was wrong. Ryan tended to compartmentalise "science and religion: considering that science and religion concern different domains and so there is not need to relate them" (Taber et al., 2011, p. 1006). For example, she was generally surprised to be asked about how she personally felt about stem cells and gave a scientific viewpoint because this was a science question. Finally, Tam tended to see "multiple frameworks: recognising that sometimes one has to choose between science and religion" (Taber et al. 2011, p. 1006). Tam was sceptical about many of the topics students were taught in science. However, she also easily talked about science and religion within the same topic and did not completely accept one and reject the other. For example, she did not believe that abortion was morally right. However, if people were going to abort, they might as well make good use of the fetal tissue and learn something about stem cells.

The students had pretty definitive opinions about the use of stem cells. However, when probed further about their opinions, they also asked a lot of questions that were not discussed or brought up by the students during class (either in my own observations or from the students' perspectives). For example, Hua (interview 2) was curious about what stem cells would form into if a scientist was not directing the cells' formation. Cindy, Cheng, and Zack, who really did not have a clear understanding of stem cells, and Seth, Tala, Jennifer, and Lenny, all wanted to know if using embryonic stem cells definitely killed the baby or if they were maybe just injured. Martin, Zack, and Lenny all wanted me to tell them whether it was morally right to use embryonic stem cells.

*Possibilities***.** The teacher in this study used stem cells as a topic because there was an outcome in the IB curriculum referencing stem cells. It is a controversial issue, and most importantly, according to the teacher, the issue of stem cells is a major topic heading in the textbook (personal communication, April 17, 2014). This viewpoint has been corroborated by many researchers (e.g. Davis & Kracjik, 2005; Marsh, 2004; Remillard, 2005) who have indicated that teachers often use the required textbooks as sources of information gathering for their classes. There is no explicit outcome in the Science 10 Program of Studies that requires teachers to teach about stem cells. However, there are a number of outcomes that can be covered using stem cells as the specific content (although not a comprehensive list, see outcome examples in Figure 4).

Hodson (1993) has asserted that there are powerful teaching opportunities present when teachers take into account the knowledge and experience that children's cultural backgrounds present, such as those around plant and animal knowledge, health practices, energy resources, dress, tools, and utensils. However, teachers often ignore this valuable teaching opportunity.

Information about stem cells is not part of a specific knowledge outcome. However, this particular topic does lend itself well to discussions incorporating broad notions of culture in meaningful ways; at the same time, it connects to different components of the foundations of the Science Program of Studies, including the nature of science, social and environmental contexts, and attitudes. While this particular unit has a nature of science emphasis, the Science 10 Program of Studies does highlight, as part of the social and environmental contexts, that "society provides direction for scientific and technological development. . . . Decisions regarding the application of scientific and technological development include a variety of perspectives, including social, cultural, environmental, ethical and economic considerations" (Alberta Education, 2014, p. 10).

Unit C: Cycling of Matter in Living Systems

Outcomes for Science, Technology and Society (STS) Knowledge

Students will:

1. Explain the relationship between developments in imaging technology and the current understanding of the cell
    - identify areas of cell research at the molecular level
2. Describe the function of cell organelles and structure in a cell, in terms of life processes, and use models to explain these processes and their applications
    - compare the structure, chemical composition and function of plant and animal cells, and describe the complementary nature of the structure and function of plant and animal cells
3. Analyze plants as an example of a multicellular organism with specialized structures at the cellular, tissue and system level
    - explain why, when a single-celled organism or colony of single-celled organisms reaches a certain size, it requires a multicellular level of organization, and relate this to the specialization of cell, tissues and systems in plants

Attitude Outcomes

Mutual Respect
Students will be encouraged to:
Appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds

Stewardship
Students will be encouraged to:
Demonstrate sensitivity and responsibility in pursuing a balance between the needs of humans and a sustainable environment

Figure 4. Select outcomes from the Science 10 Program of Studies (Alberta Education, 2014).

The topic of stem cells was presented in the classes as a technological application. The students were, in part, assessed on the technological application and the evidence they used to describe how different groups made decisions about the perspectives they held. However, the decision-making associated with use of stem cells was not fully or explicitly discussed. During class time, students did not "apply a variety of perspectives in assessing the risks and benefits of scientific and technological developments" (Alberta Education, 2014, p. 10). However, during interviews, it was clear that many of them had personal perspectives on the issue that were not capitalised on in a way that may have produced more meaningful learning.

In studying the relationship between students' exposure to moral problems and advancing epistemological development, Zeidler, Sadler, Applebaum, and Callahan (2009) found that advancements in epistemological reasoning did not occur uniformly across different contexts. The more personal or moral the context, the greater the difficulty students have in advancing reasoning. Deeply entrenched core beliefs, such as those about when life begins, are strongly correlated with students' evaluation of evidence. If the goal is to involve students in evaluating a technological development and in decision-making, particularly with a topic such as use of stem cells, then greater emphasis needs to be placed on developing epistemological reasoning. Otherwise, as they did in this study, students are able to produce a laundry list of pros and cons, but they are not able to really evaluate something from multiple perspectives.

The ability to identify sources of evidence but not integrate this evidence in more meaningful scientific argumentation has previously been shown in Yang's (2005) analysis of 10th grade students' personal epistemological orientations to evaluating views and evidence. The grade 10 students in Yang's study realised the importance of scientific and other forms of evidence. However, they did not understand how to amalgamate this information. As has been shown previously (e.g. Grace & Radcliff, 2002; Nielsen, 2012; Sadler, 2004), unless prompted, students tend to focus on persuading others of their own viewpoints rather than on multiple and varied viewpoints. The value of a culturally diverse classroom is one in which there are likely to be diverse perspectives, beyond the personal, which can be capitalised upon.

Chapter Five: Conclusion and Recommendations

The purpose of this case study was to explore student perspectives of the implementation of science education in a culturally diverse classroom. The following questions were used to guide the investigation:

1. How do student's view science, science education, and culture within a culturally diverse classroom?
2. What are the perspectives and experiences of students as they interact with each other, their teachers, and the curriculum in a culturally diverse classroom?

This chapter will outline the theoretical and practical significance of this work.

Research Question One

How do students view science, science education, and culture within culturally diverse classrooms?

Science. Students in this study viewed science in terms of the disciplines taught in school, specifically Biology, Chemistry, and Physics, as explanations for how and why things work in the world, and as universal in content. Participants emphasized 'ready made science' (Latour, 1987) and not 'science in the making' (Wong & Hodson, 2010). Science was, for example, whatever they learned in Biology class or the model(s) of the atom, not the processes used to study biological organisms or the development and refinement of different models of the atom.

The vast majority of the participants in this study held views similar to Cobern and Loving (2001), who argue that good explanations in science are universal, particularly Western science. Western science is what many researchers (Aikenhead, 2006; CMEC, 1997; Lee, 2001) argue is 'the science' taught in schools, even though there may be competing explanations about natural phenomena in local contexts. Participants described competing explanations for how the world works almost exclusively in terms of religions explanations, for example, creationism versus evolution. However, not all of the participants necessarily believed in these particular competing explanations, describing them as something other people might believe. Even when the participants did believe in alternative explanations, they did not think of these explanations as necessarily competing. For example, when Ayana described that explanations for how the world works are supported by both science and the Quran in similar ways. In opposition to the divisiveness in the universalism versus multicultural debate, the participants in this study were not as set on an either or perspective, even though most agreed that science content was universal. Students in this study were more flexible with respect to the way they viewed science compared with many of the universal and multicultural theorists.

In general, students had difficulty specifically identifying what science was. In demarcating science from non-science, student explanations and examples tended to be general and simplistic. In Ryan and Aikenhead's (1992) study of student views on science, technology, society, students had not acquired a uniform view of science and generally were divided between content and process perspectives. In their study, the social part of science, or the science-technology-society piece was all but absent. For the most part, the students in this study mirrored the lack of uniform view of science and focus on content and process. This is not surprising as even historians and philosophers of science have difficulty delineating between science and non-science (Reiss, 2004). Reiss (2004) suggests that the question, " 'what is science?' can only by answered: 'That which is recognized as such by a scientific community'" (p. 11). Reiss goes on to say that this rather unsatisfying answer leads to school science espousing a very narrow view of the methods of science, which is the view that students then hold.

Influences on science, including cultural, religious, political, and personal influences, were discussed by the participants within the context of scientific interpretation and the ways in which scientists arrived at decisions. At a fairly superficial level, the participants acknowledged that science was embedded in a cultural context by virtue of it being a human endeavor as Matthews (1994) and Siegel (1997) suggest. Students were aware that people, including scientists, were prone to influence, and that some issues were not solely scientific or non-scientific. However, students still had difficulty integrating different perspectives, including cultural, political, and scientific perspectives when asked to make a decision. This is not surprising given that assessment practices in schools generally - and specifically in this study - never ask students to present an issue by integrating multiple perspectives. As the students indicated, they were allowed to believe whatever they wanted but there was a correct answer for the test and that is all they really needed to know.

Nature of science (NOS) and scientific literacy including, decision-making on scientific issues, has long been important sought after goal of science education (e.g. CMEC, 1997; Lederman, 2007; Millar & Osborne, 1998; United Nations Educational, Scientific and Cultural Organization, 1993). In their study of 13 well-established scientists' views on NOS, Wong and Hodson (2009) highlight that the practices the scientists employed were in stark contrast to the traditional view that many textbooks and science curricula portray. They suggest that these practices, including how different influences affect scientific research, have great potential as case studies for students to develop more enhanced and enriched understanding of NOS. Arguments from multiculturalists rest on practices taught in school, for example teaching about *the* scientific method as the process of experimentation, and not on how science is actually done. Many of the scientists in Wong and Hodson's study stress that flexibility of approach is incredibly important with respect to scientific investigation. Although the students in this study held views that science content was universal, they also demonstrated a belief that science was prone to interpretation based on a researcher's previous experience and background. The students demonstrated a willingness to consider scientific processes more openly than scholars espousing a purely universalist account and more in line with the ways in which scientists see their own work. The willingness of students to see science as more than just a strict body of facts offers a great opportunity for educators to leverage students' backgrounds within the classroom. While this may not be necessary from an epistemological standpoint in terms of understanding the science content, it may assist with reaching the goals for NOS and scientific literacy.

Science education. In contrast to much of the literature discussed, the student participants in this study did not feel either welcomed or estranged from school science, or that integration of cultural elements would help to develop their epistemological understanding of science. It is certainly possible, given this study's small sample size, that students did not have the language to articulate their difficulties or that they did not have the ability to conceptualize their own situation. However, as described earlier, in a cross-cultural study of high school students, and in support of the position that the students in this study took, Zeidler, et al. (2013) found that students' epistemological beliefs about science reflected more on the importance they ascribed to science as a complex, interconnected network, and less on culturally unique identities. The students in this study, who indicated they were not 'sciencey' and had no plans for a career in science, would have perhaps been identified by other researchers as not welcomed or estranged from science. Except that these same students saw value in science and science education but had other interests they wanted to pursue or possessed more overarching challenges.

Tam, for example, was deeply religious and self-identified as a non-science person. She regularly talked about why she did not care to pursue science and she easily reconciled her religious beliefs with science, science classes, and scientific perspectives. Her parents were both in science-based careers, her achievement in science was very high, and her conversations with me were among the most sophisticated, certainly of all the student participants. Yet, she simply preferred art, dance, and literature more. Aikenhead's (1996) seminal work on border crossings, what a great deal of multicultural science education literature is based on, may have identified her as an 'Other Smart Kid' (after Costa, 1995), a student who does well in school including science but does not find science personally meaningful. However, Tam's life world, unlike those of the Other Smart Kids Aikenhead discusses, was very congruent with the worlds of both school and science. Aikenhead suggests that Other Smart Kids require bridges to school science, provided by the teacher, in order to assist them in learning science in a meaningful way but not in a way in which they are required to culturally assimilate. However, students such as Tam are already doing what Aikenhead proposes. Just as anthropologists do not need to accept the cultural practices of the people they study (Aikenhead, 1996), students do not need to accept the values of science to learn something of value. She did not feel like she was required to give something up or assimilate her belief system in order to learn science meaningfully. Tam, like the vast majority of participants, expressed that they were free, even in science class, to believe what they wanted if they also learned the scientific perspective.

Cindy was another student who would have been described as estranged from school science. Her achievement was low, she was a fairly recent immigrant, and she did not personally care for science very much. However, Cindy was not specifically having difficulties in science class. By her own account, and those of her teachers, she was struggling in all subjects, with the exception of Mandarin, as a result of her difficulty with both written and verbal English language. Further compounding her challenges in school was Cindy's difficulty in translating what she was doing in school to her parents. While these challenges impacted Cindy in science, more broadly they impacted her throughout all of her schooling. Incorporating a multicultural or culturally responsive curriculum in her science class may have assisted her in science class. However, it could be argued that challenges in language of instruction, instructional support, and peer interactions at a systemic school level would have an even greater impact, and not just in science. In Aikenhead's (1996) border crossing, Cindy does not fit well in any of the categories when thinking about science class specifically. In order to support Cindy in school, helping her to manage the border crossing into science would only be as helpful as supports put in place for her and her family with language, peer, and school supports.

Culture. Many students struggled to identify their own culture, if they believed they even had one, and to define culture more broadly in meaningful ways. They were, however, confident that cultural diversity was present at their school even though they tended to base their assertion around racial and ethnic differences, specifically related to country of origin, even without explicitly saying so. Some students were able to identify generational and friendship/peer group cultural differences, which were also described by the participants directly and indirectly as having a greater influence on how they approached and thought about school compared to the cultural diversity present within their class or school. For example, many of the students described their friendship groups as being based around the similar cultural value of the importance of school.

Parsons (2014) strongly asserts that racial and ethnic diversity infiltrates ontology and epistemology, and that problems arise by not directly addressing this diversity in science education. Within the context of the great degree of cultural diversity the students described as being exposed to in their school, many students echoed what the multicultural university participants in Halualani's (2008) study on intercultural contact stated - that there was so much diversity around them, they simply forgot it existed, or that the diversity was an asset in their learning. Students in this study saw value in other people's perspective. However, very little was done, if anything, in any of their science classes to elicit these perspectives. While it is possible the students did not understand how their culture influenced their views on learning science they were able to, when probed in interviews, to talk about how culture might influence others learning science. Most of the student participants, even those who had immigrated to Canada, used 'Canadian-grown' descriptors of themselves when talking about their experiences in school and science class.

Conclusion. Student perspectives about science and science education were largely influenced by their experiences in their science classrooms. Overwhelmingly the students had participated in science classes that, to the best of their recollection, presented science in a didactic manner. The students' lack of participation in actually doing science might explain why they held such concrete views that science was a body of universal facts that scientists participated in discovering or experimenting with. The teaching and assessment practices throughout their schooling did not support views which might have reinforced 'science in the making' or the integration of multiple perspectives. Therefore, it is not surprising that the students felt they needed to put the correct answer on the test, as defined by the teacher, but could then just believe whatever they wanted. These particular students were, for the most part, in fairly privileged positions. For example, most of the students were still living in two parent households, participated in many different extra curricular activities, and their parents were in science, engineering, or business based careers. While they understood the importance of school, as reinforced by their parents, they also had the cultural capital and freedom to not feel the need to assimilate to the beliefs of the school.

Student descriptions of being 'Canadian-grown' are perhaps a result of their privileged positions as described above, and possibly speaks to some of the ways in which Wax (1993) spoke about the tension between separation and diffusion of culture as a larger construct. The students in this study participated, in ways that Wax could not have predicted at the time, in mass communication through social media networks and travel opportunities all across the globe. These experiences, coupled with growing up in a place that their parents either chose to come to or were born in, which has diversity as an asset built into its constitution, may explain why the students in this study so easily seem to navigate their sense of self outside of science class and within science class.

Research Question Two

What are the perspectives and experiences of students as they interact with each other, the teacher, and the curriculum in culturally diverse classrooms?

The participants in this study indicated that no overt connection between culture and science had ever occurred in any of their science classes and, in many cases, they felt there was an explicit separation of culture and science in their classes. The topic of stem cells, used in part to address multiple perspectives within the science curriculum, demonstrates one area where there is a direct interaction between culture and science within public discourse (Fonseca, et al., 2012; Van Rooy, 1993). However, when taken up in the classroom, the diverse perspectives that students shared during interviews were not capitalized on or even addressed in any sort of meaningful way. The science program of studies offers opportunities to engage in discussions around culture, and in fact, requires students to engage in decision-making (e.g. Alberta Education, 2014). In addition, the students in this study possessed knowledge and experience that may have proved valuable in their discussions and project about stem cells. However, this teaching and learning opportunity was missed.

The science programs of studies do outline specific instances where students are expected to engage with a variety of perspectives, including cultural. These specific instances are relegated primarily to the front portion of the programs of studies that outline the foundation of the curriculum and not in the back matter, which outlines the required outcomes of the course. Given the student's views about science, science education, and culture addressed in question one, it is perhaps not surprising that the perspectives and experiences of students in their culturally diverse classrooms is lacking with respect to the ways in which they engage with the teacher and the curriculum. Students never indicated issues with developing an understanding of science, but at the same time, did not bring the diverse perspectives they discussed in interviews to the classroom. This was possibly because they were never asked to do so in the classroom in a meaningful way. In general, they displayed an inability to or were not encouraged to move beyond 'ready made science' to more adequately achieve outcomes related to multiple perspectives and viewpoints.

Conclusion. Participants in this study indicated that no overt connection between culture and science has every taken place in their science classes, and at the same time, the students did not feel as though integrating culture would be meaningful. This might be, in this particular context with these particular students, because success in their science class, as measured by achievement or simply moving on to the next course, never required an integration of culture. No value was ascribed to incorporating culture into the science classroom, as evidenced by the lack of teaching or assessment practices in support of doing so. In addition, students indicated that when they did speak to their family about science, it was either conversations around achievement or what specific content the students were learning. The lack of support for the integration of culture, either from school or home, likely explains why students did not see value in incorporating culture in science.

Significance

Since at least the 1980s, researchers have been calling for the integration of culture in science education, through multicultural and culturally relevant science education as a means of addressing achievement gaps, and unequal participation in science (see literature review for an extensive discussion of this). However, as Krugly-Smolska (2013) notes, little empirical research has been done within the area of culture and science education, and is instead, based largely on theoretical discussion papers. This study has attempted to address some of the pervasive theoretical assumptions within this field by allowing students the opportunity to discuss these issues in their own words. There is no evidence from this study, from the students, their achievement, or their teacher, to suggest that students within these culturally diverse classes encountered cultural challenges specific to accessing or achievement in school science. This finding is in direct contrast to the literature, which suggests that science education is inaccessible for many students, in particular, culturally and linguistically diverse students as a result of the cultural disconnect between themselves and the science classroom (Atwater, et al., 2013; Lee, 2001; Meyer & Crawford, 2011; Pedretti & Nazire, 2011).

In general, students tended to either be performing similarly across school subjects or when discrepancies existed, science was not the subject in which students were struggling the most. Many of the students described this and their previous science classes as presenting science facts with no mention of a concerted effort to teach using what might be considered culturally relevant pedagogies. Students understanding of the nature of science and scientific literacy was either lacking or not called upon in the classroom. It is possible that the contrast, between the literature and the perspectives of these particular students in this study, is a result of the way in which they have been taught science.

Theoretical. McKinley and Gan (2014) identify that "the core epistemological debate that affects science education involves that between proponents of universal and multicultural views of science" (p. 287). Universalists, generally, assert that science is objective, can provide universal truths, provides the best explanations about natural phenomena, and that culture, race, class, etc. is irrelevant to science knowledge (Carter, 2008; Matthews, 1994; Siegel, 2002; Stanley & Brickhouse, 1994). Multiculturalists, generally, believe that science has developed within a "male dominated, Eurocentric, and middle-class context" (Hammond & Brandt, 2004, p. 651) and is "invasive of other systems of meaning" (Cobern & Aikenhead, 1998) such as, Indigenous knowledge systems. This debate has extended to science education, with multiculturalists suggesting that science education is inaccessible for many students as a result of the Eurocentric focus of science education in schools (Aikenhead, 1996, 2006; Hodson, 1993; Milne, 2011) leading to achievement gaps, poor standardized test results, and racial and ethnic disparity in science for minority and culturally and linguistically diverse students (e.g. Atwater, et al., 2013; Lee, 2001; Meyer & Crawford, 2011; Pedretti & Nazire, 2011). As a means to address the disparity, researchers have called for the inclusion of culture within science classes and have developed a myriad of discussion papers in support of their position.

However, while the debate between universalists and multiculturalists wages on, and has extended to other theoretical frames including hybridity, third space, funds of knowledge, and figured worlds, students continue to sit in science classrooms that are becoming more and more culturally diverse with very little meaningful change. I could not find literature in which larger, ongoing gains were made with respect to achievement and/or equity as a result of integrating a universalist or multicultural approach in the classroom. I argue here that this continued debate and theoretical (re)orientation is essentially taking us nowhere.

As Krugly-Smolska (2013) notes, the danger in making hypothesized links between learning a Western oriented science curriculum and achievement or participation gaps, is that these theories become enacted in classrooms without research support. For example, researchers often point to Aikenhead's (1997, 2001) work offering a conceptual framework for designing a culturally relevant science curriculum that integrates Western science with that of 'Aboriginal science' of First Nations in northern Saskatchewan as a Canadian example and model for developing resources that are cultural relevant for minority students. As a model for how to incorporate culturally relevant pedagogy in science, this could be problematic in terms of addressing achievement gaps when students within a culturally diverse classroom do not share an Indigenous worldview, just as much as they might not share a Western scientific worldview. In addition, there is no research looking at achievement gains but instead anecdotal accounts of students participating in science in culturally meaningful ways as defined by the author. However, for a number of other and more important reasons, including educating students about Canada's full history, and more appropriately responding to the Calls to Action of the Truth and Reconciliation Commission of Canada, Aikenhead and others work is exceptionally important. This should be reason enough to consider the inclusion of culture within science education. It does not, however, serve anyone's interest to extrapolate theories beyond their original intent, particularly when policies and actions in the classroom are being enacted without appropriate evidence to suggest these are the best course of action.

Davis and Sumara (2006) discuss how importing different theories from other domains into education is problematic because "those theories tend to be strictly descriptive, focused much more on the characterization of a specific phenomenon than on how one might go about affecting that phenomenon" (p. 129). Over interpretation of the practical use of these theories becomes "stretched and distorted descriptions of learning and knowledge into prescriptions for teaching – evidenced in now commonplace references to 'constructivist teaching' and 'critical pedagogy'" (pg. 130). As a practicing classroom teacher, this is incredibly evident in the work that I do everyday. While many theorists describe critical pedagogy, the tangible means by which to accomplish this in classrooms, in particular science classrooms, is often lacking. For example, as mentioned in the literature review, Ladson-Billings (1995) asserts that a culturally relevant pedagogy involves teachers who establish connectedness with their students, and encourage students to learn collaboratively. With the exception of discussions surrounding different power dynamics, it is not clear how a culturally relevant pedagogy differs from other student-centred theories.

The students in this study provided evidence that both supported and contradicted existing literature and theoretical work. For example, students generally held views of science content as universal. However, they understood the impact that religion, politics, location, etc., may have on science and scientists. They struggled with incorporating multiple perspectives in decision-making, but not because they did not hold different perspectives, they were simply not asked to provide their perspectives in meaningful ways. This did not hinder their ability to learn science as they did not see science in school as being framed from a particular Western world orientation that they could not access.

Students generally saw science as a perspective that they could call upon and were significantly more flexible in their ability to navigate different contexts/expectations/etc. that new research, such as figured worlds, are beginning to explore in more depth. Urrieta (2007) has identified that "figured worlds is a concept used to study identity production in education" (p. 112) but also in "making worlds of possibility" (p. 114). For example, Tam's view of herself as a Chinese person, Christian, academic student, and 'Canadian-grown', in particular, all appeared to shape Tam's figured world of science class. Within this world of science class, Tam perceived herself in apparent contradictory ways, as both a good science student and yet not a 'sciencey' person. She was able to learn science taught in her classes with a great deal of success and yet, was able to take a questioning stance on a number of issues, as highlighted by her personal exploration of Darwinism, which suggests areas where teachers might help to open up worlds of possibility. In opposition to literature that might suggest Tam was unable to access school science, viewed from a figured world lens, it would appear that Tam is able to, with greater ease than researchers have argued access school science. The concept of figured worlds offers a potential theoretical frame in which to pursue further studies around student identity work in culturally diverse classrooms and their ability to access school science.

For all the debating between universalists and multiculturalists, the students in this study did not subscribe as vehemently to one side of the debate or the other, as the literature would suggest. Students in this study did believe that science content was universal but that a researcher's background, in particular around topics that required some kind of decision-making, could influence interpretations of scientific work. In addition, students showed a willingness to discuss scientific matters in conjunction with their own or what they perceived others cultural beliefs were. The debate between universalists and multiculturalists has not resulted in markedly different results with respect to if and how students access school science and whether or not students succeed in science or not. However, understanding the ways in which culturally diverse students come to participate in science and not, as opposed to how researchers believe students feel, might bring about a more fruitful discussion.

Practical. The rationale for incorporating culture in science is overwhelmingly to improve the achievement gaps of minority students and access to school science and science-based careers. However, the students in this study did not experience the epistemological barriers described in the literature. More broadly, the achievement gap in Canada, while smaller than in the USA, has been more greatly helped by dealing with socioeconomic status in high-poverty communities than by other factors (Clark, 2014). In their extensive review around how different factors affect students and learning science, Lee and Luykx (2006) identify the inconsistent and contradictory results across studies, suggesting that

> although it seems valid to conclude that all these factors [students' cognitive and affective attributes, cultural beliefs and practices, cognitive processes underlying scientific inquiry and reasoning, and sociopolitical processes] contribute to nonmainstream students' science learning, it is difficult to specify the role of each factor both independently and in interaction with the others, due to the limited literature within each area (p. 56).

Students in this study did not indicate a significant understanding of the nature of science or scientific literacy. In their study of science teacher beliefs about multiculturalism, Petty and Narayan (2012) suggest that the achievement gap in science could be attributed to the impoverished nature of science taught in schools, and this is certainly a potential factor for many of the students in this study. The Alberta Science Programs of Studies currently includes nature of science and social and environmental contexts of science and technology as foundational components overarching all learning outcomes. However, teachers tend not to focus on these foundational aspects, as they are difficult to assess.

Multicultural and culturally relevant science education, for most researchers who attempt to articulate what this actually might look like in a science classroom, requires additions to the science curriculum or significant reframing of the science curriculum. I have argued that the rationales provided for including this specifically in the science curriculum may not be warranted. However, there is still significant value to be held in reconsidering the ways in which we engage with culture in the curriculum. From a practical standpoint, the debate is getting us nowhere, but we are still living in an increasingly culturally diverse society, with increasingly diverse perspectives. From the perspective of developing well-informed citizens, capable of making decisions on science related issues, this has important implications. What this study highlights, is that students do have those perspectives and opinions, some of which are culturally based and some of which are not. Changing the entire structure of education broadly, and science education specifically, within the short or medium term is not possible. However, a realistic and practical approach might be to engage teachers in acknowledging the value that the diverse perspectives that their students bring to discussions about hopefully all of science, but at least with respect to the foundational elements, including NOS and the social and environmental contexts of science and technology which the science curriculum is based on.

Summary. From both a practical and theoretical perspective, incorporating student perspectives in the ways teachers and researchers develop theories, resources, lesson plans, etc.

is vitally important. The debate between universalists and multiculturalists has yet to yield large scale, meaningful change for culturally diverse science learners. Potentially because students have rarely been consulted in the development of theories or the subsequent enactment of these theories in classrooms. As Fullan (2007) notes, "neglect of the phenomenology of change – that is, how people actually experience change as distinct from how it was intended – is at the heart of the spectacular lack of success of most social reform" (p. 1177).

Siegel (1997, 2002) has long argued that western modern science is not the only way to understand the natural world. However, he also believes that it should be made clear to students that western modern science provides the best approach to understanding nature based on a number of criteria, including for example, the ability to test hypotheses. Because of this, Siegel is labeled a universalist. However, he also argues for a common ground between multiculturalism and a universalist conception of science. Siegel (2002) suggests

> we embrace multiculturalism in science education because it is in doing so that we meet our fundamental obligation to treat students with *respect* as students and person, and this obligation is a *universal* one insofar as it applies to all students and science educators (p. 810, emphasis in original).

As stated elsewhere in this study, incorporating culture and multiculturalism is incredibly important for many reasons, including to value diversity of perspective, as an understanding of the multicultural society in which students live, to better address the Calls to Action in the Truth and Reconciliation Commission of Canada, and so on. However, there continues to be little evidence to suggest that incorporating culture and multiculturalism in science education has addressed the hypothesized links to achievement and access gaps. The students in this study have called to question some of the assumptions regarding student's ability to epistemologically access science education. Siegel (1997) advocates “science educators ought to embrace both a universalistic conception of multiculturalism (on moral grounds), and a universalistic conception of science (on epistemic grounds)” (p. 97). Viewing multiculturalism in science education as a moral imperative and not an epistemological one could allow “science education to include explicit attention to philosophical questions concerning the nature of science, and in particular, to questions concerning the interrelationships between science, its epistemology, and the cultures within which it is embedded and practiced” (Siegel, 1997, p. 103), which I have argued is a more realistic approach than simply changing the entire structure of schooling and science education.

There are a number of messages that can be taken from this study. First, culture is a problematic lens through which to investigate education. Increasing globalisation means that students are exposed to and experience culture differently than the ways in which culture has been discussed in the literature, particularly as it related to concepts such as multiculturalism and border crossing. While there is substantial research discussing the incorporation of culture in education, the extent to which different groups of stakeholders, for example parents, would like to see culture incorporated is largely unknown, except when discussing topics that are seen as controversial (e.g. Stemwedel, 2012). The role that parents played in shaping the views of their children in this study were not explored.

Given the lack of support for incorporating culture within science education, it might seem as though this study advocates for dropping this cause all together. However, I would argue that although this particular study calls into question some of the prevailing assumptions about why we should incorporate culture into the curriculum, there is still a great need to do so. If the lens of culture is removed from this study and replaced instead with experience, there is significant benefit in incorporating or learning about student's prior and current experiences when in the science classroom.

Recommendations

At the time of writing, Alberta Education (2017b) was in year one of a 6-year curriculum redesign process[7]. While this study does not support a distinctly multicultural or culturally relevant pedagogical approach as on overlay for science education, there are a number of areas within the curriculum where the incorporation of culture could be included in meaningful ways. With respect to the current science Program of Studies and in the development of the new science Programs of Studies, the following recommendations are suggested:

1. Assist teachers with how to incorporate and elicit cultural perspectives on different topics within the program by developing case studies and subsequent lesson plans. Encourage teachers to access documents produced by the Alberta Teachers' Association such as *Here Comes Everyone: Teaching in the Intercultural Classroom* (The Alberta Teachers' Association, 2010).
2. Include within the Programs of Study, specific and measureable outcomes that address culture within the science curriculum. Additionally, include questions that measure these

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[7] In the interest of transparency, I have been selected to sit on behalf of the Alberta Teachers' Association Science Council on the Stakeholder Focus Groups. At the time of writing, I had not yet been to a meeting and had no additional knowledge of the curriculum re-design process other than what was publically available.

outcomes on standardized exams.[8]

3. As has happened for Mathematics, reinstitute the written portion of the diploma exams, in order to better assess holistic understanding around Nature of Science and scientific literacy.

In this study, I sought to explore student perspectives of the implementation of science education in a culturally diverse classroom. I have argued for a number of reasons that theorists and researchers need to take into account student perspectives, in part, because the students in this study had conflicting perspectives from those currently being advocated. However, this study is limited due to the small sample size, and the results cannot be generalized to the student population as a whole. It is possible that because of the complexity of a school environment, it was these students in particular that held contradictory views. Moving forward, larger scale studies where student perspectives are sought would be warranted. This study was also conducted with a teacher who believed that culture was important to science education and yet, admittedly, did not incorporate culture in meaningful ways in the classroom. An interesting extension of this study would be to seek out a teacher who made conscious efforts to incorporate a multicultural or culturally relevant approach and then compare student perspectives. While this study specifically sought out a culturally diverse school and classroom, gathering student perspectives from schools with less cultural diversity that reflects certain areas of the province would also provide a potentially interesting comparison. Would the students in these schools

[8] Science Diploma exams currently ask questions about perspectives, including cultural. However, they are limited in asking strictly identification questions due to the nature of multiple choice and numeric response delivery.

who were not exposed to as much cultural diversity on a day-to-day basis hold similar views or not compared to the students in this study?

Researchers have long submitted that culturally and linguistically diverse students experience achievement gaps, poor standardized test results, and unequal participation rates in science and science education (e.g. Atwater, et al., 2013; Lee, 2001; Meyer & Crawford, 2011; Pedretti & Nazine, 2011). It has been suggested that the reason for these gaps is because what is taught in science classes and how science is taught has created an environment where students feel estranged from an unable to access school science (e.g. Carter, 2007; Cobern & Aikenhead, 1998; Lee, 2001; Gaskell, 2003). Much of the research on multicultural science education has been based on theoretical discussion papers with little empirical work being done (Krugly-Smolksa, 2013). Student voices were largely absent from these theories and it was my hope that this study could at least provide a voice for students.

Based upon the literature, I expected to find that some students had difficulty accessing school science as a result of cultural incongruence between their home worlds and their school worlds. However, the students in this study frequently did not conform to perspectives present in the literature. This finding was surprising given the dearth of literature suggesting they would. More investigation into the assumptions espoused in the dominant theoretical frames may be warranted. However, it is important to (re)consider student perspectives during these investigations. Just as the students in this study felt science was something that was done to them, by not considering their perspectives in the creation of theories, I argue we are simply doing research to them. In this study, it was obvious that students had been exposed to an impoverished version of science, which could only be verified from their experiences in this particular classroom. However, focusing on a multicultural or culturally relevant pedagogy as defined by the science education literature would not have likely addressed some of the significant needs that some of the students had. However, by incorporating their perspectives and experiences into the classroom, the students may have been provided a richer and more accurate representation of science.

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Appendix A

Interview Schedule

Participants	Interview Date(s)
Cindy	#1 – March 4, 2014 #2 – May 6, 2014
Ryan	#1 – March 18, 2014 #2 – May 14, 2014
Tam	#1 – March 19, 2014 #2 – May 14, 2014
Martin	#1 – March 26, 2014 #2 – May 5, 2014
Seth	#1 – March 26, 2014 #2 – May 5, 2014
Hua	#1 – March 27, 2014 #2 – May 7, 2014
Tala	#1 – March 27, 2014 #2 – May 6, 2014
Jennifer	#1 – March 27, 2014 #2 – May 6, 2014
Claire	#1 – March 28, 2014 #2 – May 8, 2014
Cheng	#1 – April 8, 2014 #2 – May 8, 2014
Zack	#1 – April 8, 2014 #2 – May 8, 2014
Ayana	#1 – April 9, 2014 #2 – May 15, 2014
Lenny	#1 – April 10, 2014 #2 – May 15, 2014

Appendix B

Interview Protocol – Students (Interview 1)

Background

1. Tell me a little bit about yourself and your family.
    - How old are you?
    - Were you born in Canada or somewhere else (how long have you been in Canada)?
    - Were your parents born in Canada (how long have they been here)?
2. Do you speak any other languages?
    - What is your first language?
    - What language do you speak at home?
3. What other classes did you take this year?
4. Do you have any commitments outside of school?
5. What do you think is important for others to know about your background or culture? How has this influenced who you are?

Beliefs about science and science education

6. How would you define science?
7. Why do you think we learn science in school?
8. Do you think culture or politics affect science? How?
9. Why do you want to take Science 10 – what are your plans after this class and after high school?

Learning

10. Do you consider yourself a good science student? What is a good science student like?
11. What are the easiest things for you in science and what are the difficult things?
12. What kinds of things are done in class that are helpful and not helpful when you are learning science?
13. Do you feel like your science teacher understands your questions when you are confused? What do they do to help with your confusion?
14. How would you describe yourself outside of school? Do you act the same as when you are in class or different?
15. Do you talk with your parents/guardians about the science you learn in school? Why or why not?
16. Are the expectations your parents have for you at home different than those at school?

Cultural understanding

17. How would you define culture?
18. How much do you know about other cultures? How do you know it?
19. Do you think there is cultural diversity within your school? Science class? In what ways are these students culturally different or similar to you? What types of cultural diversity do you think there is?
20. Does having students from other cultures in your science class affect how you learn? If so, how?

Interview Protocol – Students (Interview 2)

1. Now that you have been in this class a little bit longer, can you tell me anything else about what you think science is?

2. What makes science different from other disciplines of inquiry (e.g. religion, philosophy)? (VNOS-Sci)

3. Some students have said
    - that science always gives us the truth?
    - that science cannot always tell us everything there is to know?
    - that science is the only way of knowing something?

4. Some astronomers believe that the universe is expanding, some shrinking and others believe there has been no change. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

5. What scientists choose to study and how they learn about the natural world may be influenced by a variety of factors. How do scientists decide what to investigate and how to investigate it? (VOSI-Sci)

6. Would you consider the following methods/decisions scientific or not? ((sorting activity))

7. One of the things you talked about in class was stem cells. Do you believe they should be used? Why or why not?
    - Is there a difference between using embryonic or adult stem cells? Why?
    - What kinds of things do you think about when making your decision?

8. If you think about when you learned about steam engines, do you think it is helpful to learn about the past developments?
    - Why do you think you learn about them?
    - Do you think there were other developments or just the ones you learned about in class?

9. Does your school promote cultural diversity? How?
    - Is cultural diversity presented in your science class?

Appendix C

Sorting Activity Statements

Electron microscopes can be used to view the structures of viruses.

People choose to purchase hybrid vehicles.

A plant called willow bark is used to treat headaches. People know to do this because it is passed down from one generation to the next.

A government decides to focus on nuclear energy as a source of energy as non-renewable energy sources are running out.

3.4 billion people are at risk for developing malaria (primarily in Africa, Asia and South America). However, there has been virtually no development in drugs to treat malaria in the past 50 years.

Doctors believed that some diseases were caused by an imbalance of fluids in the blood and they could correct the imbalance by a process called bloodletting.

Ancient Greek thinkers arrived at their ideas by a series of logical arguments but did not use experimental investigations. For example, they thought the universe was composed of small particles, atomos, that could not be broken down.

Appendix D

Codebook

Code	Description	Additional notes (or illustrative quotes)
Learner Factors		
Perspectives about Science		
Definitions	Students define what science is and/or what science is not, and how students demarcate science from other disciplines or ways of knowing.	
Discipline based	Students equate science with specific disciplines.	Example, references to Biology, Chemistry, Physics.
Explanatory	Students describe science as a way to explain the world.	"How everything works. Why things work the way they work" (Claire, interview 1)
Universal	Students discuss science as being the same everywhere and/or people learning the same science.	"Everyone, kind of, just learns the same stuff about science, it's pretty universal" (Tam, interview 1)
Influences	Students describe the different factors that influence the way science is done, how people approach science, or science is interpreted.	
Cultural/religious	Cultural or religious beliefs and practices influence science.	"Some places value religion more than science….people learn about how God created the world and then here we learn about Big Bang Theory" (Cheng, interview 1)
Political	The impact that politics or governments play in influencing science.	"the government controls the country so if they don't support something like stem cells, there's no way

		the scientist's have support" (Ryan, interview 1)
Individual	Influences are described or equated with personal or individual perspectives, opinions, or processes.	"Because they'd be testing it on different things, right? Like if you were to interview someone else in the school, it'd be different answers too" (Tala, interview 1) – on why scientists arrive at different conclusions
Processes of Science		From Wong & Hodson (2009).
Methods of science investigation	Student descriptions of the ways that scientists approach the work of science.	
Experiments	Students describe experiments or testing in science.	"they must have been doing tests to see if it was true" (Jennifer, interview 2)
Logic	Students discuss logical thinking processes in science.	"It's just like people logically thinking out evolution should have been this way" (Tam, interview 2)
Observation	Students describe watching or using other senses to gather data.	Students sometimes talked about observation as not scientific in and of itself.
Role and status of scientific knowledge	Students describe the use of theories in science and the ability of science to determine the truth.	
Theory (laws, models)	Students describe the ways in which theories, hypothesis, laws, and models operate in science.	Category combined to include all terms – students use them interchangeably
Proof (truth)	Ability of science to determine the truth.	Proof and truth were talked about in the same way.
Perspectives about Science Education		

Reasons for school science	Student descriptions about why science was a subject in school.	
Future prospects	Student descriptions of science as useful or needed for later.	"because a lot of jobs nowadays you need to have science, like doctor or health or even just engineering and stuff like that" (Hua, interview 1)
Schooling	Descriptions of post-secondary entrance or programs.	
Careers	Descriptions of possible career options	
General knowledge		
Broad	Student discussions of science education for a foundation and be more open minded; applicability to everyday life	"school in general is to make you kind of build a foundation in every aspect…. In science, because we need to know why things happen" (Ryan, interview 1)
Specific	Student descriptions of specific topics or content.	Examples. WHMIS symbols, electricity, human body
Science learning	Student discussions of practices related to the learning of science.	
Memorization	Student descriptions of what and how students remembered things.	Not application
Understanding	Students differentiating knowing something from understanding.	Example. describe process, can ask questions, etc.
Good science student	Student descriptions of what a good science student thought, achieved, and how they participated.	
Grades	Student connections to achievement.	
Actions	Student descriptions of behaviours of good science students.	Often more superficial compared with mindset.

Mindset	Student descriptions about what good science students were thinking about.	
Cultural influences	Student discussions of culture in their science classes.	
No cultural influence	Student descriptions that culture does not influence science education.	
Canadian grown	Impact of growing up in Canada or attending school in Canada (developed after Tam's interview)	"even though people have different ethnic backgrounds, most people are still just, like, Canadian kind of brought up, [background] doesn't really affect much. And, even if it does, I think people usually don't speak up about, like, the differences" (Tam, interview 1)
Impact of diversity	Student descriptions about how diversity might impact science education.	"some places … don't really value science, they just rely on religion or creation or something to explain the things that are happening around the world so I guess, maybe some places don't have the same teaching" (Zack, interview 1)
Contextual beliefs and values	Student beliefs that you could believe whatever you wanted outside of class.	Often paired with, you needed to just learn the correct answer for the test.
Understanding of Culture		
Definitions of culture	Students descriptions of culture.	Included traditions, values, beliefs.
Broad	Student descriptions of culture that included generalities.	"beliefs, values, where you're from, traditions, language" (Lenny, interview 1)

Acultural	Student descriptions of not having a culture.	"I don't have an accent or anything so no one, no one I interact with really has any inclination to think I was born anywhere but here. So no, [my culture] never really comes up." (Martin, interview 1)
Cultural diversity	The ways in which students described diversity.	
Racial and ethnic background	Students specifically mentioning race, ethnicity, or country of origin.	
Other groups	Students identifying cultural groups other than by race or ethnicity.	Example. Friendship groups
Cultural bias	Student stereotypes	Stereotypes were limited to superficial things.
School supports/promotion	Student descriptions of school activities or programs that promoted diversity.	Example. Culture sharing day, offering of languages.
Curriculum Implementation		
Curriculum-as-plan		
Understanding of curriculum	Who wrote it, why certain topics were picked.	
Curriculum-as-lived		
Connections		
Teacher-student	REMOVED – no instances.	
Culture-science	Connections between science and culture.	The ways in which science connected or didn't with culture, religion, etc.
Student perspectives on stem-cells	Student discussions around the stem-cell debate and project in class.	
Personal	Student descriptions based on personal values.	
Religious	Student descriptions based on religious values or the	

	values of different religions.	
Scientific	Student descriptions connected to scientific reasons for stem cells.	

Appendix E

Student Demographic Summary

Participants	Course	Gender	Languages * primarily spoken at home	Born in	Parents born
Cindy	Science 10 prep	F	Mandarin* (first language), Cantonese*, English	Taiwan	Mom – Vietnam Dad - Taiwan
Ryan	Science 10IB	F	Cantonese* (first language), Mandarin, Korean (little bit), English*	Canada (Alberta)	Vietnam
Tam	Science 10IB	F	Cantonese (first language), English* (parents speak C but she responds in E)	Canada (Alberta)	Hong Kong
Martin	Science 10 prep	M	English	Canada (Alberta)	Aunt - Canada
Seth	Science 10 prep	M	English	Scotland	Scotland
Hua	Science 10IB	F	Mandarin (first language)*, English	Harbin, China	Dad – Nanjing

					Mom - Harbin
Tala	Science 10 prep	F	Filipino (first language), English	Green Hills, Philippines	Philippines
Jennifer	Science 10 prep	F	English	Canada (Alberta)	Canada
Claire	Science 10IB	F	English	Canada (Alberta)	Canada
Cheng	Science 10IB	M	Cantonese (first language), Mandarin, English*	Canada (Alberta)	Guangzhou, China
Zack	Science 10IB	M	Cantonese, Mandarin, Taishanese* (first language), English	Canada (Alberta)	Guangzhou, China
Ayana	Science 10IB	F	Harari* (first language), English*	Canada (Alberta)	Ethiopia
Lenny	Science 10IB	M	English	Canada (Alberta)	Canada