# Surfacing Tensions:

# Teaching Science through the Lens of Sustainability and Well-being

By

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**Abstract**

In this autobiographical narrative inquiry, I consider the role of science education in contributing to a sustainable society. As a high school science teacher and narrative inquirer, I use my lived experience to uncover the possibilities and limitations when moving toward teaching through the lens of sustainability and well-being. Using a narrative inquiry methodology, I unpack three narrative vignettes that arose from reflections on my teaching experiences between September 2018 and April 2020. Through this unpacking, I come to understand how the pedagogy and content of Big History can act as a framework to teach through the lens of sustainability and well-being and foster ecoliteracy within my students.

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To Boden,

For your future and the future of all our children.

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# Chapter 1 Introduction

## Background

There is no doubt, as the 21st century progresses, that humankind will face a number of great social and ecological challenges. These challenges include the loss of biodiversity, a changing climate, and an exponential rise in the human population (Elgin, 2010). As these concerns loom, many are turning to the scientific and technological communities to solve these problems (Fensham, 2011, p. 699). It is thought that science and technological advancements, coupled with a greater understanding and appreciation for our environment, will give us a fighting chance against the serious challenges that we face. This is where science education, particularly within schools, becomes a contentious point of discussion. In recent years, we have seen an increase in socio-scientific issues within secondary school science curricula (Fensham, 2011). For instance, the Manitoba science curriculum states that science education should aim to "prepare students to critically address science-related societal, economic, ethical and environmental issues" (Manitoba Department of Education, n.d.). This brings forward the question of whether or not science education can effectively prepare students to address these complex issues.

As a high school science teacher, I wonder about the role of science education in preparing young people for these challenges. I haven't always perceived teaching as a political exercise; however, I think I have always recognized the capacity for social change that exists within education. In many ways, I believe this is what attracted me to a career in education. I felt that I could make a difference in the lives of young people and, perhaps, this could contribute to some kind of social change. When I was a Faculty of Education student, one of my assignments was to develop a "Philosophy of Teaching and Learning". At that time, I wrote about how science education should provide a historical and social context for learning. As a beginning teacher, I felt strongly about the capacity for "stories" to help students better understand the concepts to be learned, while inspiring curiosity and encouraging inquiry. Not only did I view teaching as a "sharing of cultural stories", but I became increasingly aware of my own story as a journey—moving toward *teaching through the lens of sustainability and well-being*. This awareness became increasingly prominent as I began my graduate studies, reflecting on my story and writing about my journey.

Since I began my Master of Education program, I have been interested in the role of science education in a "sustainable society". As I wondered about this, I sought to understand what was meant by a "sustainable society". My personal, professional and academic experiences have all played a role in shaping my understanding of "sustainability", as well as my thinking about the role of high school science education in establishing such a society. As I reflected on these experiences, I began to engage in a kind of research that is rooted in Dewey's understanding of "research as the study of experience" (Clandinin & Connelly, 2000, xxiii). The idea that one can study education by studying one's experience was appealing to me; especially as I adopted the Deweyan perspective that recognizes the roles of *continuity* and *interaction* in shaping experiences (Dewey, 1938). These principles allowed me to reflect on my past, present and future experiences (continuity), while acknowledging how my experiences have been shaped through personal and social conditions (interaction) (Dewey, 1938; Clandinin & Connelly, 2000; Clandinin, 2013). This led to a richer and more complex understanding of my experience, while revealing some interesting questions for exploration. Rather than trying to reduce my "wonderings" to a research problem that can be measured and generalized to other situations; I hoped to further develop my understanding of science and sustainability education by using my experience as the basis for my inquiry, starting with an initial reflection of my past experiences (Clandinin & Connelly, 2000).

These "narrative beginnings" (Clandinin, 2013, p. 55) make up the first chapter of my thesis and include a collection of stories of my personal, professional, and academic experiences that have led me to my research. By engaging in these narrative beginnings, I revealed the background and purpose for my research, while highlighting my position and assumptions within the research. In particular, my questions regarding the role of science education have come from reflecting on these experiences and recognizing "moments of tension" within my stories (Clandinin, 2013, p. 76). For this reason, I have devoted the second chapter to explore the relevant literature on science education. The third chapter of this thesis describes the autobiographical narrative inquiry methodology that I used to make sense of my "wonderings" which are explored thoroughly in the fourth chapter in which I inquire into my stories. Lastly, as my story of "moving toward teaching science through the lens of sustainability and well-being" unfolds, the concluding chapter aims to shed light on the possibilities and constraints that are afforded by this pedagogy.

**Narrative Beginnings**

In order to understand my lived experiences, I need to reflect on my story of moving toward teaching science through the lens of sustainability and well-being. This reflection includes a telling and retelling of the stories I live in, while recognizing that these stories are situated within larger cultural, institutional, and social stories (Clandinin, 2013). The notion of *living*, *telling*, *retelling*, and *reliving* stories (Clandinin, 2013, p. 34) is important, as I understand the world narratively. For as long as I can remember, I have thought about my lived experiences as stories. Previously, I may not have fully articulated a narrative understanding of the world, but now, I recognize the distinction between thinking *about* stories and thinking *with* stories (Clandinin, 2013, p. 29). As I assume this narrative understanding of the world, these stories become “narrative fragments” (Clandinin & Connelly, 2000, p. 17) of my lived experiences and are the starting point of my inquiry.

Clandinin (2013) has described these initial reflections as “narrative beginnings” (p. 55), where the researcher must position herself and her stories within the three-dimensional space of temporality, sociality, and place. My story of moving toward teaching science through the lens of sustainability and well-being did not simply begin with my graduate work. The three-dimensional space in which my story lives goes back in time to my stories of school as a child, my stories as a university science student and my stories as a young adult becoming ever more concerned about the state of the planet. The temporal dimension of my stories moves back to my years as a Faculty of Education student and as a young science teacher in a small rural community, while travelling forward to my future as I move toward teaching through the lens of sustainability and well-being. As well, these stories are not simply about me; they are told within larger cultural, social, and institutional stories. The sociality dimension of my stories is shaped by both personal and social conditions (Clandinin, 2013). Finally, as I tell and retell my stories, I pay close attention to the places in which these stories are rooted. The dimension of place is especially important for my narrative beginnings as I consider how my rural upbringing has played a role in shaping what Clandinin (2013) refers to as my “research puzzle” (p. 42). The next few paragraphs include some stories of my lived experiences, written as narrative fragments that have led me to my research.

**An awakening.** When I first began teaching, I was especially concerned about the state of the environment. As a young adult, I was becoming more environmentally conscious and was particularly alarmed by the problem of climate change. I had not learned about this issue until my third or fourth year of university; curiously, after watching Al Gore's *An Inconvenient Truth*. I remember watching the documentary, alone in my apartment one weekend, and proceeding to watch it a couple more times before the weekend was over. I remember feeling an overwhelming sense of concern, while simultaneously feeling a great appreciation for the planet on which we live.

At that time, I was an undergraduate student of physics and math and beginning to gain a sense of connection between the various fields of science, and, therefore, a greater understanding of the universe. Through this understanding, I began to feel more connected with the world and sought out experiences that further deepened these connections. In particular, I began to recognize the value of spending time outdoors; and it reminded me of all the time I had spent outdoors as a child, growing up on a farm.

**Reflecting on my childhood—connecting to family and place.** When I think of my childhood, I think about summer days playing with my siblings and cousins on the farm. Even today, as I drive home to the farm, feelings of peace and calm come over me. This place is very special to me, and I am grateful that I can share my childhood stories with my nieces and nephews, who are now growing up in this place that we all call home. As I re-tell and re-live my childhood stories on the farm, my stories of school and growing up in a small, rural community surface.

> This past September, my five-year-old niece started kindergarten. I can only imagine the excitement and anxiety felt by parents when they send their first born to school. I certainly sensed both feelings from my brother and sister-in-law. We all have stories of school; memories of experiences felt at a certain time and place and shared with certain

> people. When I think of my own stories of school, I go back to my hometown school; a school of roughly 200 students from Kindergarten through Grade 12. Both of my parents went to this school; along with many of my cousins, aunts, and uncles. As in most small, rural communities, the stories of school are interwoven with the stories of family. In many ways, I think this is why my niece going to school for the first time was so exciting; she happened to be going to the same school that most of my family has attended. Not only is she part of the next generation; she is now living her own story of school, which is embedded within her ancestors' stories, including mine. (Story of Remembered Experiences, Written on January 30, 2017)

I have only begun to fully appreciate these childhood "stories of place" as an adult. After graduating high school, I was excited to move to the city for university. But I never felt quite at home in the city. I knew that I would come back to the country to teach. As I took on my first teaching position, I knew that connecting with the community was important.

**My first year of teaching.** I clearly remember the phone call in which I received the news of being hired; I was very excited, but knew I had a lot of work ahead of me in the next couple of months—in order to be ready for the classroom in September. Throughout my university studies, I had been working in this community during the summers and felt some comfort in already knowing some of the staff, students, and parents. But I could sense that teaching and living in a small community would have both its ups and downs.

> I was very excited to have been offered a permanent high school position. I was a little wary about accepting a position within the community that I lived, particularly because I was taking over the position from someone who had taught at the school for over 30 years. This teacher was a legend in the community and an icon in the school. Many of my

> peers who grew up in the community associated the discipline of science with this teacher.
>
> As a new teacher I was excited about trying new things that I had learned in my Bachelor of Education program. I felt inspired to engage students in experiential learning opportunities and inquiry, although I was not exactly sure how this would work. This hesitation coupled with the pressure to maintain a traditional style of teaching within this particular classroom, led to feelings of ineptitude as a new teacher. Fortunately, I was very well supported by the administration and encouraged to take on some innovative projects. But, even though I received praise and accolades for the work I was doing, I still felt like I was not doing a good job. (Story of Remembered Experiences, Written on August 24, 2016).

While these feelings of incompetence surfaced throughout my first year of teaching, there were many times that I felt good about what I was doing. As I reflect on this now, these moments generally involved experiences in which students were engaging with outdoor environmental activities and connecting with the community:

> *We had a wonderful weekend… what a well-organized event! I made such great connections with other teachers/ educators- my mind is racing with possibilities for next year!* (Email sent to a colleague, Written on May 29, 2010)

I wrote this after coming home from a weekend spent with a small group of students at an outdoor environmental science competition. I remember feeling exhausted, yet invigorated. I knew that those experiences of collaborating with other educators in the community were going to lead to some exciting opportunities for me and my students. In particular, I remember speaking with another local science teacher about a curricular program in which his students were involved with the local conservation district, collecting water samples, and monitoring the water quality of the local river. I wanted my students to connect their classroom learning experience to their community. I was excited to pursue more of these opportunities, but still felt that I had some challenges ahead of me.

> Throughout my two-year education degree, I constantly heard about the concepts of "student-centered" and inquiry-based learning. As educators, we seem to agree that we want to establish this kind of environment in our classroom. I know that as I developed my "philosophy of teaching" as a student, I hoped that student-centered, inquiry-based learning would be established in my classroom.
>
> And, yet, as my first year of teaching is coming to a close, I know that this is not easy to accomplish. I found it easier (and more natural) to take on the traditional role of the classroom teacher. Of course, I tried to incorporate opportunities for inquiry and student-centered learning, but they occurred within the structure of a traditional class setting. For instance, students were asked to investigate an issue surrounding conservation and then present their findings in some way. They were encouraged to be creative and choose non-traditional forms of presentation. I ended up marking 5 papers and 2 PowerPoint presentations. To me, this showed that the students felt more comfortable with producing traditional forms of presentation—just as they would feel more comfortable with my traditional role as the teacher. (Reflection on my practice, Written on May 16, 2010).

Even in my first year of teaching, I could feel these tensions between my teaching philosophy and my practice. These tensions would continue to follow me into my graduate studies in Education for Sustainability and Well-being. In particular, I found myself questioning the role of science education in contributing to a sustainable society. I wondered about the possibilities afforded by teaching science through the lens of sustainability and well-being. I wondered about the constraints that existed within the educational system that would limit the possibilities for social change through education. I wondered about the history of formal science education and how its aims and purposes have evolved over time. I began to think critically about the role of science education in perpetuating ideologies that were not aligned with my understanding of "Education for Sustainability and Well-being". This critical perspective was rooted in my experiences as a teacher moving toward teaching science through the lens of sustainability and well-being. Ultimately, this brought about a need to explore the literature on science education, paying close attention to is aims and purposes.

# Chapter 2 Literature Review

When I think about the tensions that I have felt as a science educator, they often relate to the aims and purposes of education. Specifically, I find myself wondering about the goals of science education and how they contribute to the development of a sustainable society. As an education student, I studied the science curriculum and understood the goals of science education as described in the *Action Plan for Science Education in Manitoba*:

“Science education aims to:

- encourage students at all grades to develop a critical sense of wonder and curiosity about scientific and technological endeavors
- enable students to use science and technology to acquire new knowledge and solve problems, so that they may improve the quality of their own lives and the lives of others
- prepare students to critically address science-related societal, economic, ethical, and environmental issues
- provide students with a proficiency in science that creates opportunities for them to pursue progressively higher levels of study, prepares them for science-related occupations, and engages them in science-related hobbies appropriate to their interests and abilities
- develop in students of varying aptitudes and interests a knowledge of the wide variety of careers related to science, technology, and the environment” (Manitoba Department of Education, n. d.)

In particular, I found the first 3 goals to be especially important. In order to try to stay true to these goals, I created a document called "Developing our Philosophy of Teaching and Learning" that included philosophy statements such as:

> I believe that science education should inspire curiosity and encourage inquiry.
>
> I believe that science education should provide a historical and social context for the learning of concepts. (Personal artifact, created September 9, 2009).

However, at the time, I did not know how difficult it would be to achieve these aims. As well, I had not fully understood these goals as a means to foster "scientific literacy" in my students, as described in the Manitoba science curriculum. Truthfully, at the time, I am not sure I would have been able to explain what was meant by "scientific literacy". Even as a more experienced science teacher, I struggled with articulating this concept. This revealed a starting point of inquiry into the literature. In the following paragraphs, I will attempt to synthesize the literature on the goals of science education, beginning with the overarching aim of fostering scientific literacy in all students.

**Scientific Literacy for All**

Manitoba Education has adopted these 5 goals (stated above) from the *Pan-Canadian Science Framework*, released in 1997, which is "guided by the vision that all Canadian students, regardless of gender or cultural background, will have an opportunity to develop scientific literacy" (CMEC, 2013, p. 3). The Council of Ministers of Education, Canada defines "scientific literacy" as "an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them" (CMEC, 2013, p. 3). Although CMEC provides this description for the concept of scientific literacy, some argue that, in general, the concept of scientific literacy remains to be clearly articulated (Fensham, 2008; Milford et al., 2010; Murray, 2014). The vagueness of the concept, and lack of clear definition, makes it difficult to oppose; as Milford et al. (2010) suggest: “who would support illiteracy in science?” (p. 379). This provides a justification and route for reviewing the literature; understanding the origins of scientific literacy, reviewing conceptual underpinnings, while highlighting the points for critical consideration. The following paragraphs will further explore these ideas.

Murray (2014) traces the emergence of the concept of scientific literacy in the United States to an article written by Paul Hurd in 1958 titled *Scientific Literacy: Its Meaning for American Schools* (p. 43). In this post-*Sputnik* era, efforts were underway to reform science education for a society that needed to cope with rapid technological advancements and compete with international superpowers (Murray, 2014). In his article, Hurd argued for a “new kind of literacy” (Murray, 2014, p. 43) in order to understand the social, economic, and political problems of the time; and stressed that science education could “no longer be regarded as an intellectual luxury for the select few” (as cited in Murray, 2014, p. 43). Roberts (2007) affirms that scientific literacy, since its emergence, has signified a departure from a science curriculum that was primarily intended to prepare a select few students for careers in science. This notion of “scientific literacy for all” would become increasingly popular as the twentieth century progressed (Roberts, 2007) and attempts to define and assess scientific literacy continue to prevail in the literature.

Many authors describe scientific literacy in terms of two competencies: 1) understanding and using scientific principles to cope with daily living and 2) understanding and making decisions on socio-scientific issues (Zeidler et al., 2005; Ackay & Yager, 2010; Hodson, 2010). The latter competency is given a great deal of consideration in the literature and has been often cited as *science-technology-society (STS)* (Zeidler et al., 2005; Fensham, 2008; Ackay & Yager, 2010; Hodson, 2010; Murray, 2014) and *science-technology-society-environment (STSE)* (Hodson, 2010; Milford et al., 2010; DeBoer, 2011; Pedretti & Nazir, 2011; Murray, 2014) education. Pedretti and Nazir (2011) acknowledge that these can be viewed as distinct movements but have taken the position that they "all recognize the importance of broadly conceptualizing scientific literacy to include informed decision making; the ability to analyze, synthesize and evaluate information; nature of science (NOS) perspectives; the coupling of science, ethics, and moral reasoning; and agency" (p. 604). Ultimately, STS and STSE education are both meant to foster scientific literacy in all students (Ackay & Yager, 2010; Pedretti & Nazir, 2011). However, some authors have brought forward critical points for consideration.

**Competing aims of science education.** Fensham's (2008) report, commissioned by UNESCO to analyze emerging issues in science education policymaking, notes that one of the major issues in science education is getting the right balance between preparing enough students to pursue scientific/technological careers and giving all students the knowledge they need to understand and make decisions on socio-scientific issues. It seems that these are conflicting aims in science education. Roberts (2007) describes these two goals as different visions of scientific literacy and has named them *Vision I* and *Vision II* respectively (p. 730). Roberts (2007) explains how *Vision I* understands scientific literacy "by looking inward at the canon of orthodox natural science" (p. 730). In other words, scientific literacy is achieved by gaining a greater understanding of the knowledge and processes inherent in science itself (Roberts, 2007). In contrast, *Vision II* describes scientific literacy in terms of being able to use science and/or scientific thinking to make decisions, as citizens, about socio-scientific issues (Roberts, 2007). According to Roberts (2011), these two visions of scientific literacy have been in competition for a long time, which has resulted in the lack of a clear consensus regarding its meaning. Roberts (2011) also points out that these conflicting visions of scientific literacy can lead to diverging outcomes in science education.

**Scientific "illiteracy" as a deficit.** To further develop Roberts' (2007) conceptualization of scientific literacy, Lui (2009) makes the distinction between the concepts of *science literacy* and *scientific literacy*. According to Lui (2009), *scientific literacy* refers to the "approaches to achieving science literacy" (p. 302), while *science literacy* is the goal of science education. Although Roberts (2007) does not make this explicit distinction, he acknowledges the interchangeability of these terms, as well as the lack of consensus in the literature regarding their definitions. Lui (2009) attempts to build upon Roberts' (2007) heuristic understanding of scientific literacy by thinking critically about *science literacy* as the goal of science education.

According to Lui (2009), there are at least three flaws in the varying notions of *science literacy* as the goal of science education. He argues that the first flaw is based on the understanding of science literacy, using a "deficit model" (Lui, 2009, p. 305). This model assumes that there is a lack of science literacy in the general population and that this deficit must be corrected (Lui, 2009, p. 305). This model also ignores the fact that many who lack these scientific conceptions of the world may have developed their own knowledge and understanding of phenomena through personal experience, as well as cultural transmission of knowledge (Lui, 2009, p. 305). Although these understandings may not be aligned with scientific views, they still may be "functional" in everyday contexts (Lui, 2009, p. 305). Lui (2009) further explains how shifting these personal/cultural understandings of the world to scientific conceptions can be especially challenging for groups who have been historically marginalized by those who hold and privilege scientific worldviews. In light of this, Aikenhead (2006) suggests a reconceptualization of science education to include and validate other ways of knowing and understanding the world, in particular, when these worldviews have evolved from traditional Indigenous cultures.

**Scientific literacy as a standard of achievement.** Lui (2009) explains that the second flaw in understanding science literacy as a goal in science education is based on the idea that science literacy is “a state to achieve or commodity to acquire” (p. 306). As new initiatives are put in place to help students meet certain “standards” of science literacy, there is the perception that this outcome can be achieved by the end of a high school. The problem with this, as Lui (2009) suggests, is the notion that science literacy can be “achieved”. He cites Shamos’ 1995 book *The Myth of Scientific Literacy* which argues that “true science literacy cannot be achieved” (as cited in Lui, 2009, p. 204). Lui (2009) suggests that, rather than thinking about science literacy as a benchmark to reach, it should be thought of as life-long evolving process. This recommendation is also made in Fensham’s (2008) UNESCO report when he advises that policy makers should “consider replacing the generic use of ‘scientific literacy’, as a goal of science education, with more precisely defined scientific knowledge and scientific abilities, that have meaning beyond school” (p. 8). He also suggests that in later years of school there should be two course options available for students as their scientific literacy continues to develop: one for students who intend to take up future studies in science and one designed for all students as future citizens (Fensham, 2008, p. 8). He argues that this notion of *Science for Citizenship* has been helpful in redefining scientific literacy in the high school years (Fensham, 2008, p. 28). In DeBoer’s (2011) article on the globalization of science education, he analyzes “how standards are being used in a variety of countries to describe expectations for students" (p. 569). He notes that in the United States, common core initiatives attempt to bring more consistency to what students are learning (DeBoer, 2011, p. 572). In terms of science education, this could result in "grand-level mission statements… followed by lofty rhetoric about the importance of science education" (Fensham, 2009, p. 1083), such as CMEC's (2013) recommendation that all Canadian students will have the opportunity to develop scientific literacy. Fensham (2009) argues that the difficulty in linking these mission statements to what actually happens in the classroom "can mean their authoritative ring becomes a new justification for the traditional approach to the teaching and learning of science" (p. 1083).

**Scientific literacy as value-free.** This traditional approach to teaching and learning science leads us to Lui's (2009) third flaw in understanding science literacy as a goal of science education. He bases this third flaw on what he calls the "static model" (Lui, 2009, p. 305). This conception of science literacy is very closely related to Roberts' (2007) *Vision I* of scientific literacy in which there is a "one-way flow of information from the knowledgeable to the less knowledgeable" (Lui, 2009, p. 306). This becomes problematic when scientific literacy is perceived as value-free, universal, and without context (Roberts, 2007; Fensham, 2009; Lui, 2009). Fensham (2009) argues that this understanding of scientific literacy stems from the Anglo-american tradition of teaching discrete subjects, and within science education, separating disciplines of science into discrete units. He describes this as a vertical structure of schooling in which the "type of content for learning is set from top to bottom in a logical, developmental fashion" (Fensham, 2009, p. 1083). This leads to a view of scientific literacy that is based on understanding content for higher levels of study in science (Roberts, 2007; Fensham, 2009).

Many argue that this notion of scientific literacy results in the perception of science as being value-free and fails to recognize the political, cultural and social contexts in which science occurs (Zeidler et al., 2005; Roberts, 2007; Lui, 2009; Ackay & Yager, 2010; Hodson, 2010; Pedretti & Nazir, 2011). In order to overcome this flaw at the policy-level, Fensham (2009) suggests reconceptualizing the vertical structure of schooling as a horizontal structure in which the early years of schooling are devoted to extending the curiosity of young students and developing their inquiry skills (p. 1085). Later years of schooling would focus on investigating and making decisions on socio-scientific issues that students may encounter as citizens (Fensham, 2009, p. 1085). Fensham (2009) argues that this horizontal structure of science education is more aligned with Roberts' (2007) *Vision II* of scientific literacy which is derived from students' understanding and ability to make decisions on socio-scientific issues. However, the distinction between these two structures of schooling may not be so clear, as finding the right balance between teaching content, competencies, skills, and attitudes may be challenging (DeBoer, 2011). Roberts (2007) argues that these challenges stem from the inherent tensions in science education with respect to its (conflicting) aims.

**Aims of Science Education**

In order to further explore these tensions, I return to the aims of science education as stated in the *An Action Plan for Science Education in Manitoba*. This document states five aims in science education with the overarching goal of developing scientific literacy in all students (Manitoba Education, n.d.). For the purposes of this literature review, I have categorized the five aims into three broader ideas: 1) The nature of science and the affective domain, 2) Using science and technology to solve problems (STSE education), and 3) Science for career preparation and participation in a globalized knowledge economy. As I surveyed the literature on the aims of science education, I have sought out sources that refer to these broader ideas, including how they are represented in schools. By comparing and contrasting these ideas, I hope to uncover points for critical reflection. The following paragraphs will explore these ideas further.

**The nature of science and the affective domain.** According to Manitoba Education (n.d.), “science education aims to encourage students at all grade levels to develop a critical sense of wonder and curiosity about scientific and technological endeavors”. As a beginning teacher, I agreed with this sentiment when I developed my “philosophy of teaching” and wrote: “I believe that science education should inspire curiosity and encourage a sense of inquiry” (Personal artifact, created September 9, 2009). This notion of science education appealing to the affective domain of students has been explored by many authors (Zeidler et al., 2005; Fensham, 2008; DeBoer, 2011; Pedretti & Nazir, 2011). Aikenhead has termed this kind of science education as “humanistic school science” (as cited in Fensham, 2009, p. 21). Compared to traditional science education, a humanistic view of science is value-centered and inclusive of alternative forms of knowledge (Pedretti & Nazir, 2011). It also promotes cognitive and moral development (Zeidler et al., 2005; Pedretti & Nazir, 2011) as students explore locally relevant socioscientific issues (Zeidler et al., 2005; Ackay & Yager, 2010; Hodson, 2010; DeBoer, 2011). Developing the natural curiosity and creativity of young learners in this way allows for a greater appreciation for science itself and a better understanding of the nature of science (Fensham, 2008; Pedretti & Nazir, 2011).

Understanding the nature of science and appreciating its power and limitations is, in itself, often cited as an important aim of science education (Zeidler et al., 2005; Fensham, 2008; Lui, 2009; Hodson, 2011). In Fensham’s (2008) UNESCO report on emerging issues in science education policymaking, he recommends that "policy makers should consider what will encourage a better balance between teaching science as established information and those features of science that are referred to as the Nature of Science" (p. 7). Many authors have written about the nature of science (NOS) and how it is or could be represented in science education (Abd-El-Khalick & Lederman, 2000; Zeidler et al., 2005; Fensham, 2008; McComas, 2008; Milford et. al, 2010; Roberts, 2010; Hodson, 2011; Pedretti & Nazir, 2011). In trying to clarify the meaning of NOS, Fensham (2008) makes the distinction between knowledge *of* science and knowledge *about* science (p. 25). Knowledge *of* science refers to knowledge about the natural world, whereas knowledge *about* science refers to knowledge about science procedures, such as inquiry (Fensham, 2008, p. 25). He argues that open-ended investigations are still scarce in science education and that structured "recipe"-like experiments, that do not fairly represent the nature of science, are more common (Fensham, 2008, p. 25). Hodson (2011) agrees that "it has been consistently reported that both students and teachers have inadequate, incomplete or confused NOS understanding" (p. 39).

These misunderstandings about the nature of science may stem from a lack of awareness and understanding about the historical and social contexts in which scientific thinking emerges (Lederman, 1998). I understood this as a beginning teacher when I wrote in my "philosophy of teaching" that "science education should provide a historical and social context for the learning concepts" (Personal artifact, created September 9, 2009). At the time, I had not yet read the papers of William McComas (2008) who describes the nature of science as a "rich description of science; how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors" (McComas, 2008, p. 250). However, I recognized how my understanding of science concepts grew stronger as I learned more about the history of science and how it works. Abd-El-Khalick and Lederman (2000) affirm that teaching about the history of science can reveal, for students, insights into the nature of science; however, they caution that it may not provide a full understanding of how science works. They suggest that explicitly teaching about the nature of science while providing historical examples may be more effective (Abd-El-Khalick & Lederman, 2000).

My understanding about the nature of science strengthened as I learned more about the history of science in both formal and informal settings. It is important to acknowledge that students often learn about science outside the classroom and that this "informal" learning may be even more meaningful and rich. Lui (2009) suggests that bridging formal and informal science education and connecting students learning to outside the classroom could lead to a greater appreciation for science and better understanding of the nature of science. By engaging in truly open-ended inquiry, students appreciate the interplay between science and society and become better adept to make decisions on socioscientific issues and solve problems (Fensham, 2008; Hodson, 2010, 2011). As well, students begin to understand the ethical issues that arise from scientific and technological advancements, while recognizing the limitations of science in solving the world's problems (Hodson, 2011). This moves away from a "dehumanized and decontextualized" view of science (Pedretti & Nazir, 2011, p. 611) toward one that is relevant to the students and their communities. By engaging in inquiry on locally relevant socioscientific issues, students gain a greater "intrinsic appreciation" for the pursuit of science (Pedretti & Nazir, 2011, p. 610). As students become more engaged in these inquiries, they begin to recognize opportunities to solve problems and take action on these issues.

**Using science and technology to solve problems (STSE education).** *An Action Plan for Science Education in Manitoba* states that developing scientifically literate individuals that can “more effectively interpret information, solve problems, make informed decisions, accommodate change and create new knowledge” is of utmost importance (Manitoba Education, n.d.). This notion of using science and technology to solve problems is reiterated in its aim to “prepare students to critically address science-related societal, economic, ethical and environmental issues” and “solve problems so that they may improve the quality of their own lives and the lives of others” (Manitoba Education, n.d.). This aim of science education emerged from the need to make science learning more relevant to students (Pedretti & Nazir, 2011). According to Murray (2014), by the 1970s, a need to include technology, environmental and ethical issues in science education became evident. Yager (2000) describes this as a time of great political, social, and environmental crises (p. 51), and so it was time to include societal issues and decision-making in the science curriculum.

Murray (2014) calls this “trajectory” in science education the “science – technology – society humanistic science movement” (p. 25). This movement in science education has also been called the *STS* (science-technology-society) movement (Zeidler et al., 2005; Fensham, 2008; Ackay & Yager, 2010; Hodson, 2010; Murray, 2014) and, more recently expanded to *STSE*, where “E” stands for environment (Hodson, 2010, p. 198). Pedretti and Nazir (2011) have reviewed the literature on STSE education over the past 40 years and found that, although this slogan has been adopted for a variety of purposes (p. 602), there are six main currents that arise within the discourse of STSE: application/design, historical, logical reasoning, value centered, sociocultural, and socio-ecojustice. Ultimately, this movement recognizes the role of science in society and the potential for scientific/technological advancements to solve problems (Fensham, 2008; Ackay & Yager, 2010; Pedretti & Nazir, 2011).

DeBoer (2011) points out that "science and technology provide opportunities to find solutions to global problems, and the search for and training of technical talent should be an international effort" (p. 570). This perspective on the "globalization" of science education (DeBoer, 2011) is optimistic about the role of science education in preparing students for the challenges of the 21st century. However, Zeidler et al. (2005) are critical of the STS/STSE movement since, although it "stresses the impact of decisions in science and technology on society, it does not mandate explicit attention to the ethical issues contained within choices about means and ends, nor does it consider the moral or character development of students" (p. 359). They suggest a "socioscientific issues" (SSI) approach to science education that accordingly expands on the STS/STSE movement (Zeidler et al., 2005). Hodson (2010) further builds on this by suggesting a "much more radical, politicized form of SSI-oriented teaching and learning" in which students "engage in sociopolitical actions that they believe will make a difference" (p.199). The acknowledgement of moral and ethical concerns within science and taking action to improve the quality of lives of others, ultimately, promotes the aim of science education for effective global citizenship (Fensham, 2008; Ackay & Yager, 2010; Hodson, 2010; Milford et al., 2010; Aikenhead et al., 2011; DeBoer, 2011; Pedretti & Nazair, 2011). Some argue that this aim is indeed part of the STS/STSE movement (Ackay & Yager, 2010; Pedretti & Nazir, 2011).

In any case, these goals of science education seem to be articulated in *An Action Plan for Science Education in Manitoba*. Fensham (2009) describes these various influences on science education as "demands" (p. 1079). He argues that although the *cultural, social, individual,* and *environmental* demands on science education (as described in the STS/STSE/SSI movements) are often "given prominence in the preambles to a curriculum" (p. 1079), they are not fairly represented in the curriculum's content and its assessment (Fensham, 2009). Rather, science content and assessment are largely influenced by *political*, *economic*, and *subject maintenance* demands (Fensham, 2009). This brings forward another aim of science education: preparing students for careers in science and to participate in a knowledge-based economy.

**Science for career preparation and participation in a globalized knowledge economy.** The last two aims described in *An Action Plan for Science Education in Manitoba* focus on preparing students for science-related occupations by creating awareness about the wide variety of careers in science and preparing students for progressively higher levels of study in science. Although Fensham (2009) argues that these demands on science education "carry much more weight in determining the details of a curriculum's content and its assessment" (p. 1079), it has been noted that these aims of science education are not widely studied in the science education research community (Fensham, 2009; Milford et al., 2010). However, the goal of preparing students for careers in science has been part of the discourse of science education for decades.

Murray (2014) describes three "trajectories" (p. 24) of science education since the 1950s: 1) science education in the national interest (in particular, preparing students for careers in science to establish scientific superiority over other nations), 2) STSE movement (as described previously), and 3) science education influenced by factors of globalization and international assessments. According to Murray (2014), Canada has taken up this third distinct pathway since the 2000s, when the influences of globalization have become ever more apparent. In particular, this notion of science in the national interest has morphed into the neoliberal aim of achieving economic superiority within a globalized knowledge-based society (Murray, 2014). Aikenhead, Orpwood and Fensham (2011) have explored the role of science education for a knowledge society that functions under a "knowledge-based economy", in which jobs, especially science-related occupations, are under constant change, "driven by new forms of information technology, design requirements, and technology transfer" (p. 29). They found that scientific literacy in a knowledge society is much more about knowing how to learn, rather than accumulating knowledge (Aikenhead et al., 2011). These skills, or competencies, are necessary for economic competitiveness in a global economy (Aikenhead et al., 2011; DeBoer, 2011).

The aim of preparing students for science-related occupations is noted as an important goal for 21st century science education (Fensham, 2008). Fensham (2008) recommends that schools, particularly at the high school level, need to inform students and their parents about the "exciting prospects of science-based careers" (p. 7). This idea of creating awareness around science-related careers is often termed "STEM education", which includes careers in science, technology, engineering, and math (DeCoito, 2016). In DeCoito's (2016) knowledge synthesis of STEM education in Canada, she found that, although there were a number of STEM initiatives implemented across Canada in the last ten years, there was little research conducted on their effectiveness in terms of attracting students to careers in science. According to DeCoito (2016), this is problematic, since Canada is experiencing a "crisis" in terms of filling STEM careers, which threatens the country's global competitiveness (p. 114). However, there is an apparent "lack of commentary by various provincial and territorial ministries of education on STEM education in the school system" (DeCoito, 2016, p. 123).

In Murray's (2015) summary of his national study on the future of science education in Canada, he demonstrates that STEM education, or preparing students for careers in science to increase international competitiveness, was of overall low priority compared to other aims (such as those previously described). This may be because STEM education is in opposition to the goal of science education for sustainability (Murray, 2014), which seems to be of greater concern to the participants of his study (Murray, 2015). In particular, the concern of “science education as now being in the interests of the private sector and its globalizing economic agenda” arises (Murray, 2014, p. 58), as DeCoito (2016) reports that major technology companies are supporting STEM initiatives in Canada (p. 123). However, some argue that preparing students for careers in science could indeed lead to solving global problems, as the trend of globalization lends itself to greater international cooperation (Ackay & Yager, 2010; DeBoer, 2011).

The globalization of science education has had a number of effects on the policies and practices within science education (DeBoer, 2011; Fensham, 2011). Firstly, an increased interest and participation in large-scale international assessments has played a role in the development of the discourse on the aim of science education for global citizenship (Fensham, 2008, 2009, 2011; Aikenhead et al., 2011; DeBoer, 2011; Murray, 2014). Although these large-scale international assessments are often used to argue for the improvement of science education in order to gain an economic advantage over other countries, DeBoer (2011) argues that international standards could help “identify the most important science knowledge and skills for global citizens to have” (p. 568). Thus, globalization of science education could result in increased collaboration and cooperation among countries to solve global problems (DeBoer, 2011; Fensham, 2011).

As international efforts are underway to solve science-based issues, preparing students to become the next generation of scientists may be an important undertaking (Fensham, 2009). In fact, science-related career awareness and preparation have been described as an important component of the STS (science-technology-society) movement (Ackay & Yager, 2010). But some argue that this notion of science education for career preparation may be viewed as a departure from the aim of science education for effective global citizenship as described in the SSI-orientation of science education (Zeidler et al., 2005; Hodson, 2010). It may also seem to not align with the aim of science education as developing the moral and ethical characters of students so that they can make decisions on socioscientific issues and use science to improve the quality of their lives and the lives of others (Zeidler et al., 2010). This disagreement in the literature reveals a point of tension that I intend to further explore in my research.

**Conclusions and Next Steps: Science Education for Sustainability and Well-being**

In this chapter I have explored the literature on the aims of science education, including the overarching aim of fostering scientific literacy in all students. As I reviewed the relevant literature, I found that discussions around the role of science education in contributing to a sustainable society were commonplace. In particular, the discussions surrounding the STSE, SSI and humanistic science movements all seem to align with my conceptions of education for sustainability and well-being. However, upon writing this review, I felt that I needed to delve more deeply into what is meant by education for sustainability and well-being in order to more fully understand the role of science education in contributing to a sustainable society. This intention for further inquiry led me to a research methodology that encompasses these questions, while considering my narrative understanding of experience.

# Chapter 3 Methodology

The literature on the aims of science education brings forward interesting questions to consider. Are all of these aims equally important? How do practicing teachers understand these goals? What are the limitations and possibilities that exist as educators seek to achieve these aims? In particular, I am interested in how these goals of science education align with a "pedagogical stance" (Poggi, Errico & Leone, 2003, p. 3233) of teaching through the lens of sustainability and well-being; and how this unfolds in a high school science classroom. This chapter will describe the methodology with which I explored some of these questions, including the personal, practical and social justifications (Clandinin, 2013) for my research.

## Coming to the Research: An Educator's Pedagogical Stance

> As a graduate student within the Education for Sustainability and Well-being cohort, I began to think critically about the role of science education in the development of a sustainable society. Although the policies and practices surrounding science education have expanded to consider issues of social, cultural, and ecological sustainability (Fensham, 2011; Milford, Jagger, Yore, & Anderson, 2010; Murray, 2014; Pedretti & Nazir, 2011; Yager, 2000), I felt uncertain about the impacts of this expansion. In particular, I was concerned about the prevalence of the academic achievement discourse (Armstrong, 2006) within science education; as well as the predominantly Eurocentric lens through which science is taught (Aikenhead, 2006; Battiste, 2013). And, although Manitoba Education has identified Education for Sustainable Development as a top priority, including its integration within science (Manitoba Education, n. d.), I was left wondering about what this could mean. As I began to think critically about education for sustainability and the lack of clarity regarding its meaning (Jickling & Wals, 2008), I also

> wondered about the issues of power, privilege, and race that are rarely brought forward within the discourse of sustainability education (McLean, 2013; Willow, 2010). (Surfacing Tensions: Teaching Science through the Lens of Sustainability and Well-being, Unpublished manuscript, Written on August 13, 2016)

These questions and concerns have arisen largely as a result of my graduate studies within the Education for Sustainability and Well-being cohort. I entered the program with the hope that science education could contribute to the development of a sustainable society. As a cohort, we were asked to think critically about the role of education in the development of a sustainable society. Throughout the program, I have reflected on my role as a high school science educator and have thought about the possibilities and constraints that arise within this role. As my graduate studies progressed, I have seen myself as moving toward teaching science through the lens of sustainability and well-being. As I reflected on what this meant in terms of my pedagogy, I sought to make changes to my practice that were more aligned with this stance.

The concept of "pedagogical stance" is useful in this context as teaching science through the lens of sustainability and well-being includes more than the delivery of curricular content by the teacher. Poggi, Errico, and Leone (2003) have defined "pedagogical stance" as the "stance taken by a teacher toward pupils while interacting with them in his/her role of teacher" (p. 3233). This stance must be congruent with the goals of the teacher within their professional role (Poggi et al., 2003). Therefore, as I move toward teaching science education through the lens of sustainability and well-being, my pedagogical stance is based on the goal of contributing to the development of a sustainable society.

**The research puzzle.** With this goal in mind, I have become aware of surfacing tensions. Although I have only begun to articulate this pedagogical stance more recently, I have been aware of these tensions throughout my career. As I tell my story of moving toward teaching science through the lens of sustainability and well-being, I try to make sense of these tensions. I have thought about these wonderings as a *research puzzle* (Clandinin & Connelly, 2000, p. 41) as I embarked on an autobiographical narrative inquiry to understand these tensions. Clandinin (2013) defines narrative inquiry as "an approach to the study of human lives conceived as a way of honoring lived experience as a source of important knowledge and understanding" (p. 17). In this sense, an autobiographical narrative inquiry seeks to understand the lived experience of the inquirer (Clandinin, 2013). Clandinin (2013) explains how "framing a research puzzle is part of the process of thinking narratively as well as something that is central to the research design process" (p. 42). She identifies it as the first design consideration in planning a narrative inquiry (Clandinin, 2013). In the next paragraphs, I will further describe the research methodology of my inquiry, while bearing in mind the "seven design considerations" of narrative inquiry: 1) research puzzles rather than research questions, 2) entering in the midst, 3) from field to field texts, 4) from field texts to interim research texts, 5) from interim research texts to research texts, 6) the importance of the relational, and 7) positioning of narrative inquiry (Clandinin, 2013, p. 42-52).

**Method of the study.** Clandinin (2013) describes the second design consideration of narrative inquiry as "entering in the midst" (p. 43). This recognizes that, as narrative inquirers, we enter into research relationships in the midst of our personal, professional and academic lives (Clandinin, 2013). As I developed my narrative beginnings, I began to "inquire into various field texts" (Clandinin, 2013, p. 43), such as photographs, memory box items, and written work from my previous studies in education. This allowed me to further frame my research puzzle and led me to explore the relevant literature on the aims of science education. As well, I began to imagine how the study would unfold, while considering the personal, practical, and social justifications of my inquiry (Clandinin, 2013).

***Constructing research texts*.** Thinking about my autobiographical narrative inquiry as a chronological learning trajectory will allow me to make distinctions about my past, present and future developments as a learner. This temporal dimension of my inquiry is rooted in Dewey's view of experience on a continuum, and that "experiences grow out of other experiences, and experiences lead to further experiences" (Clandinin & Connelly, 2000, p. 2). This notion was crucial as I began to construct experiential research texts, paying close attention to the three "commonplaces" of narrative inquiry—temporality, sociality, and place (Clandinin, 2013, p. 39). The third, fourth, and fifth design considerations of narrative inquiry led me to the construction of research texts which included an investigation and articulation of present learning (Clandinin, 2013). The next few paragraphs explain this process in more detail.

Over the last couple of years, as I was "in the midst" of my learning and living alongside my story, I needed to move from the field to *field texts*—this is the third design consideration of narrative inquiry (Clandinin, 2013). Narrative inquirers use this term (rather than *data*) "to signal that the texts we compose in narrative inquiry are experiential, intersubjective texts rather than objective texts" (Clandinin, 2012, p. 46). I began by examining the field texts that I produced over my two years as a graduate student, such as response journals, assignments and final papers. As well, I examined one year of field texts that I produced as I moved toward teaching science through the lens of sustainability. I used voice-to-text technology to create daily reflections on my teaching, along with a weekly written reflection. Throughout this time, I was also aware of the "multiple ways to tell and live experiences" (Clandinin, 2013, p. 46), inquiring into a diversity of field texts. As I began to analyze the field texts, I looked for "moments of tension as places of inquiry" (Clandinin, 2013, p. 76). This allowed me to develop "interim research texts" (Clandinin, 2013, p. 47).

Moving from field texts to interim research texts is the fourth design consideration of narrative inquiry. At this point, it was important to continue to think narratively and "attend closely to the field texts within the three-dimensional space" (Clandinin, 2013, p. 47). In other words, I needed to continue to think about my story in terms of temporality, sociality, and place. As I developed my interim research texts, I considered this diagram which was created by Katherine Devlin (2012) to help her understand the three-dimensional space of her autobiographical narrative inquiry:

Figure 1: Three-dimensional Space of Narrative Inquiry

> In the diagram, the grey circle represents the place in time of the experience, while the black circle represents the people who are present during the experience. The inward exploration is the internal process of people, their thoughts, hopes, feelings, and values. The outward exploration contains the physical and social environment, what is seen, what is heard, and what actions take place. The arrows represent backward and forward spaces which allow the researcher to examine the past, the present situation, and give value to the future (Clandinin & Connelly, 2000, p. 50). Through the three-dimensional inquiry space, the researcher is able to explore and understand experience in deeper ways. (Devlin, 2012, pp. 39-40)

As I further developed these interim research texts, it was helpful to think about Downey and Clandinin's (2010) metaphor of a shattered mirror:

> In narrative inquiry, we do not intend to reassemble the bits but rather to enter the strewn bits of a person's life in the midst and in relational ways, attending to what is possible in understanding the temporal, social, and place dimensions within an ongoing life. (as cited in Clandinin, 2013, p. 48)

In other words, as I began to develop final research texts—the fifth design consideration of narrative inquiry—I was careful in how I analyzed my field texts to construct these final texts. It may be tempting to dissect and search for common themes "to develop or confirm existing taxonomies or conceptual systems" (Clandinin, 2013, p. 52). However, this is not the intention of narrative inquiry (Clandinin, 2013). Rather than trying to create smooth coherent texts, I recognize that the power of narrative inquiry is its ability to make the "complexity of storied lives visible" (Clandinin, 2013, p. 50). I am conscious of the pervasive desire to understand the world through dissection and categorization, and I am especially aware that this has largely arisen from a Eurocentric worldview that privileges the scientific method as a means for research. Autobiographical narrative inquiry provides an alternative to this kind of research as it honors the lived experience of the inquirer as a valid source of knowledge and understanding (Clandinin, 2013).

***Ethical considerations.*** The ethical issues surrounding narrative inquiry are largely relational, and the importance of negotiating relationships within the research puzzle is the sixth design consideration of this methodology (Clandinin, 2013, p. 51). Although I embarked on an autobiographical narrative inquiry, I am aware that this study affects my students; and my students affect the study. As I shift my practice, moving toward teaching science through the lens of sustainability and well-being, I must attend carefully to how I have changed throughout the inquiry (Clandinin, 2013). As well, I realize that I will continue to change long after the inquiry is complete; as I continue to live, tell, retell, and relive my stories. Clandinin (2013) makes a comparison between narrative inquiry and the slow food movement, calling it a "slow research methodology" (p. 51). For this reason, it was important to take my time when moving from field texts to interim research texts to final research texts, recognizing that this is not a simple linear process. Sometimes, new wonderings may arise, requiring further inquiry into field texts and uncovering untold stories.

***Positioning final research texts.*** As I composed my final research texts as laid out in the following chapters, it was important to remember that in narrative inquiry "final research texts do not have final answers, because narrative inquirers do not come with questions" (Clandinin, 2013, p. 51). This brings me to the seventh design consideration of narrative inquiry which positions this kind of research within a Deweyan understanding of experience (Clandinin, 2013). Dewey's two principles of experience—continuity and interaction—are reflected in the three-dimensional narrative inquiry space of temporality, sociality, and place (Clandinin, 2013, p. 12). Although the final research texts must attend carefully to each of these commonplaces, it is important to recognize that the knowledge developed from narrative inquiry is "textured by particularity and incompleteness" (Clandinin, 2013, p. 52). However, these limitations of the research do not diminish its ability to enact change; which brings forward the justifications for this inquiry.

***Personal, Practical & Social Justifications*.** According to Clandinin (2013), narrative inquirers must be prepared to justify their research purposes, while attending to the questions of "So What?" and "Who Cares?" (p. 35). These questions should be considered in terms of personal, practical and social justifications (Clandinin, 2013). As I engaged in narrative beginnings, the personal justifications for this inquiry revealed themselves. I recognized and articulated some of the tensions that have surfaced as I am moving toward teaching science through the lens of sustainability and well-being. I felt that I needed to make sense of these tensions and examine them more fully in order to truly shift my practice toward this pedagogical stance.

This brings forward the practical justification for this inquiry in which I "attend to the importance of considering the possibility of shifting, or changing, practice" (Clandinin, 2013, p. 36). As I shifted my practice and adopted a pedagogical stance of teaching for sustainability and well-being, my research texts may create an opportunity for other educators to reflect on their practice. After all, these texts are intended to engage audience in "resonant remembering as they lay their experiences alongside the inquiry experiences" (Clandinin, 2013, p. 51).

Finally, social justification may be thought of as "theoretical justifications, as well as social action, and policy justifications" (Clandinin, 2013, p. 37). The products of my learning through this autobiographical narrative inquiry would be useful to anyone thinking about the role of science education in the development of a sustainable society. As science education continues to hold a privileged status as a discipline and sustainability education becomes increasingly popular, this autobiographical narrative inquiry could shed light on the possibilities and limitations that are afforded by these educational domains. Ultimately, as I tell my story, others may see their stories in mine and begin to "rethink and reimagine the ways in which they practice and the ways in which they relate to others" (Clandinin, 2012, p. 51). Conference presentations and writings in popular teacher journals would help to make the knowledge more accessible for those in the field, while potentially giving pause to those engaged in relevant policymaking.

**Chapter Summary**

As I continue to think critically about science and sustainability education, I wonder about the possibilities and limitations that are afforded by moving toward teaching science through the lens of sustainability and well-being. In this chapter, I have explored the pertinent design considerations for an autobiographical narrative inquiry that would allow for a deeper examination of this research puzzle. Through this exploration, I have come to understand narrative inquiry as “both the phenomenon under study and the methodology for its study” (Clandinin, 2013, p. 216). As such, it is both a worldview and theoretical framework for understanding experience. As Dewey understood experience through interaction and continuity, narrative inquirers build upon this theory, situating their stories within the three-dimensional space of sociality, temporality, and place (Clandinin, 2006).

At this point, it is important to acknowledge that I have made a conscious choice in narrative inquiry as the research methodology for my study. Not only does this paradigm align with my own worldview of thinking *with* stories (Clandinin, 2013, p. 29), it also provides an alternative to a positivist pursuit of knowledge. As a high school science teacher, I am aware of the positivist nature of science and, as I move toward teaching science through the lens of sustainability and well-being, I wonder about the possibilities of validating other ways of knowing and understanding the world (Aikenhead, 2006) within my practice. For this reason, I believe that it is important for me to engage in narrative inquiry as a “methodological response”

(Clandinin, 2006, p. 45) to positivism. In the end, I have no doubt that engaging in this kind of inquiry would have important personal and practical benefits. As well, I believe that it could bring forward important considerations for others who are trying to make sense of the role of science education in contributing to a sustainable society.

# Chapter 4 Inquiring into My Stories, September 2018 - April 2020

## Introduction

As a narrative inquirer, my research is based in the study of my experience. For approximately 18 months, I reflected regularly on my day-to-day classroom experiences, either in writing or orally. Through these reflections, I was hoping to uncover moments of tension that would lead to further inquiry into my stories. What follows are three narrative vignettes that have led me to consider more deeply the role of science education in a sustainable society. In the first narrative vignette, tensions around scientific literacy arise when I consider how to best help students understand the nature of science. In the second narrative vignette, tensions around the inherent Eurocentrism in science education become apparent when I think about the privileging of science as a knowledge system. In the third narrative vignette, tensions around science content and knowledge specialization reveal themselves when I think about how I can present science content within a unified story of our place in the universe. Although these narratives stem from distinct points of tension, as I inquire into and unpack these stories, I uncover overlapping ideas. However, rather than searching for themes, I will attempt to make sense of these ideas by continuing to think narratively and to consider the progression of my understanding within the three-dimensional space of narrative inquiry.

My reflections largely focused on a particular course that was new to my teaching assignment, one that gave me greater freedom and opportunity to take risks with my teaching and further explore questions that arose in the midst of my research. However, as a narrative inquirer, I am mindful that my reflections on this particular classroom experience do not occur in isolation from the larger three-dimensional space in which all experience is rooted. As these field texts developed into research texts, it was important to situate the narrative within the three dimensions of temporality, sociality, and place. In other words, the research texts have been constructed not only by reflecting on the story within the narrative, but also the stories of my past, present and future, while considering the role of people and places within these stories. In the end, as I make meaning from these stories and experiences, I move closer to connecting the pieces of my research puzzle and closer to understanding what it means to teach science through the lens of sustainability and well-being.

**Narrative Vignette 1: The first day of class (September 9, 2019)**

Today was the first day of class. I was nervous as I read over the class list, as I knew there were a lot of students with special academic and behavioural needs. I prepared a seating plan, but as usual, there were changes. Some students didn't show up, while some that weren't even on the class list arrived. Fortunately, I received an additional education assistant (EA) to help with the students with extra needs. I started the class by asking the students to brainstorm a list of science topics that interest them. Some students were able to come up with a good list, but most struggled with coming up with even a few topics that they may be interested in. I moved on and started going over the course outline which explains how the purpose of this class is to "encourage curiosity" and "develop scientific skills and attitudes". As I was going over this, I couldn't help but wonder: *do they have any idea what I'm talking about*?

**Unpacking: The first day of class**

This was going to be my second attempt at teaching a course that, rather than focusing on scientific content knowledge, focused on scientific literacy, skills, and attitudes. The course, called Current Topics in the Sciences (TIS), has far fewer "specific learning outcomes" than a typical high school science course, and they all fall under the “general learning outcomes” for scientific literacy in Manitoba. At this point, I had already delved into the literature on scientific literacy and had a pretty good understanding of the outcomes of scientific literacy as presented by Manitoba Education. But my inexperience with designing and teaching a course focused completely on fostering scientific literacy made me uneasy. However, I also felt empowered and excited. For too many years, I had focused on content knowledge, and this led me to question the value of what I was doing. In the early years of my career, it was hard not to feel discouraged when I was exhausted, overworked and overwhelmed with the numerous daily to-dos. I felt like I wasn’t doing a good job, or at least, I wasn’t doing what I had set out to do.

What had I set out to do? Fortunately, through the process of my graduate studies, I had the opportunity to reflect upon this question at length. I went back to my days as an education student when I developed a “philosophy” of teaching. I found that I had written that I believed that “science education should encourage a sense of curiosity within my students”. Now I found myself 11 years later, teaching a course specifically designed with this purpose. And on this first day of class, I discovered that many of the students struggled to even come up with a list of topics that they may be interested in.

To be honest, I was not completely shocked by this, as it was not my first attempt at trying to uncover students’ curiosity about science and the natural and physical world. Over the past years, I often began science courses with a question such as this. In many of these courses, I would include an opportunity for students to nurture this curiosity, by providing them opportunities to pursue “inquiry projects” alongside the curricular content, for which they could research, read, and write about a topic that interested them. We would regularly talk about “science in the news” so that students would have the chance to explore and consider science topics that were relevant and current. As well, students were given the opportunity to explore their interests and show their learning in a variety of ways. But, somehow, this was not quite enough. It felt a little too superficial.

As I reviewed the literature on scientific literacy, this notion of the "nature of science" continued to come up repeatedly. Of course, I had heard of this "nature of science" outcome in scientific literacy, but, for some reason, had failed to pay much attention to it. In fact, it did not appear in my early "philosophy of education". I am not sure exactly why that was. Perhaps, because I had not been taught about "the nature of science", and/or I wasn't exactly sure how I could teach it myself. But I knew that, in this age of "fake news" and public skepticism toward science, this was an important concept. As I was developing the TIS course, the question of "How do we know what we know?" came up in a YouTube video I watched on the History of Science (CrashCourse, 2018). And I knew immediately that this needed to be a central question in the course.

In fact, this was not the first time that variations of this question had been posed by my students. It tends to come up when the students are confused about what they are learning. Not confused in a sense that they don't know how to solve a problem or perform a task but confused in a way that their current worldviews are somehow being challenged. It especially tends to arise when those "big questions" about the world and universe are addressed. For example, when I teach about the Big Bang and the origin of the universe, almost always, students will ask the question, "How do we know that?". Unfortunately, because we tend to be pressed with time in a typical science class, my answer goes back to the evidence that we have previously discussed, such as Hubble's discovery that galaxies are moving away from us, which eventually led to the development of this theory. But, because students may not have a clear understanding of how science actually works, this explanation is not sufficient. It presents the answer as merely a fact and fails to capture the true nature of science. One of the "specific learning outcomes" in the TIS curriculum partially addresses this concern by "recogniz(ing) both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena" (Manitoba Education, n.d.).

In the beginning of my career, I tried to shed light on this by highlighting the historical contributions that led to the development of the various theories and concepts that we were discussing. Afterall, learning about the history of science, played a large role in my interest and curiosity about science, and I will discuss this in further detail when unpacking vignette #2. Because I devoured books and videos on this subject, I had a fairly good understanding of how science worked, but I began to question whether my students had this same understanding from the short snippets of "stories" that I told in class. I began to wonder whether there was another way to teach students about the nature of science. Perhaps they needed to experience the actual doing of science themselves.

**Teaching the nature of science through experience.** In my literature review, I had the opportunity to explore in depth the concept of "the nature of science". This has allowed me to critically reflect on how I incorporate this important aspect of scientific literacy into my science courses. For one, I do not believe that I spend enough time on this concept. Especially in the courses that have quite a dense curriculum with the majority of learning outcomes relating to specific science knowledge; I tend to focus on teaching and assessing this knowledge. The issue with this is that students do not have the opportunity to fully explore and appreciate the power and limitations inherent within the nature of science. Rather, they tend to see science as established information. They may have great knowledge *of* science, but very little knowledge *about* science. I believe that this is especially concerning in a time when information is so readily accessible. If students do not fully understand how science is conducted, they may struggle with thinking critically about scientific topics and issues that they regularly encounter in the media.

With all this said, the question that remained was how should I go about teaching the nature of science? I vaguely remember being tested on the scientific method when I was in high school. And one of the first posters I put up in my first year of teaching was one with the steps of the scientific method. However, in the first 10 years of my career, I rarely referenced it. I knew that I should be spending more time on this, but I did not think that presenting it as a list of discrete linear steps and testing the students' knowledge on these steps would be worthwhile. Afterall, I understood that “how science worked” was much more complex than how it was presented in this poster.

I know that some of the best ways for students to learn about something is through experience. It seems intuitive that the nature of science would be best taught through experience. In fact, when I think about how I have incorporated the nature of science in my courses, I tend to think about the labs and experiments I prepared for my students to reinforce the course content. After all, it gave students some exposure to the stages of a scientific investigation. However, I knew that this was really a superficial way to understand the workings of science. Fensham (2008) describes this as when science teachers lean toward using recipe-like experiments that will give expected results. I have found these activities to be valuable in consolidating content knowledge, but I am not sure they gave my students any greater understanding about the nature of science.

I wondered if allowing students the opportunity to come up with their own questions that could be tested scientifically would lead to a better understanding of the nature of science. Could this be done through “science fair-like” projects or student-led open-ended investigations? I had been thinking about these kinds of projects (which I will refer to as science inquiry projects) since my first year of teaching. I struggled with seeing how I could fit them into my science classes which focused so much on content knowledge. So, when I was given the opportunity to teach TIS for a second year, I knew I had to give it a try. Because my students have had little experience with this kind of project work, I knew that they would require scaffolds and supports. Initially, I struggled with imagining how this may work. Then, I stumbled across a website (ScienceBuddies.org) that did just that. This non-profit site was an excellent resource as it described the key components of the scientific method, while allowing students to develop their projects alongside the content. I decided I was going to give this a try with my TIS students.

**What does the literature say?** Although I have thoroughly reviewed the literature on scientific literacy and the nature of science, I have not specifically examined the literature on the use of science inquiry projects or open-ended investigations in teaching about the nature of science. This is because the use of science inquiry projects to promote scientific literacy was a new question that arose while in the midst of my research. I thought it would be worthwhile to explore this further in the literature, while considering my experience within the classroom.

One study conducted with 9th grade AP students, found that science fair projects did, in fact, increase students’ understanding of the nature of science and how it is conducted (Thomas, 2018). Although the student composition in this study seemed to differ from my class, one finding that I found relevant to my experience was that students were better able to understand the nature of science when each section of the science fair project was broken down into individual steps. For example, students worked on developing strong hypotheses, which may involve several revisions, before moving on to the experimental design. This was similar to my experience with my students. In the first few classes, I did a short lesson on questions, hypotheses, and predictions. Then students were given the opportunity to develop their own based on their science fair project idea. I found that most students' hypotheses required revisions, which resulted in me re-teaching the concepts in small groups and one-on-one. This reminded me that the nature of science is not an intuitive process and that there is value in teaching steps of the scientific method, using a "direct teaching" approach, coupled with opportunities for application.

In the previously mentioned study, the students were all working on science fair projects; however, since my students were not actually participating in a science fair, there was more flexibility in how they chose to conduct their inquiries. Anderson (2007) asserts that using inquiry to teach about the nature of science is important. Rather than having the experiences predetermined (as in a recipe-like lab experiment), "there is value in having student choice of hypotheses tested, means of doing such testing, and interpretations to be placed on the results" (p. 819). As well, when students are working through their own inquiries, they can experience both the frustrations and excitement that come from conducting scientific work (Anderson, 2007). These feelings were certainly present in my classroom when students were working through their projects.

Although I began my career as an educator believing in the value of inquiry learning, this was the first time that I had observed my students working at answering a question of their choosing in a manner that somewhat resembled a scientific investigation. However, I was still uncertain about how much "true inquiry" was taking place, especially in the cases, where students required a lot of support and guidance. I even questioned my own understanding of scientific inquiry and the nature of science. In Capps and Crawford's (2012) study they found this perspective to be common among science educators. They examined the teaching practice of 26 well-qualified 5th-9th grade teachers who were incorporating the nature of science and inquiry learning into their science classes (Capps & Crawford, 2012). In general, they found that "teachers focused on basic abilities to do inquiry instead of the essential features or important understandings about inquiry" (Capps & Crawford, 2012, p. 497). As well, although many of these teachers indicated that they were teaching about the nature of science through inquiry learning, their findings indicated that even these qualified and highly motivated teachers held limited views about the nature of science and inquiry learning (Capps & Crawford, 2012). The findings of this study certainly resonated with me and caused me to pause and further reflect on the experience.

**Reflecting on the experience.** When I think back to this first day of class as described in my vignette, I am reminded about the uncertainty I felt; whether these students would actually be able to work though their own science projects. I knew I would be introducing this project shortly, along with my teachings around scientific methods, and I wondered whether these students, who struggled with simply coming up with ideas that they were curious about, would fare when it came to designing and implementing their own scientific investigations. Truthfully, this uncertainty remains. My hope was that through their own experiences, students would gain a greater understanding of how science is carried out and new knowledge is constructed. Did that hope come to fruition? Answering this question is not simple. When conducting any type of research, it is tempting to analyze results and draw conclusions. But, in order to stay true to the narrative inquiry methodology, I am cautious when it comes to answering any research question. However, I do think that there would be some value in considering the successes and challenges

I encountered through this experience, while contemplating the next steps necessary to take this inquiry further.

First, I need to consider how successful I was at what I had set out to do, and I need to clearly identify what I set out to do. I wrote earlier that my intention was for students to learn about the nature of science through experience. The student-led open-ended investigations would give them a glimpse into how science is conducted. Of course, I knew that this experience would have its limitations, but my expectation was that they would get a better understanding than if I continued to teach as I had-- emphasizing science content knowledge. In particular, I wanted students to get first-hand experience with the methods in scientific experimental work by choosing their own research question, designing, and conducting the experiment to answer their question, analyzing their results and drawing conclusions. Although I knew that this would not fully capture the nature of science, it is an important component of understanding how science is carried out; and I knew that my students were previously not given enough opportunities to engage with this kind of experimental work.

Because of their lack of experience, I knew that my students would require many supports and scaffolds, all the while encouraging them to seek out answers to questions that they were interested in and to design an investigation in a way that made sense to them. For some students, simply choosing a topic or question of interest was too difficult. Because we used the ScienceBuddies.org website as a resource to learn about the methods of a scientific investigation, students could choose topics that were suggested on the website. Most of the students chose a suggested topic from the website, but some did come up with a question of their own choosing. For example, one student wanted to explore how school affected the mental health of teenagers; another student wanted to explore how coding could lead to the design of a video game. When it came to the design of their investigations, some students were able to design their experiment from scratch, after learning about the concepts of manipulating variables to test hypotheses and fair tests. However, some relied on the resources provided by the website to lead them to an experimental design; while others embarked on what looked more like “design projects” than “experiments” (as in the case of the video game project) and did not create an experimental design.

Regardless of their project choice, all students learned about the standard steps of a scientific investigation and had the opportunity to apply their knowledge. My hope was that students would learn about the nature of science not only through their own experiences, but also by observing the work of their classmates where they would get a wider glimpse into the multiple ways science is carried out. How successful was this? Researchers and teachers alike rely on assessments to help us determine whether a learning outcome was achieved. However, because of the nature of this inquiry, I am cautious to rely on the assessments alone as an indication of some kind of achievement. As I think back to those classes and explore my reflections at the time, many emotions surface, including anxiousness, uncertainty, excitement, confusion, enthusiasm, and frustration. These are my emotions which arose in relation to my students. I am careful to not classify these emotions as “good” or “bad”. I believe that the best learning comes from confusion and uncertainty. But this spectrum of emotions suggests that there were both successes and challenges that arose throughout the experience.

So, what went well? When I think of those moments of enthusiasm, students had a plan, they had chosen their topics and they were excited to be working on their own research question in a way that made sense to them. The enthusiasm waned when students encountered roadblocks or were not sure how to proceed. I am not too surprised by this, as I have frequently found that students are reluctant to persist through a challenge without the guided help of an adult. But, in these particular projects I could not “tell” my students what to do next. I reminded them that they were the researchers in their project, and they had to work through the problems. It is my tendency to think that these feelings of frustration on the students' part meant that things were not going well, but in retrospect, I think the opposite is true. “Doing science” is not straightforward and clear cut and there is value in students experiencing that firsthand.

When it comes to assessment, I understood from the onset that it was going to be messy and difficult. When assessing skills, it is not unusual for teachers to lean on assessment rubrics, but I have often felt that rubrics do not adequately capture the whole student experience and fail to give a complete picture of the students’ learning. Because of this, I tried to incorporate many opportunities for students to demonstrate and reflect on their learning, especially in 1-to-1 student-teacher meetings. But I still struggled with determining how to assess their learning, especially how to assign a mark. I believe that for many high school teachers, including myself, this is uncomfortable, because it might mean that we do not have a clear understanding of the learning process and expectations. For these reasons, I am often hesitant to take the time to embark on a project like this with so many unknowns. But I felt it was worthwhile, so I decided to not let my uncertainties about assessment deter me. I believed that focusing on the process, rather than the outcome would be more appropriate.

While students worked on their projects, I tried to meet with individual students and student groups to assess their progress and provide feedback. But, with a class of nearly 30 students, many with special learning needs, this was difficult to manage. It required a lot of my time and energy to meet with students and student groups, while ensuring that the remainder of the class stayed on task, working on their own projects. In an ideal world, students would be so engaged in their work that it would require very little classroom management interventions, but this was not the case in this situation. I often found myself reminding students about deadlines and consequences of late work, hoping that it would help them stay on task. Overall, I would say that students were fairly engaged in their projects and showed enthusiasm for what they were working on. From my observations, they enjoyed working in groups (although, some chose to work individually), and they enjoyed that they had choice in what they were exploring.

When I consider what I would do differently next time, I think it would be beneficial to have the same group of students go through the entire process a second time. I would re-teach the steps of the scientific method as they work through developing their new questions, hypotheses and designing their experiments. As well, I would ask them to reflect on their experience through journaling and ask guided questions that would help to uncover their understanding of the nature of science. I believe that writing regular reflections is a useful practice in developing self-awareness, and I have had success using this strategy in the past. As well, regular meetings with students who are discussing their ideas about the nature of science would be insightful. I think that there is value in letting students reflect on their learning both in writing and in conversation. When I imagine all these possibilities, it is hard not to think about how much time this would all take. Fortunately, in my TIS class, the sole focus is scientific literacy, and I can devote large chunks of time to a project like this. Another difficulty arises when students complete a project before others. But if they are in this perpetual state of research, designing and conducting experiments, perhaps that issue would solve itself.

I continue to wonder about how this will ultimately impact their understanding of the nature of science; after all, understanding the methods used in experimental scientific work is just one aspect of understanding the nature of science. But I do believe that the more practice they get with this kind of experience, the more they will come to understand how scientists work, as it will allow them to see a wider range of possibilities of what it means to “do science”. As well, it will allow for more discussions around the limitations of science as a means to answer all questions. There is a reason that scientific literacy and the nature of science are foundational components of all science curricula in Manitoba. Prior to this experience, however, I did not have a clear plan on how to incorporate these concepts in my teaching and assessments. Now, I feel more confident, and I look forward to continuing to learn from my own experience as my pedagogy shifts and I move toward this different way of teaching science.

**Situating the narrative.** At this point I think it is important to address why I chose to unpack this narrative vignette and consider how it connects to my research puzzle. In my methodology, I described how narrative inquirers develop interim research texts by looking for moments of tension within their field texts. As I began to inquire into this moment of tension as described in the vignette, I found myself wondering about how to encourage student curiosity and foster an ability to seek out answers to questions, while developing an understanding of the nature of scientific inquiry. This brought me back to my early days of teaching when I was in the midst of developing my philosophy of teaching. As I consider my past and reflect on my present experience with the TIS students, I am able to situate my research within the temporal dimension of the three-dimensional narrative inquiry space. This space also allows me to consider how I can move forward with this inquiry and take more steps toward helping students deepen their understanding about the nature of science.

The three-dimensional space also considers the people and places (sociality and place dimensions) within which the research is situated. Myself, my students (in particular, my TIS students) and my classroom have an effect and are affected by my research. My classroom, which is divided into a classroom space and lab space has ample room for students and student groups to meet and work on their projects. I do wonder about how my students can extend their learning outside the classroom. After all, as my students further develop their scientific literacy, they will be applying these skills to situations that they encounter outside the classroom, such as seeking answers to questions or thinking critically about science presented in the media. This development of skills and shifting of attitudes is what I had set out to accomplish. Within my research puzzle, I wonder whether science education can shift student attitudes and behaviours toward sustainability. As a teacher-researcher, this brought about a need to explore the goals of science education, including the nature of science, and a need to take action by helping my students understand the nature of science through first-hand experience.

As I situate my research text within this three-dimensional space, I am aware that the inquiry is on-going. Not only do my wonderings continue, they also deepen. Is understanding the nature of science enough to shift student attitudes and behaviour toward sustainability? As I move toward teaching through the lens of sustainability and well-being, what is lacking from my pedagogy? In the second narrative vignette, I further inquire into these wonderings.

**Narrative Vignette 2: The story of science (January 25, 2019)**

I am in the process of planning for my Topics in Science (TIS) class, and I can't help but feel both excited and nervous. I'm excited, because I am free of the constraints that exist in a typical high school science course with its numerous learning outcomes. This means I will be able to delve deep into topics that interest my students. I'm also excited about spending time really examining the nature of science. I am planning on doing this by looking at the history of science. I love teaching the history of science, and I'm excited that I can share this passion with my students. But I am feeling a little apprehensive as well. For one, I know that I have a large group of students who require learning adaptations, and I wonder how they will be able to grasp some of the complex issues we will be discussing. One of my goals is for students to develop critical thinking skills, and this includes thinking critically about the nature of science and its history.

**Unpacking: The story of science**

Since starting my graduate studies, I have felt conflicted about the role of science education in our society and how, as a science educator, I may be able to shift my students' attitudes and behaviours toward sustainability. I have not always felt this way. When I was an undergraduate student, it was my studies in science classes that helped me to gain a greater appreciation of the world we live in. In particular, there was one course that I took in my 3rd year of university called the History of Science that played a huge role in shaping my thinking about the nature of science.

For as long as I can remember, I have been interested in history. When I am learning about a new idea or concept, I find that I am curious to learn about the historical development of this idea. I also find that it helps to consolidate my understanding about the concept. When I took the History of Science course, it was the first time that I began to connect the dots between all the science concepts I was learning about in my undergraduate physics and biology classes. I began to see the “grand narrative” of how we have come to understand the world we live in. This left me full of awe. I felt so fortunate that I was living at a time and in a place where I could learn about and understand the world so well. I began to understand my place in the world and see myself as part of the amazing story of our universe. This led me to feel great appreciation for our world and a kinship with nature. It is also the period when my attitudes and behaviours began to shift toward sustainability and conservation.

When I enrolled in the Faculty of Education, my experience with learning about the history of science deepened. I was fortunate that the professor who had taught the History of Science course in my undergraduate program, Dr. Art Stinner, was now co-teaching my science curriculum and instruction courses in the Faculty of Education. Dr. Stinner was an energetic and passionate storyteller of science. He had a profound impact on me as an education student and influenced my philosophy of teaching. In fact, when I received my first teaching position teaching high school science, I designed a timeline around my room that included important historical contributions to science. I knew that the timeline was incomplete, but my vision was to build upon it as I explored various science concepts with my students and discussed their historical underpinnings.

As a new teacher, I shared my teaching philosophy with my students including my belief that science should be taught through story and context. After doing so, a Grade 12 Biology student of mine brought a book to me titled “A Short History of Nearly Everything” by Bill Bryson (2003). I had never read nor heard of Bill Bryson at the time. I devoured the book, and it still is one of my favourite books; I reread it every few years. His storytelling ability is exceptional. He made me fall in love with our world and universe all over again and reinforced my desire to protect our planet. I knew that this was how I wanted to teach. I do not consider myself to be a naturally good storyteller, but the more I practiced teaching my students about science through story, the better I got.

As the number of years I spent teaching science accumulated, I began to feel more and more passionate about the role of science education in making a positive difference in this world.

My concern for the state of our planet continued to grow, and I felt like the more students understood the science behind climate change and conservation, the more they would feel empowered to shift their attitudes and behaviours toward sustainability. Yet, it was not long before I felt like something was missing from my pedagogy. I knew that engaging students through stories would help bridge the gap between their emotional and ecological intelligence (I will explore this more deeply in my narrative conclusions). I began to wonder about the privilege I placed on science as a way of knowing and understanding the world.

This wondering largely came about from my graduate studies coursework in Education for Sustainability & Well-being. In our early coursework, we examined various worldviews and spent a considerable amount of time discussing the pervasiveness of Eurocentrism in science and society, and its role in contributing to the current state of the planet (Bai, 2015; Battiste, 2013; Hawken, 2007). This was the first time that I began to think critically about the privilege afforded to science as a "way of knowing". In previous unpublished graduate papers, I explored what is meant by a sustainable society that moves away from the perspective that consumption is the route to happiness and well-being, while recognizing the harmful social and ecological consequences of this perspective (Massinon, 2015, 2016). As well, I considered the impacts of the predominantly Eurocentric lens through which science is taught, and I wondered about how this perpetuates an anthropocentric worldview which places humans above other forms of life (Massinon, 2015, 2016).

These explorations led me to acknowledge that I also need to give students an opportunity to think critically about these ideas. Rather than simply accepting science as it is presented (often without bias and critique), how could I encourage students to think more deeply about the impacts of science and technology on society and the environment? The power of science as a knowledge system has no doubt afforded our modern society greater comforts and contributed to longer lifespans for our species. But, has this knowledge system been skewed by the western perspective from which it was born? And what are the implications of this? Could the inclusion and validation of other ways of knowing in science education (such as Indigenous Traditional Knowledge or ITK) help to balance this western worldview with one that moves away from an anthropocentric perspective? How could I complement students' understanding of science to include and validate other ways of knowing and understanding the world? And how would all this help shift students' attitudes and behaviors toward sustainability and well-being?

**Teaching other ways of knowing.** When I was designing the Topics in Science (TIS) course, I knew I wanted to teach students about the nature of science, and I wanted to help them truly understand the power that science has afforded humankind. But I also wanted them to think critically about how we privilege this way of knowing and understanding the world, including its impacts on people and the planet. Thinking critically about the impacts of science and technology on society and the environment is foundational to scientific literacy. I decided that one way that I could help students with this learning outcome would be to point out the inherent Eurocentrism in the scientific method and ask them to consider the implications that arise from this.

Science, as it is taught in schools, developed from a western worldview which follows reductionist practices to understand the nature of the universe. This way of thinking and making sense of the world has no doubt contributed to a great increase in our collective learning as a species. But within the worldview from which science was born is the notion that as we gain a greater understanding of the universe, we can harness this understanding to exert power over the natural world. This application of scientific learning (or technology) has brought us to a place where this extraordinary power held by our species over nature is threatening our very existence. I wondered how I could expand my students' understanding of science to include other ways of knowing and understanding the world (in particular, ITK) and how validating this knowledge system could make a difference in moving us toward sustainability and well-being.

**What does the literature say?** In my literature review, I spent a considerable amount of time exploring the aims of science education to solve problems in our world. As well, the idea of moving away from a "dehumanized and decontextualized" (Pedretti & Nazir, 2011, p. 611) view of science came forth when I explored the literature on the nature of science and the affective domain. What I failed to explore in much depth, was the consequence of teaching science through a narrow Eurocentric lens. As well, what issues arise when teaching science from a western perspective that privileges these Eurocentric stories of science? These were new questions that arose when writing my research texts and the tensions that were present in my narrative vignette have brought about a need to explore them further.

My starting point on these questions was to examine the information put forth by Manitoba Education. Interestingly, I came across a document titled *Integrating Aboriginal Perspectives in Curricula* that was published in 2003. It was also during this time (in the late 1990s and early 2000s) that Manitoba Education was revamping its science curriculum and described its goal of science education as "scientific literacy for all". While the purpose of this document is described as "enabling teachers to facilitate students' understanding of the Aboriginal perspectives in Manitoba" (Manitoba Education, 2003), it includes learning outcomes for early, middle and senior years students in all subject areas, including science that are described in detail. Two learning outcomes that stood out to me were "students will respect the traditional Aboriginal people's understanding of, and practices associated with, the various cycles that are part of the ecosystems" and "students will describe the similarities and differences in the views held by government policy and local Aboriginal peoples toward resource use and management" (p. 42). Within these learning outcomes, I can begin to see what is missing from my pedagogy.

I have been familiar with the concept of "decolonizing education" for some time now, as it has become an important talking point in discussions in the field of education in Manitoba. I believe that it is not only an important step toward reconciliation, but it also allows for a richer educational experience for all students. In particular "decolonizing science education" may be exactly what is needed to shift student attitudes and behaviours toward sustainability. Battiste (2013) has criticized the predominant Eurocentric perspective within science education, as it perpetuates an anthropocentric worldview that disregards the important interconnections between all living things and the environment. Kopnina (2012) has suggested moving away from this worldview toward an ecocentric perspective, which validates other ways of knowing (such as ITK) and places humans within the complex interactions of nature, not above them.

Glen Aikenhead (2006) from the University of Saskatchewan has written extensively on the topic of integrating Indigenous perspectives into science education. He was also an important contributor for the literature on S-T-S (science-technology-society) and the humanistic science education movement as described in my literature review. He describes many benefits of integrating Indigenous perspectives with science curricula for both Indigenous and non-Indigenous students. As well, he asserts that both knowledge systems are different but complementary (Aikenhead, 2006) and that moving toward an enhanced cross-cultural school science curriculum would benefit both Indigenous and non-Indigenous students (Aikenhead & Elliot, 2010).

In their 2010 paper, Aikenhead and Elliott highlight a project undertaken by two Manitoba researchers (Sutherland & Henning, 2009) who conducted a literature analysis and an interactive action-research project with 50 cross-cultural science educators. Cross-cultural science education is described as promoting the decolonization of school science; an education that emphasizes the strengths of both knowledge systems (Aikenhead & Eliott, 2009). From the literature analysis, Sutherland and Henning (2009) described four components or levels to successful cross-cultural science programs: 1) coming to know, 2) cross-cultural pedagogy, 3) social and ecological justice and 4) ecological literacy (Aikenhead & Elliott, 2010). As I move toward teaching through the lens of sustainability and well-being, it is worthwhile for me to consider each of these levels more fully in the next few paragraphs

*Coming-to-know* (level 1) is described as how knowledge is transferred in Indigenous communities and recognizing that this process is distinctly different from the Eurocentric approach to gaining knowledge. In essence, coming-to-know in Indigenous cultures is much more about knowledge construction rather than transference. Knowledge is built through experience and in the midst of experiences. As well, coming-to-know occurs by "turning inward". By personal reflection, one can begin to make sense of the world. Moreover, the journey of coming-to-know is on-going and lifelong. Ultimately, the process of making knowledge is just as important as the knowledge itself (Aikenhead & Elliott, 2010).

*Cross-cultural pedagogy* (level 2) refers to culturally relevant approaches to teaching science. For Indigenous students this is especially important, as a Eurocentric science curriculum may seem entirely foreign to them. Even though the content of the science curriculum may be important to their daily lives and communities, the manner in which it is presented may make the content irrelevant or inaccessible (Aikenhead & Elliott, 2010). Sutherland and Swayze (2012) give some examples of cross-cultural pedagogy including working with elders to share traditional cultural teachings, place-based education, and involving the family and community in the child's education.

*Social and ecological justice* (level 3) come about when students extend their knowledge that has been constructed through personal experiences (coming-to-know) and cross-cultural pedagogy to the larger world around them and seek to take action on their learning. Not only does this empower students to enact change, it also lends itself to a deeper understanding of scientific concepts, including the interactions between science, society and the environment. Moreover, it sheds light on the power dynamics that are at play within socio-scientific issues, pushing back against the idea that science is in any way "neutral" or free from bias (Aikenhead & Elliott, 2010).

*Ecological literacy* (level 4) is the ultimate goal of a successful cross-cultural science program, according to Sutherland and Henning (2009). At this level, students not only have a thorough understanding of ecology, but they also have the capacity to solve problems and the desire to shift attitudes and behaviours toward sustainability (Aikenhead & Elliott, 2010). Through my research, I have come to understand Ecological literacy (or Eco-literacy) as the overarching goal of teaching science through the lens of sustainability and well-being. I will explore this idea further in my narrative conclusions.

**Reflecting on the experience.** Returning to my Narrative Vignette 2, the points of tension arose when I began thinking about how to teach students about the nature of science, while holding a critical lens. As I described previously, my understanding about the nature of science largely came about from my uncovering of the "stories of science". Not only did this give me a greater understanding of the world, but it also led to a greater appreciation of the world and desire to protect it. When I began planning for my Topics in Science (TIS) class, I knew that I wanted to begin by looking into the "history of science". However, I had this sense of unease. I knew that I, as a "storyteller" of science, would be picking and choosing the stories that I told, just like Dr. Stinner and Bill Bryson had chosen the stories that they both told so well.

For most of my career as a science teacher, I glorified western scientists, so much so that I had created a timeline around my classroom with their names and pictures on the wall. My TIS students were already familiar with my timeline since I had taught nearly all of them in Grades 9 and 10 Science. So, when we began our inquiry into the history of science, I asked them to come up with a list of people who had made contributions to science. They quickly looked up at the timeline and started naming off the scientists. Next, I asked them to consider what all these people had in common. The immediate response was "they're scientists". It took a little more probing until they realized they were all men. But it took quite a bit more guiding for them to see that they all came from the same part of the world and were white.

At this point, I wrote the word "Eurocentric" on the board and started to explain to the class that this was the predominant perspective when making sense of the world through science. Of course, today science is done by people all over the world, both men and women; but I think it is worthwhile considering that this knowledge system that we regard so highly is rooted in a western worldview. I wanted my students to consider the implications of this—rather than simply accepting science as a way of understanding the world. I know that I have felt these tensions and uncertainties as a science teacher when I think about how I teach my students about science. In my first narrative vignette, I unpacked the tension that I felt as I shifted from teaching science content to scientific processes. I know this is an important component in scientific literacy. But when I included stories about the history of science in order to highlight the development of the methods of science it seemed necessary to point out that the methods of science were born from a specific worldview.

My intention with this discussion regarding Eurocentrism in science was not to label it as “bad” but rather to help students consider the implications of this. The positivist nature of science in which theories are constructed from direct observation and verifiable evidence has afforded us many modern advancements and no doubt improved the overall quality of human life on Earth. But what are the consequences of this “detachment” from the metaphysical world? Science is of course not meant to answer questions that are metaphysical in nature and for which there is no evidence, and I do not think it should attempt to do so. But I wonder about how privileging science as a knowledge system has brought us to a place in this modern world where we are now “detached” from an emotional and spiritual connection to the universe.

This conversation is especially sensitive at a time when there is widespread misinformation and pervasive distrust in science (I will come back to this in my reflections on how the COVID-19 pandemic has affected this discussion). However, I know that teaching “about" science topics is not enough for students to become scientifically literate. Teaching “how science works” and the “nature of science” helps students to understand science as a process rather than simply acquired knowledge. I think that this brings us closer to the “coming to know" pedagogy in traditional Indigenous knowledge systems. And I wonder about how expanding our understanding of science to include other ways of knowing would help to reconnect us to the universe in a more emotional and spiritual way. How would this help to shift student attitudes and behaviours toward sustainability?

I know that starting the conversation about Eurocentrism and the predominant western perspective in science (and society) was simply a starting point, and I have a lot of work left to do in this domain. I know that as a “storyteller” of science I am bringing in my own biases when I pick and choose the scientists and the stories about them that I tell. I have come to understand my privileging of Western science and its history as a point of tension in my pedagogy, particularly as I move toward teaching through the lens of sustainability and well-being. I realize that I need to uncover my “positionality” as both a teacher and teacher-researcher to be able to understand this more deeply and make sense of these tensions.

As a white middle-class woman who excelled throughout her educational career, I feel extremely comfortable in a classroom, both as the teacher and the student. As one of the few women in my physics undergraduate program, there was some awareness about my intersectionality, but my self-confidence as a student overcame any sense of not belonging. As an education student and new teacher, I found my place among my peers who also sought to effect change through their teaching. I was proud to be a science teacher, as I felt like I could make a difference in this world by enlightening my students, sharing all that I had learned as a student of science myself. I was excited for them to share in the sense of awe I felt when I began to understand the world through the stories of science.

Of course, privileging science as a way of understanding the world makes sense for a high school science teacher. But I am more than a high school science teacher. Yet even before I was a teacher, I was drawn to these Eurocentric stories about how we have come to know what we know. As a teacher I assumed that my students would also be drawn to these stories and fascinated by them as I was. But what if these stories did not align with their worldviews? Did one have to see themselves in these stories for them to effect change? As well, what happens when students are asked to simply accept science as it is presented and are not challenged to think critically about the social and ethical issues that arise from technological advancements made possible through science?

Now, I know that I am missing an important piece to my pedagogy. I have started the conversation about Eurocentrism within science, but I have not moved far enough into a cross-cultural science pedagogy where traditional Indigenous knowledge complements the Western science stories. I wonder about my ability to do this as a white woman educated within a Eurocentric science curriculum. This is what holds me back-- a lack of awareness, exposure, and self-confidence in this space. I am also cautious of the pervasive tokenism that occurs when white educators attempt to integrate Aboriginal perspectives and the mandated curriculum. But I acknowledge that this conversation with my students is a starting point, and that the self-awareness that has grown from my research is an important steppingstone. I am simply mindful that the work is not finished.

Where do I go from here? I am reminded of a series of YouTube videos I watched that initially got me thinking about how I could incorporate the history of science in my TIS class. These videos were created by The Crash Course (https://thecrashcourse.com/) and have over 40 episodes of short 10-minute videos that highlight the history of science from the ancient Greeks to the Scientific Revolution to modern science in the 20th & 21st centuries. I went back to the video series when writing this research text, and I found the last episode in the series *Episode 46, The Limits of History: Crash Course History of Science* to be aligned with my thinking about these tensions. In this episode, the host acknowledges that “the history of science, it turns out, isn’t all about lone hero-knowledge-makers, but about complex systems of understanding and controlling the world-- systems that aren’t always moral or just” (CrashCourse, 2019). This nuance reminds me that the story of science becomes even more powerful when those complex systems of understanding and controlling the world are more fully explored and examined with a critical lens. This is where the power and limitations of science as a knowledge system become apparent and the inclusion of other ways of knowing within science education and as part of the story of science become important.

**Situating the narrative.** Although the narrative vignette captures only a snapshot of my emotions when planning for a new course, the unpacking of the vignette brings forward a tension between the possibilities and limitations afforded by science education. This tension can be fully appreciated when situating the narrative within the three-dimensional space of narrative inquiry--temporality, sociality, and place.

The tensions I felt when planning my TIS course arose largely as a result of my graduate studies coursework. It was within this coursework that I first began to question the possibilities afforded by science education in contributing to a sustainable society. This brought me back to my days as an undergraduate student, and then, as a new teacher, excited about the potential to effect change through my science classes. This temporal dimension of the narrative brings out the dimension of place. As a new teacher, I was especially excited about the projects that extended my students’ learning experience outside the classroom and into the community. It is no wonder that tensions would arise years later when planning a course that would involve students spending the vast majority of their time within a classroom.

When considering the dimension of place embedded in this narrative, I am brought forward to my days as a graduate student holding a critical lens to the possibilities afforded by science education. This is when I began to question how I was privileging science as a way of knowing the world. Of course, this came from my own science education from which I built a picture in my mind of what it looks like to make sense of the world. For me, this picture was rich and storied; it projected this grand narrative of how we have come to understand the world. But it did not take into consideration the implications that arise when this positivist worldview is privileged over ones that nurture the spiritual-emotional connection between humans and the universe.

As I reflect on this, I see the temporal dimension of my narrative; tensions between a place of possibilities (as a science student and excited new teacher) and a place of limitations (as a graduate student bringing a critical lens to science education). The dimension of sociality is significant as I consider my experience of coming to understand the world. The stories about the history of science that allowed me to more deeply understand how the world worked were able to do that because I saw myself in those stories and as a part of those stories. Not only did they resonate with my existing worldview; they consolidated and strengthened this worldview. Once I began to question and challenge myself about this worldview, the tensions arose. Now, I acknowledge these tensions as a place for growth and learning and see that, even from a place of limitations, one can pivot to a place of possibilities.

**Narrative Vignette 3: The story of us (May 15, 2019)**

Today, in Topics we started the "Big History" unit. I was nervous because within this unit we would be studying interesting but sometimes "controversial" origin questions such as the Big Bang, origins of life on Earth and evolution. These topics may be perceived as controversial by students who may regard them as being in conflict with their faith. I decided to address this right away by asking students to think about whether or not they thought science and religion were in conflict. After discussing these various ideas, I decided to meet with students individually and discuss this further. One student in particular, who has a strong faith background, told me that he is excited to learn about all of this and that for him it strengthens his faith.

**Unpacking: The story of us**

There is always a sense of unease when I am about to present these "origin" concepts for the first time to my students. How will they react? How much do they know? How should I respond when a student blurts out, "It's just a theory!"? How can I avoid offending anyone? Of course, the easy response to that question is to quickly gloss over it, acknowledge that it is a theory or simply not teach it at all. I wonder how many science teachers also feel this way about teaching the Big Bang or other "origin concepts" such as evolution. But there has always been something about these questions regarding origins that I have been drawn to. As I described when unpacking the second narrative, I have always found histories (and thus origins) to be fascinating. I am sure this is part of human nature to ask these "big" questions.

When I was designing the TIS course I knew that I wanted to explore these big questions- *Where are we? When are we? What are we? How do we know what we know?* These questions came up when I stumbled across the concept of "Big History". David Christian the co-founder of the Big History Project describes Big History as an interdisciplinary field that examines history starting with the Big Bang (OER Project, 2020). He also refers to it as the "story of us" (OER Project, 2020). Because of my attraction to the use of stories in the classroom, I began to wonder about the possibilities of using Big History to teach through the lens of sustainability and well-being.

**Teaching Big History.** I first learned about the concept of Big History when exploring The Crash Course website (https://thecrashcourse.com/), which contained the YouTube videos on the History of Science. The website offers educational videos grouped into 15 courses (such as History of Science, Astronomy, Biology, etc.) meant to complement a high school or college level science or humanities course. One of their "courses" called Big History was appealing to me, because it seemed to connect various science topics within a larger narrative of the story of the universe. I liked how the topics explored within these short 10-minute videos connected to these "big questions". For several years now, I have organized my science units around "big ideas" and "big questions".

Within the TIS curriculum, these "big questions" are part of General Learning Outcome 4: Essential Concepts - "explore, understand, and use scientific knowledge in a variety of contexts" (Manitoba Education, n.d.). The Crash Course Big History videos seem to do just that when presenting this information as a narrative - a story of the universe - starting from the Big Bang to the Anthropocene on Earth. This also allowed for an exploration of human impact on the planet and consequences to life on Earth, including the survival of our species. As I prepared my lessons and watched the videos, I became very excited about using Big History as a framework to not only explore these questions of origin, but to also examine the nature of science when the inevitable question "how do we know that?" arises from my students.

As I began to research more about Big History, I stumbled across a website called the Big History Project (https://www.oerproject.com/Big-History). I was blown away by this teaching resource, which describes Big History as a story about us; an examination of our past, explanation of our present and imagination of our future (OER Project, 2020). As I dug a little deeper, I found that the website was co-founded (with the financial support of Bill Gates) by

David Christian a Professor of History at Macquarie University in Sydney, Australia. I was familiar with his 2011 Ted Talk *The history of our world in 18 min*, as it reminded me of Bill Bryson's (2005) *A Short History of Nearly Everything*. Both of these narratives connected the dots between various science disciplines through story and left me with a sense of awe and appreciation for my place in this story. As well, they both offered a cautionary warning about how our species was jeopardizing our ability to continue to thrive on the planet. I decided that I needed to incorporate the Big History Project into my TIS course.

When I was first learning about Big History, I was more than halfway through my TIS course, and I was part-way through a "Space" unit. I had designed the unit to incorporate the "Living Space Project" (Let's Talk Science, n.d.). As students studied the key environmental conditions that are monitored and managed in order to keep astronauts healthy on the International Space Station, they simultaneously measured environmental conditions such as temperature, CO2, and relative humidity in the classroom to ultimately make a plan for classroom environmental improvement. This was my first-time teaching TIS since being hired in 2010, and, with the flexibility allowed by the curriculum, I had not made a specific plan of how I wanted to finish off the course. I intended to do something related to environmental sciences and sustainability. I knew that with the warming weather, we could spend more time outside studying ecology topics. But I worried that there would be a disconnect between the "environmental science" unit I was contemplating and the units we had previously studied. This happens all the time in a typical school science classroom as the curriculum from Grade 1 through Grade 9 is divided into 4 distinct units, namely: Biology, Chemistry, Physics, and Earth and Space Sciences. However, in recent years, I have been making attempts to connect these seemingly disconnected topics under an overarching theme. This was easier to do in my Gr. 11 & 12 biology and chemistry classes, but I struggled doing this in my Gr. 9 & 10 general science classes.

The connection of interdisciplinary topics under a central theme or within a narrative was important to me because it is how I see and understand the world. Thanks to my studies of the history of science, as I described in unpacking the second narrative, I was helped to understand my place in the universe, and this stirred in me a great desire to share this knowledge with more people. I felt that once they had a better understanding of their place in the universe, they would begin to shift their attitudes and behaviours toward conserving and protecting the planet. So, when I had a chance to teach TIS once again in the 2019-2020 school year, I decided that Big History would be the framework that I used to design my course content upon.

I should note that before diving into Big History, I wanted students to get some first-hand experience in "doing" science. I spent about 3 weeks on the open-ended student-led investigations and the methods of scientific inquiry as described in the unpacking of the first narrative. Once the student-led investigations were well underway, we began examining Big History through the Big History Project (students would return to their investigations about once a week throughout the semester). The Big History Project would guide our course until March 2020. I cannot overstate the vastness of the Big History Project as a resource. I was especially impressed with the organization of the content (the history of everything!) within 10 units of study. These units are organized under themes such as "The Big Bang", "Life", and "Agriculture & Civilization". Traditionally, we would see these topics taught in separate courses or distinct units, but Big History connects these topics under the narrative of an "increasingly complex universe". I wondered how this narrative could be used to teach science through the lens of sustainability and well-being.

**What does the literature say?** Since the concept of Big History was not one that I explored in my literature review, I thought it would be worthwhile to examine it here. Before looking into the literature, my only exposure to Big History was through The Crash Course Big History videos, the Big History Project and David Christian's (2018) book *Origin stories*. I know that these three references are quite interconnected and largely based on the writings and thinking of David Christian, who has been cited as the "Father of Big History" (OER Project, 2020). So, along with Christian's work, I sought out references that would help me to gain a better idea of the conceptual framework of Big History as classroom pedagogy. As well, I wanted to look at the literature and flesh out both the benefits and potential downfalls of using Big History in the science classroom.

***What is Big History?*** According to The International Big History Association (IBHA), Big History "seeks to understand the integrated history of the Cosmos, Earth, Life, and Humanity, using the best available empirical evidence and scholarly methods" (International Big History Association, 2021). In addition to David Christian's works, the IBHA also recommends resources from Cynthia Brown (2007), Eric Chaisson (2006), Fred Spier (2015), Tyler Volk (2017) and its publication "Journal of Big History" that includes articles from a variety of authors. The Big History framework is rooted in the conception of "thresholds of increasing complexity" that have occurred throughout the history of time (starting with the Big Bang) when the right "goldilocks" conditions and ingredients resulted in the emergence of a new level of complexity. According to Simon, Behman, and Burke (2014), this story of complexity was "pioneered by astrophysicist Eric Chaisson and furthered by cultural anthropologist Fred Spier" (p. 201 k). Christian, along with the historians Cynthia Brown and Craig Benjamin, organized this story by dividing the narrative into 8 "thresholds" of increasing complexity—1) the Big

Bang, 2) the formation of stars, 3) the creation of new elements (in dying stars), 4) the formation of our Solar System and Earth, 5) the origin of life on Earth, 6) the evolution of humans, 7) the rise of agriculture and civilization, and 8) the modern revolution (Simon et al., 2014, p. 201 k).

Christian claims that his understanding of the universe in this way has come from the development of a "Big History" course at Macquarie University in Sydney, Australia that he began teaching in 1989 (International Big History Association, 2021). Christian is a trained historian and when he initially taught this course, he brought in experts from various fields to talk about important points in the history of the universe (i.e., the Big Bang, the formation of the Earth, origin of life on Earth, the agriculture revolution, and the like). Although he found these experts did a fantastic job in teaching their subject matter, they each used the jargon and theoretical underpinnings for their various disciplines which resulted in a disconnection between the course topics. Over the years, as his understanding of these "big ideas" developed further, he began to see the history of the universe as this grand narrative of increasing complexity. Within this narrative, he could unify the knowledge of these scientific disciplines.

***The case for teaching Big History.*** In *Teaching Big History*, Simon et al. (2014), describe Big History as "a meta-narrative that unifies the sum of human knowledge in all disciplines" (p. 177). The authors acknowledge David Christian and Cynthia Brown as the "big historians" whose works have influenced their pedagogy. They argue that when Big History is used as the core of a general education program, it "prepares students for the challenges humanity faces in the twenty-first century" (p. 291). Why is that? Because rather than fragmenting the collective human knowledge into various subjects and disciplines, Big History gives students "an understanding of the patterns that recur throughout the history of space and time, of Earth and life, and of human society and culture" so that they can be prepared to "understand the challenges and anticipate the opportunities that the future may hold" (p. 291).

This sentiment is echoed by Ruano (2019) in an article that describes how two eco-pedagogical experiences developed with the Environmental Education Program of Ecuador used Big History as a theoretical framework to "raise environmental awareness" and to promote a "transdisciplinary vision" that would help students better understand the interconnections between humankind, nature, and the cosmos. Ruano (2019) claims that the scientific theoretical framework of Big History was enriched when integrated with Indigenous traditional knowledge. Traditionally, the history of science has excluded Indigenous worldviews and spirituality because these human dimensions cannot be measured or quantified (Ruano, 2019). However, Ruano (2019) argues that facing the challenges of global climate change requires "rescuing essential human dimensions to propose regenerative cultures and transform our relationship with nature and the whole cosmos" (p. 90). For this reason, he believes that a transdisciplinary approach to Big History "opens a dialogue with ancestral wisdom and intercultural knowledge" (Ruano, 2019, p. 93), while providing a modern scientific understanding of the interconnections between humans, nature, and the universe.

***Cautions and criticisms.*** Big History is a fairly new pedagogical framework and for this reason the literature on its use in the classroom, not to mention the high school science classroom, is sparse. Most of the writing on Big History in the classroom is by proponents of the field who are using Big History in their classrooms. Astrobiologist, Eric Chaisson, who himself was a pioneer in the cosmic-evolution narrative, cautions that alongside the macroscopic Big History worldview must be an objective, quantitative reasoning that is rooted in science (Chaisson, 2014). Sociologist Fred Furedi (2013) argues the opposite. He describes Big History as “anti-humanist”, having assigned human history to a marginal role among the history of the universe (Furedi, 2013). As well, in terms of its use in the classroom, some concerns have been raised by Bill Gates’ backing of The Big History Project; although his role in the project, besides being its financier, is unclear (Weiner, 2016). As I reflect on my own experience using Big History in the classroom, I will attempt to highlight some of my own questions and causes for concern.

**Reflecting on the experience.** Using Big History to teach science through the lens of sustainability and well-being was a new idea that arose in the midst of my research. Before entering into my research, I wondered about the possibility of teaching science through this lens, and my starting point was to try and understand the goals of science education. I explored this thoroughly in my literature review in which I described the various aims of science education under three themes: 1) the nature of science and the affective domain; 2) using science and technology to solve problems (STSE) education; and 3) science for career preparation and participation in a globalized knowledge economy. Recently, I returned to this initial literature review and began to see the Big History pedagogy represented in these aims. As I reflect on my experience using Big History in the classroom, I will bring to light these connections.

When I first began teaching The Big History unit, I followed the Big History Project outline quite closely. The Introductory unit outlined by the Big History Project includes an exploration of the concept of “origin stories”. As I recalled in my narrative vignette, I tend to feel a little uneasy when I am about to explore a topic related to origins (whether it be life or the universe). I find these questions fascinating (as I am sure my students do), but I worry about making some of them uncomfortable, if they believe it conflicts with their faith. On several occasions, throughout my career as a science teacher, I have had students express such discomfort. Unfortunately, I have felt that, in the past, when exploring these important questions about origins, I have not spent enough time discussing these ideas and feelings as a class. I am not sure if that is even my place to do so, but this nagging sense that so much more learning could have taken place during these lessons does not leave me.

As science teachers, I think it is easier to simply "stick to the facts" and teach about the origins of life and the universe without acknowledging the conflict that may be occurring within any number of students. Worse than this, would be to introduce the topics with the premise "this is just a theory" or not teach these topics at all. I have never used either of these approaches, but I have often felt that such big, important questions such as "What is life?" or "How did the universe begin?" were simply not thoroughly explored in my classes. As a high school science teacher, I do not think it is unusual to get lost in the minutiae of details within a course curriculum, but I think continuing to come back to the bigger, broader questions is of utmost importance.

In my literature review, I wrote about the goal of science education for appealing to the affective domain of students. What better way to appeal to the affective domain than to explore these big origin questions? I think that the presentation of all this knowledge within a narrative makes it especially appealing. It humanizes science and makes us part of the story of the universe. I am reminded of the student in my narrative vignette who, with strong religious convictions, was excited to explore this "modern scientific origin story". It is hard not to get excited when an exploration revolves around you and your place within a story.

I have found this particular phrase- "modern scientific origin story" (OER Project) interesting and helpful when discussing any discomfort with my students. Throughout the Big History Project there are opportunities for students to explore their ideas around faith and science. One particular activity asked students to think about whether they think religion and science conflict, contrast or converge. I think that this activity was very helpful in opening students to the idea that they can be curious and open to the modern scientific origin story, while holding on to their traditional faith-based origin stories. At the same time, this exploration sheds light on the limitations of science in answering some questions for which empirical evidence does not exist; for example, what is the meaning of life? Recognizing both the power and limitations of science is an important goal in understanding the nature of science. Within this domain, the Big History project uses "claim testing" activities throughout the course units to shed further light on the nature of science and its power in helping us to understand how the universe works.

Following the Introductory unit, are 9 units that have been organized under 8 "thresholds of increasing complexity". The overarching theme of the course is that complexity in the Universe builds over time and thresholds mark key moments when the Universe became irreversibly more complex (OER Project). This organization allows for a deeply integrative course that explores topics ranging from the Big Bang to Life on Earth to the Rise of Agriculture and the Modern Revolution. This results in a course that combines a wide variety of scientific disciplines while incorporating social-scientific issues. The concept of "disciplines" is explored early on in the Big Bang unit. Throughout the course, students had the opportunity to consider various issues from the perspective of various disciplines (also called "ways of knowing"). For example, my students worked through an activity where they had to consider the scenario:

> You are putting a research team together for a mission to Mars. The team's goal is to determine if Mars could be inhabited by humans one day. However, the spacecraft can

> only carry three people. Your job is to pick three experts whose combined knowledge will best answer the question: Could humans live on Mars? (OER Project)

Highlighting the various disciplines involved in building human knowledge had several benefits for my students. First, hearing from different experts in various fields, helped them to become aware of the wide variety of science career opportunities. As I explored in the literature review, science for career preparation is an important aim in science education, but is often not well-represented in the research, even with the high demand for filling STEM careers in Canada. This need to remain competitive globally, has also raised the issue of preparing students for a globalized-knowledge society, in which knowing how to learn is more important than accumulating knowledge. One strategy that I incorporated from the Big History Project to work on these skills was the Driving Question (DQ) Notebook. This activity presented throughout the course and re-visited at least twice per unit, helped students to really focus on the big idea of the unit, while connecting all the knowledge they were acquiring. Ultimately, the DQ notebook allowed students to think about the big questions from many perspectives.

In my literature review, I also explored the aim of science education to solve problems. This is often described in the literature as STSE (Science-Technology-Society-Environment) or STS (Science-Technology-Society) education. This movement, as I described in my literature review, acknowledges that science education must include discussions on the ethical uses of science and technology, along with the potential for scientific/technological advancements to solve problems. These discussions become especially relevant in the latter part of the Big History Project course work. As humans become the central focus of the story, there is no ignoring the social-environmental issues that come forward with the rise of technology and modern science. For me, this is where the role of science education in a sustainable society becomes apparent.

Through the Big History Project course work, my students would be able to see how humans and even themselves were part of this grand narrative-- the story of the universe.

**Situating the narrative.** The vignette highlights the point of tension that has come up whenever I am about to embark on teaching about origins in my classes-- in particular, origins of life on Earth and origins of the Universe. Because I find these questions so fascinating, I am excited to teach about them but also nervous about the students' responses. I think this nervousness is rooted in the fact that I'm not an expert in either cosmology or evolutionary biology and, thus, am worried about being challenged by a student or asked a question to which I don't know the answer. If there are any topics that stir up student curiosity and questions, it is those that deal with origins. My own curiosity about these questions and origins, in general, made me a lover of history. When I learned about the history of science in University, I began to see this story of how collective knowledge built our understanding of the universe. At the same time, learning more about the universe helped me to build this narrative about the story of the universe. When I came across the concept of Big History, all the knowledge and understanding I had constructed fell within this framework.

As I consider the 3-dimensional narrative space of my inquiry- time, place, and people, -I understand why I was both excited and nervous to teach Big History in my Topics in Science class. The excitement came from my own excitement learning about these topics as a university student. Going back in time to when I was an undergraduate student and forward to when I first began my graduate studies reveals the temporal dimension of the inquiry. As a new graduate student in the Education for Sustainability & Well-being cohort, I often reflected as to why I felt so motivated and passionate about conservation and the environment. I wondered if it had anything to do with my upbringing on the family farm. Although I spent countless hours exploring the outdoors as a child, I did not consider myself “outdoorsy” as an adolescent. It was not until early adulthood, spending time outside with my students on field trips, that I realized being outside brought me so much peace and joy. I began to happily recall those memories on the farm and wondered about how this sense of “place” affected my attitudes and values. For me, understanding my “place” within the grand narrative of the universe has been the source of my awe and appreciation.

I wanted my students to share in this sense of awe and appreciation, and therefore I felt both excited and nervous. The sense of unease arising when student emotions are stirred along with inevitable questions that come from their engagement and curiosity. Unfortunately, due to the pandemic and my maternity leave, I was not able to see my TIS class through the end of the year-long course. Many questions remain regarding whether my students’ attitudes and behaviours would shift toward sustainability, whether they would feel inspired by this grand narrative to effect change, and whether their understanding of the universe and their place within it would develop within them a sense of awe and appreciation for it. But I remind myself that I came to this research not to seek answers to specific questions but rather to try and make sense of this “puzzle” that arose whenever I thought about the role of science education in a sustainable society. In the next chapter, I will attempt to weave these narrative reflections into a tapestry of understanding, drawing together several narrative conclusions.

## Chapter 5 Narrative Conclusions: Big History as a Framework for Ecoliteracy

As a graduate student in the Education for Sustainability and Well-being cohort, I was both excited and nervous with the idea of pursuing a thesis project. I knew, however, that this would be a substantial endeavor to accomplish alongside my full-time teaching load in which I am involved in many extracurricular and co-curricular activities, most of which are related to my interests in education for sustainability and well-being. Moreover, I knew that in order to enjoy the process of engaging in a multi-year long project, such as a master's thesis, I needed to develop a research project that was meaningful to me personally and as a teacher.

In the cohort's first research methodology classes, we learned about various qualitative research methods. Initially, I was attracted to the idea of action-research, as I wanted to examine my own teaching practices and consider its effects on my students. However, the traditional action-research methodologies required developing a research question that seemed to reduce all my wonderings about my teaching into a specific testable problem. I knew that I wanted to explore how I could shift my student attitudes and behaviours toward sustainability and well-being, but the idea of examining a specific teaching practice or tool and assessing its effectiveness made me uncomfortable.

At the same time, within the cohort's theory classes, we were exploring various epistemologies and worldviews. I began thinking critically about my worldview which privileges science as a way of knowing. As a science teacher, I felt strongly that science education should play an important role in preparing students for the challenges of the 21st century, but I could not help but feel unease. Ever since my first year of teaching, even with much praise and support from my mentors and supervisors, I often felt like I was failing to accomplish what I had set out to do as a teacher. I wondered about what was holding me back- Was it the course curriculum?

Assessment standards? Student demographics? Structure of the timetable? Of course, these are external factors beyond my control, but maybe there were some ways that I could shift my teaching practices that would impact my students in a way that would shift their attitudes and behaviours toward sustainability and well-being.

What kind of shift did I want to see in my students? In my first few years of teaching (before I was a graduate student), I took a summer seminar course called “Education for Sustainability & Well-being". This was a two-week course that had a profound impact on my thinking about the meaning of sustainability and how it connects to well-being. I reflected on this briefly in my “Narrative Beginnings”, but as I weave together the understanding that I have gained through this narrative inquiry, it is worth spending more time exploring what I mean by teaching through the lens of sustainability and well-being.

**“Ecoliteracy” as the overarching goal**

When I enrolled in this summer seminar, I had a high interest in the topics of sustainability. However, my concept of sustainability education at that time was focused on scientific literacy and environmental education. In this summer seminar, I began to understand sustainability education as *ecoliteracy,* which includes a scientific understanding of ecology (i.e., ecosystems, species, and genetic diversity) but is not reduced to that. In the seminar, we studied the text *Ecoliterate: How educators are cultivating emotional, social and ecological intelligence* (Goleman, Bennett, & Barlow, 2012) in which ecoliteracy is defined as the end goal in the process of “cultivating socially and emotionally engaged ecoliteracy” (p. 2). Goleman is well-known for his work on social-emotional intelligence that extends students’ abilities “to see from another’s perspective, empathize, and show concern” (Goleman, Bennett & Barlow, 2012, p. 6). He built upon this work to introduce a third, and related, intelligence that he named ecological intelligence. Ecological intelligence applies the aforementioned abilities to an understanding of the natural systems and melds cognitive skills with empathy for all life (p. 6).

As I learned about this, I began to understand that in order to shift student attitudes and behaviors I needed to appeal to the affective domain. Hence, my teaching practices continued to evolve. I knew that personal connection was important in appealing to this domain, so I tried to embed the content in my students' communities and personal lives. I gave them opportunities to pursue learning about topics that interested them through inquiry projects. I jumped on any opportunity to take my students out of the classroom into the community and to bring in community experts. I also understood the importance of overarching questions and themes within a course curriculum, and I structured my classes around these big ideas. I was not afraid to try new things and found great joy in innovating.

**Narrative inquiry as the tool**

When I began to contemplate a thesis project, there were many ideas I could pursue. I knew I wanted to explore how my teaching practices impacted my students understanding of sustainability, but which practice should I examine? Should I look at the effects of inquiry projects? Or the impacts of school gardening? Or the semester long project where my students study the local river's ecology? Or should I focus on something completely new? The problem with studying any one of these projects was that I knew each one did not exist in isolation of the others. My Grade 12 students who were engaged in inquiry projects, studied the local river's ecology in Grade 10 and may have been involved in the school garden project which was part of the agriculture course that I taught. As well, I knew that a specific pedagogical practice could not be examined separately from the course content and design.

When I was contemplating all of this, I happened to take a week-long class (part of a larger class on qualitative research methods) titled “Narrative Inquiry”. When I signed up for the class, I had no idea what narrative inquiry was, but when I began reading the required text *Engaging in Narrative Inquiry* (Clandinin, 2013), I had an immediate sense that I should engage in this type of research. Even with this strong intuition, there were many uncertainties. This non-traditional research methodology was initially difficult to wrap my mind around. As a science student and teacher, I have far more practice with understanding a problem through a reductionist lens. I was taught that this is how science works; we reduce a problem to a testable question and draw conclusions based on the results of our tests. Over time, as more and more tests are conducted and conclusions are drawn, we gain more knowledge and understanding about the problem.

This scientific way of developing our understanding of the world has no doubt been the greatest reason for our growth as a species, both in terms of population and power. The results of scientific research have led us to the modern age in which we currently live. Knowledge specialization is required to study specific testable research questions and knowledge specialization allows researchers to study the details in a way that our understanding of the problem becomes clearer. What happens, however, if the focus becomes so sharp that sight of the larger picture is lost? This is the question I contemplated as both a science teacher and a teacher-researcher. At the time, I was thinking about how I could paint a “big picture” curriculum for my science students and connect the seemingly disconnected course content into a larger narrative, while wondering how I could make sense of my wonderings about science and sustainability education by looking at my experiences as a whole.

Narrative inquiry is a distinct departure from the traditional social science qualitative research methodology, and, although it was difficult to imagine doing my research in this way, I knew that this methodology would help me understand my experience in a more rich and meaningful manner. Through the three-dimensional space of narrative inquiry, I could seek to understand my experiences through the people and places that surround these experiences, while considering the past, present, and future of these experiences. By embarking on this research journey, I rejected a reductionist perspective. This made me think critically about the nature of science and the teaching of science through knowledge specialization. As I moved toward teaching science through the lens of sustainability and well-being, I wondered about the possibilities and limitations afforded by this pedagogical stance that my reading of Poggi, Errico, and Leeone (2003) and Goleman, Bennett, and Barlow (2012) helped me to more clearly elucidate.

The concept of "pedagogical stance" (Poggi et al., 2003) was useful for me as I came to my research puzzle. It helped me to understand and make sense of the idea of "moving toward teaching science through the lens of sustainability and well-being". Teaching science through this lens requires a shift in both pedagogy and content. For me, this shift required making "ecoliteracy" the overarching goal of my teaching. I used Goleman et al.'s (2012) "five practices of emotionally and socially engaged ecoliteracy" (pp. 10-11) as a touchstone or guiding light for my teaching. These practices, as described below, demonstrate that it is not just about shifting content or pedagogy; it is about using "a variety of learning opportunities that help students consider and apply these practices in a diverse range of contexts... so that they can strengthen and extend their capacity to live sustainably" (p. 10).

*1) Developing empathy for all forms of life* is the practice of extending compassion to all forms of life and questioning the perspective that humans are separate and superior to all other life forms.

*2) Embracing sustainability as a community practice* is the practice of recognizing that the "quality of the web of relationships within any living community determines its collective ability to survive and thrive" (p. 10). This recognition is rooted in the understanding of the workings of ecosystems but is extended to understand the interconnections of any "system", including human society.

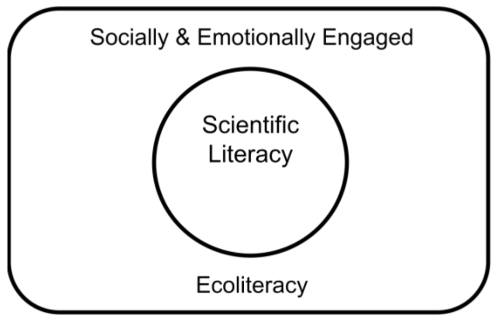
*3) Making the invisible visible* is the practice of seeing the far-reaching implications of human behaviour, while considering the social-ethical issues that arise with the acceleration of technological development.

*4) Anticipating unintended consequences* is a practice rooted in systems thinking, particularly when considering these issues of a social-ethical nature. Inherent in this, is the "precautionary principle" that cultivates a way of living that "defends rather than destroys the web of life" (p. 11), while recognizing that not all negative effects can be predicted and, thus, building resiliency within natural and social communities.

*5) Understanding how nature sustains life* requires understanding Earth's processes and the self-regulating system in which we are part. This practice is a foundation of ecology and, therefore, an important component of any science education curriculum.

When I consider these five practices, I am left wondering how they are present in my teaching. In the initial stages of my research, I wondered about the possibilities afforded by teaching science through the lens of sustainability and well-being. This lens was informed by my understanding of ecoliteracy as the overarching goal of my teaching practice. My starting point was to learn about the aims of science education which brought me to the locally prescribed goal of *scientific literacy for all*. Through my exploration of the literature, unpacking my narrative vignettes and developing my research texts, I have begun to see that scientific literacy is at the core of ecoliteracy.

Figure 2: Scientific Literacy at the core of Ecoliteracy




The epistemic question that inevitably comes up at this point is this: does one need to be scientifically literate in order to be ecoliterate? Through my research and reflection, there is no doubt that scientific literacy is a requirement for socially and emotionally engaged ecoliteracy. Scientific literacy, which includes understanding the nature of science and considering the impacts of science and technology on society and the environment, is a key component in the practices of “making the invisible visible”, “anticipating unintended consequences”, “embracing sustainability as a community practice” and “understanding how nature sustains life”. When considering the practice of “developing empathy for all forms of life”, one could argue that this is not an integral component of science education. This may, in fact, be true of a traditional science education program, but as I move toward teaching science through the lens of sustainability and well-being, I am aware of the need to expand our conception of what it means to educate Kindergarten-Grade 12 students in science.

This brings me back to the second narrative vignette. In the unpacking of the "story of science," I was keenly aware of the tension I felt when thinking about how science is generally taught through an Eurocentric lens. As I unpacked the narrative, I became aware of my shift in attitudes and behaviours towards sustainability, as I developed a greater understanding of the universe through the history of science. This historical "story of science" linked all the seemingly disconnected science that I had previously learned into a grand narrative in which I found a great sense of connection. I wanted to share this sense of emotional connection to the universe with my students in my teaching of science. Through my unpacking of the vignette, I wondered how expanding our understanding of science and moving toward a cross cultural science pedagogy, which validates other ways of knowing, would enable all of my students, regardless of their background, to connect to this story of the universe and the story of science.

As I move toward teaching science through a sustainability and well-being lens, my overarching goal becomes the fostering of ecoliteracy. Within this goal, scientific literacy is integral. However, in order to shift student attitudes and behaviours (as mine have), I understand that my pedagogy and content need to expand beyond the traditional understanding of scientific literacy as I described in my literature review. In order for students to develop empathy for all life and see themselves connected to the web of life, there needs to be a deep emotional connection and perhaps even a spiritual connection. Prior to the advent of science, cultures across the globe developed origin stories to make sense of their place in nature and the universe. Indigenous cultures continue to value the emotional, social, and ecological intelligence that is cultivated when sharing their origin stories.

In order to shift student attitudes and behaviours toward sustainability and well-being, emotional, social and ecological intelligence must be cultivated in science classes alongside scientific literacy. I have wondered how to do this. I have had a sense for some time that expanding my pedagogy and content to include Indigenous Traditional Knowledge (ITK) was a worthwhile endeavor. Even so, I have wondered how this could be done without creating a dichotomy between traditional science and ITK. Of course, these two knowledge systems are different and should be presented as such, but I do think they can be complementary. As much as scientific literacy is essential for emotionally and socially engaged ecoliteracy, ITK can contribute to science education by adding an emotional connection to the knowledge.

As I acknowledged in unpacking the second narrative vignette, I continued to be aware of surfacing tensions. After all, I was able to emotionally connect with the stories of science and gain a great sense of appreciation and awe without myself exploring ITK. As a white teacher and student of science with a western worldview, I saw myself in the story of science and was able to connect with it on an emotional level. But, as a teacher, I learned about ITK and knew that there was something about the pedagogical nature of Indigenous teachings that was worth exploring. Story-telling is the primary pedagogical tool in Indigenous teaching and this, of course, resonated with me as my emotional connection with the universe was born through the stories of science.

I have come to understand that the pedagogy of storytelling in ITK (or even the re-telling of the history of science in a classroom) is not the reason for the emotional connection. The emotional connection arises when we see ourselves in the grand narrative of the stories. I understood this as I unpacked the third narrative vignette and considered how Big History could be used as framework to teach science through the lens of sustainability and well-being. The more I learned about Big History through my research (both in the literature and my narrative inquiry), I came to see this as a framework for informing both content and pedagogy in the classroom.

**Big History as the framework**

As in Indigenous teaching practices, storytelling is the central pedagogical tool in Big History pedagogy. Big History is, after all, the telling of the "modern scientific origin story". It diverges from traditional origin stories, including Indigenous traditional stories, in that it excludes supernatural elements (i.e., forces beyond scientific understanding and the laws of nature). In addition, traditional religious and spiritual origin stories (also known as creation myths) "often provided instructions for how people ought to behave" (p. 198, Simon et al., 2015). In contrast, Big History, as the modern scientific origin story, does not provide explicit moral and ethical guidelines, but, as I will discuss further in the next section, it provides an opportunity for learners to connect emotionally with the story and, therefore, feel a sense of responsibility toward the principles of sustainability and well-being.

Story-telling is not the only important pedagogical tool that arises from the Big History curriculum. Within the story-telling pedagogy, is the opportunity to connect personally to the story. Reflective writing is an important tool in allowing students to make connections between the Big History story and themselves. It allows them to see themselves within the story. As well, reflection lends itself to a more complex level of understanding as students apply their knowledge to their own lives and/or synthesize ideas from various disciplines to make sense of their world through a cohesive knowledge narrative.

Story-telling and reflection are, of course, not unique to a Big History curriculum. Even within my science classes, prior to my learning of Big History, I used the stories of science and offered opportunities for inquiry and reflection in order to make the content more meaningful to my students. Coupled with these pedagogical tools or methods, Big History teaching also requires a shift in content. This shift moves us to understand the entirety of human knowledge as an interconnected and integrative framework of knowledge. This is especially revolutionary in the high school science setting in which subject knowledge is fragmented into disciplines, units, and learning outcomes. This fragmentation of science knowledge is perpetuated beyond high school when students enter tertiary institutions of learning and specialize in a particular discipline or field, or when students graduate from high school and think that scientific knowledge is not relevant to them since it does not apply to the work that they intend to do.

Scientific knowledge is important to all of us and recognizing its value is the foundation of scientific literacy. Yet, it seems that traditional science education is failing in this regard. Even though Manitoba science curricula begin with a pre-amble of learning outcomes directly aimed at scientific literacy, high school science teachers generally tend to zone in on the content knowledge (i.e., SLOs) that is often presented free of any relevant context. Even in a progressive classroom that incorporates 21st century teaching practices, such as flipped classrooms, inquiry and experiential learning, these new "methods" are simply pedagogies- "new ways to help students assimilate the knowledge formerly delivered through lectures. Our times call for a greater progress, a shift not merely in method but in content" (Simon et al., 2015, p.4).

This shift in content moves us away from the positivist, reductionist understanding of the world toward an approach that involves integrative, inter-disciplinary systems thinking. Of course, we cannot all be experts on all subject matter, but a basic foundational knowledge is part of being scientifically literate. Beyond that, placing this knowledge within the grand narrative of the modern scientific origin story of Big History allows us to not only connect to this knowledge personally, but perhaps see meaning in it. This emotional connection, this sense of meaning and purpose, is how we shift student attitudes and behaviours toward sustainability.

What happens when students connect emotionally to this "new content" and see these interconnections between what they have previously learned and what they are learning about in a new way? The result is "awe" or an "experience of amazement" (Simon et al., 2015, p. 336). As the modern scientific origin story, the Big History narrative diverges from traditional and religious origin stories in that it is currently our best factual account of the origin and development of the universe (with the understanding that this account can be modified as science enables us to learn more about it). But, as we present these "facts" in this grand narrative we can move students to appreciate them on a deeper level and connect to them emotionally, especially when, as teachers, we model this sense of awe.

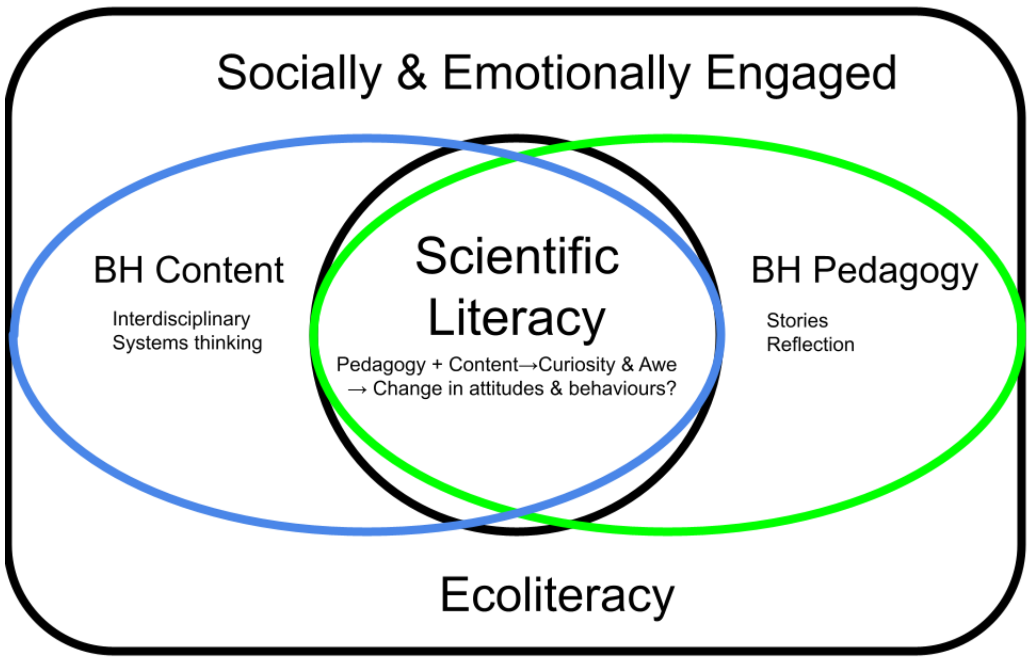
Neal Wolfe, in his chapter "The Case for Awe" (Simon et al., 2015), considers how "awe" can move students to see themselves in the universal narrative of Big History. He writes, "we find that the universe is not just something "out there" that we may know about intellectually... but that it is what we are *actually* part and parcel of" (p. 340). This understanding of being part of the universe (which includes both the natural and physical worlds), allows us to be part of its "magnificent mystery" (p. 340). From this place, a sense of curiosity about the universe will sprout, grow and thrive long after the student has left the classroom. The knowledge they have learned becomes more than "facts"; it is the story of how they fit into the universe. This sense of "place", within such a grand scale of time and space, is impactful.

I cannot overstate the importance of "place" in my research. It is a core commonplace in the three-dimensional space of narrative inquiry, and so, when unpacking my narrative vignettes, it was important to remember the places in which the vignettes were rooted in both the past and present. As well, Indigenous knowledges are place-based (Aikenhead & Elliot, 2010), and in my unpacking of the second narrative vignette I considered how ITK could help my students connect emotionally to the content. As I began to reveal how Big History allows us to see our place in the universe, I began to understand its power.

Even before this revelation, I understood that we can experience awe when we spend time in nature. I felt this myself when I would look up at the night sky or gaze over a body of water, but was this simply an automatic response to nature or was it because I had already begun to see myself as part of nature and the universe? I believe the latter to be true. It was not until I understood the story of the universe as "my story" that I began to hold this deep appreciation for nature. This is when my own attitudes and behaviours began to shift toward sustainability and well-being.

This is where Big History becomes a framework for teaching science through the lens of sustainability and well-being. Ecoliteracy remains the overarching goal for this pedagogical stance. At the core of this goal, scientific literacy is required to understand the Big History narrative as the modern scientific origin story. At the same time, the Big History framework allows students to connect with the story on an emotional level as they see themselves in the story. It is through this emotional connection that they can begin to develop a sense of community with the natural world and empathy for all forms of life.

Figure 3: Big History as the framework for fostering Ecoliteracy




A question that nags at me, and that I continue to think about, asks: does seeing one's self in the story of the universe automatically make that individual shift their attitudes toward sustainability and well-being? I realize that the Big History framework is inherently anthropocentric. Simon and colleagues (2015) maintain that Big History "tells the 13.8-billion-year story of the universe as the story of contemporary *Homo sapiens"* (p. 357). Even with this perspective, I admit that I do not know the answer. Through this autobiographical narrative inquiry, I have come to understand how seeing my place in the universe impacted my attitudes and behaviours. As well, it has given me a framework to understand how to achieve the goal of ecoliteracy as a I move toward teaching through the lens of sustainability and well-being. But I cannot help but wonder about the effectiveness of this framework in fostering ecoliteracy.

Further inquiry into these questions and unpacking of student narratives who experience the Big History framework would be required to understand this research puzzle more completely.

## Epilogue: How the COVID-19 pandemic has impacted these discussions

I began formulating my thesis proposal in 2017 and defended it in the spring of 2018. Throughout the 2018-2019 and 2019-2020 school years, I reflected on my experiences in the classroom with a focus on my Topics in Science classes. These reflections occurred alongside my teaching and planning, and at some point in the fall of 2019, I began to understand Big History as a framework to teach through the lens of sustainability and well-being. This realization did not come in the form of an "answer" to my research question—as I did not have a specific research question. Rather, as a narrative inquirer, I had articulated a research puzzle in my thesis proposal.

This puzzle included wonderings about the role of science education in shifting student attitudes and behaviours toward sustainability and well-being. I wondered about the possibilities and limitations that exist within science education. Considering the limitations inherent within science education was especially useful in helping me to make sense of my wonderings. As I unpacked my narrative vignettes and explored the tensions that surfaced, I found myself thinking more deeply about these limitations. In particular, I wondered about the consequences of privileging science as a way of knowing—how did understanding our world "scientifically" impact our attitudes and behaviors?

When I considered this question, I could not help but contrast this modern scientific understanding of the world which is born from a Eurocentric worldview with a traditional Indigenous worldview. In a traditional Indigenous worldview, the knowledge is relational and spiritual (Aikenhead & Michel, 2011). In a Eurocentric scientific worldview, the knowledge is reductionist and based on observations of the physical and natural world, thus leaving out questions dealing with the metaphysical world. As a knowledge system, science has given us a remarkably good understanding of the nature of the universe and, as new discoveries are made, this understanding grows by the day. But, as a science educator, I wondered how leaving out these “big questions” regarding “purpose” and “meaning” of the physical and natural world was doing a disservice to my students. How could I present scientific knowledge in a way that helped them to understand that they are an integral “part” of the universe, rather than detached from it?

All of these questions were on my mind when the COVID-19 pandemic hit in March 2020, and my class moved to remote learning. I had two weeks of a remote learning environment before I left my teaching assignment to begin my maternity leave. I was not able to see my class through the end of the 2019-2020 school year, but these questions about the role of science education in shifting student attitudes and behaviours did not leave me. Being at home with my newborn son, I was able to listen to and read news information from both the television and social media. The world seemed to be unravelling, and something I could not help but observe was this rising distrust in science. I also observed that in order to counteract this distrust, more and more people seemed to be declaring their support for science; using phrases like “trust the science” or “I trust the scientists”.

As well, in the early months of the pandemic, I saw how people drew analogies between this global health crisis and the global ecological and climate crises. If we could “trust the science” and make massive sudden behaviour and systemic changes to reduce the impacts of the pandemic, why were we not seeing these widespread changes to address the ecological and climate crises that scientists have been warning about for decades? And even though we were seeing more and more people declare their support and trust of science, why were we simultaneously seeing this rising distrust in science and hesitancy to follow public health guidelines? There is no doubt that the pandemic became politicized, as all social-scientific issues do. To some degree, I can empathize with those whose political leanings would cause them to distrust science. They may actually think that “believers” in science are simply following their own political “groupthink”. In certain cases, this may be accurate.

How many of us truly understand the nature and workings of science? This was a large focus of my reflection and research, and its importance was reinforced for me during this pandemic. Although I have thought deeply and critically about science as a knowledge system and the limitations of science education to enact change, today I wonder if these limitations exist because of the pervasive lack of understanding about how this knowledge system works. Those who declare their support for science must understand the nature of science in a way that enables them to think critically about how socio-scientific issues and the ways in which such issues are presented in the media. This understanding, coupled with a personal connection to these issues, is what will shift people’s behaviours and attitudes; whether it be to reduce the impacts of a global pandemic or a global ecological climate crisis.

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