HUMANISTIC SCIENCE THROUGH STORYTELLING

Investigating storytelling as a culture transmission device among science educators

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Abstract

Science education faces many challenges in the classroom such as feelings of cultural alienation, learning difficulties, unrealistic images of science and scientists, and a decline in science enrolment. Research into these challenges show that science education can be improved through a more humanistic science curriculum. One way to do this is by focusing on the historical and social nature of science rather than on canonical science content. This research project investigates how such a focus can be implemented in the classroom through the tool of storytelling. This is done through interviews with science educators about their thoughts on storytelling and by analyzing the stories they might use in a classroom. These interviews paint a culture portrait of science educators and the stories they tell and explores the implication of these stories in a classroom.

Keywords: humanistic science, nature of science, way of knowing, narrative pedagogy
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1. Introduction

Stories have been used by people to pass on knowledge for a very long time. They are an integral part of our lives, playing a prevalent role in everyday language as well as the process of meaning making through the construction of a personal narrative. On top of these impacts on the individual, stories also have the ability to shape societies by creating a common language through which people can interpret their experiences. They are one of the many ways through which we propagate culture. Canadian science educators sit at a peculiar intersection of school culture and science culture, while situated within a larger context of Canadian culture. At this particular vantage point, they are both constrained and empowered by this overlap of values and connections. As one of the gatekeepers of the conventional scientific community, they play an important role on the way science is perceived by the students. As teachers wielding power in the classroom, their stories can also have dramatic effects on the behaviours, beliefs, and language used by the students.

In the first week of April 1967 in Palo Alto, California, a history teacher by the name of Ron Jones conducted an experiment on his class to demonstrate how the German citizens may have felt during the Second World War. He started a movement called “Third Wave” based on the fictitious fact that the third in a series of waves is the strongest, and through this inducted his grade 10 Contemporary World classes into the movement. Students in the movement followed strict rules such as not congregating in groups of more than three outside the classroom, saluting each other with a wave gesture when greeting, sitting straight with their hands clasped behind the back, and prefacing each statement with “Mr. Jones.” The members of the third wave movement experienced greater motivation to learn, higher academic performance, and a stronger sense of community. This however came with a contrasting set of consequences such as telling on other
members, disrupting the learning culture of the school, ostracizing dissenting voices, etc. The movement grew from a few classes to two hundred students by the climax which took place in the school auditorium. Here Mr. Jones revealed the nature and purpose of the Third Wave movement (Jones, 2008). The case of the Third Wave Movement is illustrative of a few points I would like to make about science education in Canada today.

Science education today is very much a product of globalization in that it is very similar around the world. This is backed by the evidence from cross-cultural research efforts on comparing teacher’s worldview presuppositions in a diverse sample of countries (i.e. in Botswana, Indonesia, Japan, Nigeria and the Philippines) (Ogunniyi, Jegede, Ogawa, Yandila, & Oladele, 1995) and teaching methods and goals (i.e. in Scotland and Connecticut) (Cross, 1997). This creates a globally uniform culture of science education which may be very strongly influenced by the culture of Western science. This line of thought reframes science education around the world as not just knowledge transmission of Western science content knowledge but also as a method of cultural transmission of the Western scientific culture. The induction of students into Western scientific culture starts early in life in elementary school and continues into secondary, post-secondary, and then academia. This is sometimes referred to as the pipeline perspective on science education (Aikenhead G. S., Science Education for Everyday Life: Evidence-based Practice, 2006). That the pipeline exists is not an issue of concern in this research. The issue I would like to explore is the response to the pipeline perspective of science education (i.e. that science education has the purpose of creating more scientists). Since the beginning of a formalized science education in UK and USA, late 1800s, there has been a portion of the policy makers arguing that school science should be a subject that connects with everyday society (Aikenhead G. S., Science Education for Everyday Life: Evidence-based Practice, 2006,
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The Ontario science curriculum states that: “…scientific and technological literacy for all has become the overarching objective of science and technology education throughout the world” (Ontario Ministry of Education, 2007, p. 4). I will follow the convention set by Aikenhead and refer to this as the humanistic perspective on science education (Aikenhead G. S., Science Education for Everyday Life: Evidence-based Practice, 2006).

Humanistic science has been called many things in different parts of the world at different times. Examples of these monikers are science for public understanding, science-technology-citizenship, functional scientific literacy, socio-scientific issues, and cross-cultural school science. Its current form in the Ontario curriculum is science-technology-society-environment, usually shortened to STSE. While many teachers believe that humanistic content is worth including in the classroom, there are many challenges in the way of implementation. The Ontario science curriculum further specifies that an important part of scientific and technological literacy is an understanding of the Nature of Science (NoS). According to an article by William McComas titled Keys to Teaching the Nature of Science (2004), NoS has been recommended for inclusion for more than a century now (Central Association of Science and Mathematics Teachers, 1907), however “in spite of these continuous and well-reasoned recommendations, some students and teachers alike still fail to understand even the most basic elements of this domain” (McComas, 2004, p. 24). Within this paper, I will focus on the education of NoS through the use of stories.

Storytelling has been used as a pedagogical tool since ancient times and carries with it a myriad of benefits. Our brains interpret the world by constructing a personal narrative, and by using narratives, we can improve our ability to recall relevant information (Foer, 2011). Stories also play a role in helping non-scientists understand the Nature of Science (Wilson, 2002;
There is very little communication between scientists and non-scientists, which is a significant problem in current Western society, representing the fragmentation of knowledge in how we think about the world. This is often further complicated by politics and a vocabulary gap between the public, science journalists and scientists. This problem can be addressed from either side, by encouraging more science literacy on the non-scientist’s side and encouraging more accessible communication to the general public from the scientist’s side. Both of these solutions can be implemented in an elementary school. The first by simply increasing scientific literacy among the student body and the second by painting an image of the scientist that places them in a community of people and highlighting the role of communication in science.

In the field of education, narratives are used as a research method and as a pedagogical strategy. When storytelling is effectively used in a classroom, the students often become more engaged and their natural curiosity is activated. In my opinion, by framing questions about the natural world as a story, the students can learn inquiry and effective questioning and be more ready to apply these skills in the real world. By creating realistic situations where a simple answer is not sufficient, the students can practice critical thinking skills about the physical world but also the social and mental world. In science education, stories can paint an image of the scientist that is very personal and identifiable. In a MA thesis at OISE, Tasha Richardson argues: “Consider the portrayal of science and scientists in popular culture and media - the scientist is usually male, very smart and somewhat on the periphery of society. If these identities conflict, Lee (1998) posits that a student’s interest in [science, math and engineering] will change and ultimately will reject subjects that they find incongruent.” (Richardson, 2013, p. 20). The image of the scientist is something that I suspect can be influenced greatly through storytelling. The understanding that a farmer is acting as a scientist when that farmer considers the effects of an
early frost on their harvest is a very valuable one. This democratizing of the utility and applicability of science also allows for bridging opportunities with other ways of knowing and understanding, for example those found in the various Aboriginal traditions within North America.

In recent years, there has been a strong focus on science, technology, engineering, and math (STEM) education with special emphasis on the interactions between science, technology, society, and the environment (STSE) but also great declines in science enrolment in senior high school in post-secondary education (Sjøberg & Schreiner, 2010; EQAO, 2011). I feel like this is in part an effort to combat the culture of science denial but I feel that another important goal is to combat the culture of scientific arrogance and isolationism. The Third Wave movement created by teacher Ron Jones was meant as an illustration to the power of a group narrative by acting as a parallel to the Nazi movement in Germany. One of the reprehensible acts of Nazi Germany was the state run eugenics program where only certain people were allowed to reproduce. This was justified through Social Darwinism which allowed the eugenicists to argue that some life did not deserve life. By shaping the environment, the dominant culture was able to justify to themselves the castration and execution of wide swaths of people. By comparing this to the domestication of animals and crops, the eugenicists believed that they had the right to select for specific traits for the benefit of the species. It is my opinion that Western scientific education creates a similar environment, less dire but more sinister. By fragmenting human knowledge and by emphasizing a few fragments, we are selecting for generations of thinkers who are unbalanced experts, unable to apply their expertise outside of a very contrived environment. By telling students that some are science types and others are art types, we create scientists who are not able to empathise with the public emotionally and creatively, and artists who are not able to understand the Universe
they live in through logic and rationalism. I feel like many of these issues can be addressed through storytelling but what is the right way to do it?

1.1 Research Problem

Among science educators, three rough categories can be formed when describing their views on the nature of science education. These categories are described by Glen S. Aikenhead (2006) as humanistic, pipeline enthusiast and middle-of-the-road. In a study of Dutch chemistry teachers, the breakdown of the research sample was 15%, 11%, and 74% respectively among the 348 teachers who responded (van Driel, Bulte, & Verloop, 2005). This illustrates that while the majority use a combination of both humanistic perspectives and pipeline perspectives, there is a small percentage who are ardent adherents of the extremes of the spectrum. While it is worthwhile to examine fans of the humanistic perspective, I feel that my position as researcher and preservice teacher is better served by focusing on the pipeline enthusiasts. This is because I feel a greater affiliation with pipeline enthusiasts due to my background in academic science. At the same time I also feel the need for change in science education due to my experience going through the pipeline. While my experiences in high school and undergrad were fairly fulfilling, I did feel like my expectations of doing scientific research to be unrealistic and my actual understanding of the process of science to be insufficient.

Through an analysis of previous research, Aikenhead identifies a list of salient influences on teacher orientation which include “a teacher’s values, assumptions, beliefs, ideologies, self-identities, self-images, and loyalties to traditional school science… Changing any one of these salient influences toward a humanistic perspective is very difficult for most middle-of-the-road teachers, and is usually impossible for pipeline enthusiasts” (Aikenhead G. S., Science Education for Everyday Life: Evidence-based Practice, 2006, p. 64).
1.2 Purpose of Study

The purpose of this critical ethnographic study is to better understand the scientific culture among middle school teachers and other science educators, and to investigate the effect of using storytelling as a pedagogical tool in shifting that culture to a more humanistic view of science education. A secondary purpose is to look into why there is declining interest in school science and use that to guide the content and tone of future stories. By creating a portrait of the culture-sharing group of science educators, I intend on elucidating the cultural themes, behaviour and language of the group.

1.3 Research Questions

This research project is guided by the following questions:

- What are some typical pedagogical challenges when implementing a more humanistic science curriculum?
- Can stories be designed to shape the students’ image of the scientist and attitudes towards science?
- What elements do stories need to effectively communicate the nature of science?
- Can stories be designed to encourage the application of scientific thinking?

1.4 Background of Researcher

The background I bring to this research is a result of the pipeline perspective of science teaching. Science teaching is a form of cultural transmission but I have already been enculturated a great deal to this scientific culture from a young age due to a family background in science and strong interest in reading popular science books. My educational history spans three countries through China and Belgium, ending in Canada from grade 8 and up. In my primary and
secondary education I excelled at math and science, taking the academic track courses whenever I had the option. My post-secondary education was also in math and science and I ended up with a specialist degree in math and physics before completing a master’s degree in physics as well. This means that following the pipeline model of scientist training, I was more than half way complete time-wise.

While completing my science education, my goal and the goal of many of my peers were to complete the pipeline and in our image of a scientist, that goal involved completing a PhD in science then a post-doc then get a position as an assistant professor and eventually get a tenure track position. While those were far from our only options, the narrative of the scientist puts the goal of tenure position at a recognized institution as being more desirable that other employment opportunities where we can apply our skills in some way. The three goals of the Ontario science curriculum make for an interesting reflection on the possible applications of an education in science. To quote the curriculum “the three goals are the following: 1. to relate science and technology to society and the environment; 2. to develop the skills, strategies, and habits of mind required for scientific inquiry and technological problem solving; 3. to understand the basic concepts of science and technology” (Ontario Ministry of Education, 2007). Some professors were explicit in that physics does not prepare you for a specific career and that it provides skills and ways of thinking that are fulfilling and transferable but many offered the narrative that studying science is only for those who want to one day become a scientist.

In the process of critical research, I have also brought in my own experience as a twice immigrant in Belgium at 7 and in Canada at 13 years old. I have lived through several changes of culture, which is why I felt compelled to look at the problems of science education from a cultural perspective. As I was growing up in Canada, I took on more and more characteristics of
the dominant local culture in the University town of Guelph, Ontario. Between leaving China at age 7 and arriving in Canada at age 13, I rarely felt like I had a stable home life. My parents were often busy with the hardships of making a living in a European metropolis as Chinese immigrants, often working multiple low wage jobs. My dad was also busy with school work getting a PhD to advance his scientific career. I spent part of the time at a boarding school, part of the time in China, and part of the time home alone. In the meantime I also experienced an episode of trauma at the boarding school, making the rest of my life in Brussels detached and impersonal. Coming to Canada changed all that. After a year of searching, my dad got a job at the University of Guelph as a lab technician. With that he was able to afford a townhouse and have my mom and I move from Brussels to Guelph. By then I had built up a sense of resentment towards my parents for moving to Brussels when I was young, and so I became emotionally distant at home. This led me to focus on academics and a vibrant but superficial social life. These were my formative years and because of them I became very proficient in a scientific way of thinking.

1.5 Overview of Chapters

Chapter 1 includes the introduction and purpose of the study, the research questions, as well as how I came to be involved in this topic and study. Chapter 2 contains a review of the literature related to this topic. Chapter 3 provides the methodology and procedure used in this study including information about the participants, data collection instruments, and limitations of the study. Chapter 4 identifies the research participants and describes the data as it addresses the research questions. Chapter 5 includes what was learned, insights, recommendations for practice, further study, and a review the limitations of the study. References and a list of appendices follow at the end.
2. Literature Review

Considering the span of this research topic, I had a lot of partially related literature to evaluate. An important aspect is the Ontario curriculum which is what public school science teachers use to guide their lesson design. The curriculum serves as a starting point to the goals of science education as well as the nature of science. From there, I looked into the challenges around the world of the Western science education paradigm through a book by Glen Aikenhead (2006). To guide my analysis on teaching the nature of science, I relied on a paper by McComas (2004) about essential elements of nature of science to include in science education. An area of research I had not considered initially came from research into colonialism and alternate ways of knowing. The storytelling traditions of various indigenous groups provided me with a clear view of ways of knowing, thinking, and teaching that were highly contrasting with the Western scientific tradition. These alternative traditions are worth considering due to my cultural context as a member of the dominant culture in a colonial nation and as an immigrant who had to assimilate into that same dominant culture while growing up. Finally, my research led me to a book by Julia Kuyvenhoven (2009) on the use of storytelling as a pedagogical tool, noting very specific qualities to using stories in a grade 5 classroom.

2.1 Role of the curriculum

To better understand the relationship between storytelling and science pedagogy, this paper will examine the context of the Ontario science and technology program with a focus on grades 1 to 8. Using the Ontario science education curriculum as a guide, the goals of the science and technology program is threefold.

“The three goals are the following:
1. to relate science and technology to society and the environment
2. to develop the skills, strategies, and habits of mind required for scientific inquiry and
technological problem solving
3. to understand the basic concepts of science and technology”

(Ontario Ministry of Education, 2007, p. 3)

These three goals of the Ontario science and technology program are to support an
overarching societal objective of science and technology literacy for all. This overarching goal is
further elucidated by the Science Teachers’ Association of Ontario (STAO) and the Science
Coordinators’ and Consultants’ Association of Ontario (SCCAO) in a position paper on the
Nature of Science. The paper states:

“A scientifically and technologically literate person is one who can read and understand common
media reports about science and technology, critically evaluate the information presented, and
confidently engage in discussions and decision-making activities regarding issues that involve
science and technology.”

(SCCAO and STAO/APSO, 2006, p. 1)

The Ontario science curriculum document then goes on to say:

“An important part of scientific and technological literacy is an understanding of the nature of
science, which includes an understanding of the following:

- What scientists, engineers, and technologists do as individuals and as a community
- How scientific knowledge is generated and validated, and what benefits, costs, and risks
  are involved in using this knowledge
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- How science interacts with technology, society and the environment”

(Ontario Ministry of Education, 2007, p. 4)

With these goals in mind, I was better able to consider the challenges of teaching the science curriculum as well as how and what kind of stories can improve the transmission of NoS in a humanistic fashion.

By looking closer at the curriculum we can see how these stated goals are expressed through the expectations. Focusing on the topic of flight in the grade 6 Ontario science curriculum, I notice that the STSE component of the curriculum contains only one specific expectation: “assess the benefits and costs of aviation technology for society and the environment, taking different social and economic perspectives into account.” (Ontario Ministry of Education, 2007) In comparison to the preamble of the curriculum document, I see that this expectation addresses how science impacts society and the environment but not the reverse. The development of flight is a human achievement with a rich history and full of trials and tribulations. By going more in depth into flight as a human achievement, I can connect the topic of flight to what do engineers do, and how the technological knowledge of flight was generated through the interactions between social and environmental forces. Flipping through the curriculum reveals similar depths under the overall expectation of STSE across grades and strands.

2.2 Challenges of science education

Aikenhead outlined in his book *Science Education for Everyday Life: Evidence-Based Practice* a list of four major challenges of the traditional science curriculum: declining student enrolments, discrimination and cultural alienation, dishonest and mythical images, and learning difficulties (Aikenhead G. S., Science Education for Everyday Life: Evidence-based Practice,
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2006, p. 25). I will briefly go into detail on each of those failures and present some supporting research.

2.2.1 Declining Student Enrolment

Osborne and Dillon (2008) report that by the time students are 14 they have already formed an interest and level of engagement in science. On top of that, the ROSE project (Relevance of Science Education) found that the majority of 15-year-old students generally have positive attitudes towards both science and technology (Sjøberg & Schreiner, 2010). However, as Aikenhead (2006) points out, despite interest in science and technology, student enrolment is in decline. He examines data from a 15-year longitudinal study conducted by the U.S. Office of Technology Assessment which began in 1977 and charted the interest and progression of 4 million grade 10 students. Out of this initial sample, 18% expressed an interest in continuing their science or engineering education in post-secondary education. Of the 18% (720 thousand students), 19% lost interest during high school and did not continue taking science or engineering courses in post-secondary education. During the first year in university or college, 39% of the remaining students lost interest and did not pursue more science or engineering courses. This means that by second year university, out of the initial 4 million students, roughly 360 thousand remained in the pipeline; alternatively that 90% of the students did not reach this point in the science education pipeline. The same trend of declining enrolment in the sciences is reported in Canada which studied the 1994-1995 TIMSS (Third International Mathematics and Science Study) and noticed a drop of interest from grade 4 to grade 8 and examined enrolment data to see that only 42% of students were taking math and science courses in the last year of high school (De Broucker, Bordt, C., Harris, & Zhang, 2001).
Aikenhead (2006) attributes this phenomenon to two causes. The first cause is the students’ disenchantment with school science and the second is the students’ self-identities conflicting with students’ perceptions of science and technology. To quote Aikenhead: “Most research into students’ views of the science curriculum concluded that it is socially sterile, impersonal, frustrating, intellectually boring, and/or dismissive of students’ life-world and career goals… The most cogent single force acting against enrolment was found to be the culture of school science itself” (Aikenhead G. S., Science Education for Everyday Life: Evidence-based Practice, 2006, p. 26). Aikenhead also gives an example in UK where highly capable students in the A-levels were discouraged from studying science by the curriculum, particularly young women and minority students.

2.2.2 Discrimination and Cultural Alienation

It is an accepted fact that many students belonging to certain cultures, subcultures, or socioeconomic groups are underrepresented in high school science or in university science. These underrepresented groups include aboriginals, women, and many ethnic minority groups in Canada. This was also something I experienced personally in my undergraduate studies where the classes and student spaces have very few female students and students of certain ethnicities. It would also be clear to see that we had a skewed representation of socioeconomic backgrounds. Aikenhead also mentions research (Tobin, Seiler, & Smith, 1999) that “revealed systemic exclusion of adolescents outside the cultural power structures that sustain schooling and traditional school science” (Aikenhead G. S., Science Education for Everyday Life: Evidence-based Practice, 2006, p. 27).

Aside from discriminatory structures and practices, Canada also faces the challenge of teaching migrant students who are undergoing a transition in culture and possibly language. This
is further elucidated in article in *Science Education from People for People*: “As migrants, we are affected not only by the different ways of knowing the world in the new country but also by the strangeness of the language of science that we learn after arriving there.” (Hwang & Roth, 2009, p. 60) This is related to the challenges of Aboriginal education where there is virtually no representation in post-secondary science education. From a census in 2006, the Canadian senate concluded that half of the registered Indian on-reserve population aged from 25 to 34 did not have a high school leaving certificate, versus 29% for registered Indians living off reserve and 10% of non-Aboriginal population in the same age group (The Standing Senate Committee on Aboriginal Peoples, 2011). One way of interpreting this data is simply that the school culture can be beneficial or detrimental to education depending on the cultures that the students bring to the classroom. This is only exacerbated by Western science culture which is also distinct from everyday Western culture.

Using humanistic approaches to address underrepresentation in some traditionally marginalized groups of students is a recent focus. A review article by Hammond and Brandt (2004) looks at a variety of research articles focusing on epistemological, pedagogical, and methodological explorations that purports to be anthropological. Another collection of research can be found in *Science Education from People for People* edited by Wolf-Michael Roth (2009) which investigates subcultures (hip-hop) and ethnic groups (Zuni, Korea, Māori) and their experiences in science education and science learning.

### 2.2.3 Dishonest and Mythical Images

The third major failure outlined by Aikenhead is that images about science and scientists do not conform to realistic portrayals of scientists and the act of doing science. There are three consequences from this: students lose interest in science, students gain interest in science under
false expectations, and students become citizens with false images of science and scientists. This failure constitutes one reason for shifting to a more humanistic perspective of science education and to correct these dishonest and mythical images. The third consequence deserves a bit more elaboration as it has a very large impact. This is because often these citizens are those who someday become policy makers and key players in industry who have a false image of science and scientists. Another related phenomenon is emphasized in Aikenhead: “Most often canonical science content is not directly useable in science-related everyday situations” (Aikenhead G. S., Science Education for Everyday Life: Evidence-based Practice, 2006). It is this researcher’s opinion that storytelling can play a large role in correcting dishonest and mythical images in students but also in teachers which can lead to a change in the public perception of science down the line.

2.2.4 Learning Difficulties

Aikenhead (Science Education for Everyday Life: Evidence-based Practice, 2006) reports that most students do not learn content meaningfully. This means that most students do not incorporate scientific concepts into their everyday thinking. This is typically attributed to a lack of relevance in school science or a lack of adequate pedagogy. Surprisingly, this is even true for students entering into science-related fields. These students eventually learn the scientific skills needed on the job rather than apply concepts from the traditional science curriculum. This difficulty with meaningful learning can lead to science anxiety which was shown to begin as early as grade three or nine years of age (Udo, et. al., 2001). The ROSE project also found that by the time students are 15 years old, they have positive attitudes towards science but prefer other subjects to science because they find science school work to be “boring” or “difficult” (Sjøberg & Schreiner, 2010). An interesting coping strategy was identified in a paper by Jane
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Larson (1995) called “Fatima’s rules” named after a very articulate participant. The rules are rote memorization and going through the motions and they were used by Fatima to perform well in science class without meaningful understanding of the canonical science content. Furthermore is the worrying observation from the ROSE project, which shows a negative correlation between scores in TIMSS (Trends in International Mathematics and Science Study) and PISA (Programme for International Student Assessment) and level of interest in science. This paints the paradoxical picture of countries that score highly in science aptitude will score low in science interest. I would like to venture the explanation that countries that score higher have a stronger focus on canonical science content which also generates a lot of dissatisfaction about school science.

2.3 Teaching Nature of Science

The article by McComas outlines nine key elements that need to be included to correctly instruct a student in the nature of science (McComas, 2004). I will list them here:

1) Science demands and relies on empirical evidence.

2) Knowledge production in science includes many common features and shared habits of mind. However, in spite of such commonalities there is no single step-by-step scientific method by which all science is done.

3) Scientific knowledge is tentative but durable. This means that science cannot prove anything because the problem of induction makes “proof” impossible, but scientific conclusions are still valuable and long lasting because of the way that knowledge eventually comes to be accepted in science.

4) Laws and theories are related but distinct kinds of scientific knowledge.

5) Science is a highly creative endeavour.
6) Science has a subjective element.
7) There are historical, cultural, and social influences on science.
8) Science and technology impact each other, but they are not the same.
9) Science and its methods cannot answer all questions.

McComas explains that it is very important that these key elements of the nature of science are prominently and explicitly featured in the classroom, textbooks, descriptions of how science functions, and even laboratory and other hands-on work. I personally believe that with a stronger focus on NoS instruction, we can address many of the failures of the traditional science curriculum such as dishonest and mythical images of science and scientists. These key elements are what I can use to help me guide creating stories for the classroom.

2.4 Colonialism and Ways of Knowing

“Canada is a test case for a grand notion - the notion that dissimilar peoples can share lands, resources, power and dreams while respecting and sustaining their differences. The story of Canada is the story of many such peoples, trying and failing and trying again, to live together in peace and harmony.”

– Highlights from RCAP (Ministry of Supply and Services Canada, 1996)

In 1991, the Canadian government appointed four Aboriginal and three non-Aboriginal Canadians to the Royal Commission on Aboriginal Peoples (Canada, 1996) to investigate issues related to the First Nations, the Metis, and the Inuit people with consideration to the history of interactions with the colonial and then Canadian governments. The report ended with a list of recommendations in future interactions with the Aboriginal Peoples of Canada. Similarly, in 1997, the UN drafted a declaration called the United Nations Declaration on the Rights of Indigenous Peoples (UN, 2008). Both these documents are highly relevant to the current cultural
and political climate of Canadian society. The connection to public education is not directly apparent but I feel that there is a very crucial implication to science education. Science is a part of Western culture representing one of the ways of knowing that exist in the world. Aboriginal peoples also have their own ways of knowing that are very distinct from science. “Where a public attitude of cultural disrespect prevails, cultural difference is often seen simply as a deficiency or disability… Such attitudes erode a person's sense of self-worth and discourage a commitment to education or employment; in the long run, they may even encourage dependency and self-abuse.” (Canada, 1996) As propagators of culture, the public school system must strive to create an attitude of cultural respect for the Aboriginal ways of knowing and living. This is not only important when we have students with Aboriginal connections in our classrooms; we have a responsibility as Canadian citizens to respect the many nations we have interacted with throughout history. To show this respect, we must extend courtesy, consideration and esteem by not framing the scientific way of knowing, developed through European natural philosophers with little contribution or consideration of other cultures, as superior to alternative ways of knowing.

This thought is one that I struggle with deeply, first, because I was born in another culture where the accepted ways of knowing is rooted deeply on the Western European philosophy of science, and second, because of my long and enthusiastic exposure to pipeline science education. I can rationalize that the Western hypothetico-deductive method does not offer a complete understanding of the world but it also feels intuitively clear that science has great power to understand the world. To place any other way of knowing at an equal level goes against much of my schooling. I can only imagine what a student from an Aboriginal ancestry with connections to an Aboriginal culture and teachings would feel as they are going through this system. Through
my research, a book was recommended to me called *Our Knowledge is not Primitive: Decolonizing botanical Anishinaabe teachings* by Wendy Makoons Geniusz (2009). The book talks about many differences and similarities between Western scientific ways of knowing and Anishinaabe ways of knowing. While there is a cultural sentiment that Western scientific knowledge is superior to other forms of knowledge, the book points out that early European settlers relied heavily on the botanical knowledge of the local population for their survival in this unfamiliar land. This sharing of knowledge is not part of our popular history but was instead appropriated into Western scientific discoveries through the process of colonization. Attempts to reconcile differences in ways of knowing have been an important focus for Glen Aikenhead (2001; 2006; 2006; Aikenhead & Huntley, 1999). Also worth noting is a paper by Bechtel on the use of autobiographical narratives to bridge disparate perspectives regarding a topic of mutual concern (Bechtel, 2014), in this case caribou hunting practices in Northern Canada. These research findings are also backed up by other publications such as *Lessons in Learning: The cultural divide in science education for aboriginal learners* released by the Canadian Council on Learning (CCL, 2007). Though Bechtel (2014) finds that narratives have great potential in cultural border crossing, an earlier attempt at implementation in *kura kaupapa Māori* schools ran into challenges in the student’s acceptance of the stories (Gilbert, Hipkins, & Cooper, 2005).

### 2.5 Storytelling as Pedagogy

> "There is something about the intense listening to another person’s narrative that I think should be incorporated into our educational practice of science."

(Brandt, Emdin, Hwang, Parsons, Bruna, & Roth, 2009, p. 117)

In my research on using storytelling in the classroom, I came across a qualitative research book called *In the Presence of Each Other: A Pedagogy of Storytelling* by Kuyvenhoven (2009).
In this book, the author spent five months in a grade 4/5 classroom with 26 children and a self-identified storytelling teacher. She kept meticulous records of stories told by the teacher as well as students and conducted many interviews with them to better understand the role of storytelling in the classroom.

Through her observations, she noticed three different levels of participation when students were listening to a storyteller. Kuyvenhoven referred to these three levels of participation as talking with stories, thinking with stories and imagining with stories. These levels of participation involve different degrees of awareness, interaction, and mental activity. The author also identified different benefits to different levels of interaction as well as examples of the format of stories that resulted in one level of interaction rather than another. The three levels that she had observed were described as talking with stories, thinking with stories, and imagining with stories.

2.5.1 Talking with Stories

When an audience member is talking with stories they are paying cursory attention to the story itself but instead take what they hear as only part of the experience. The audience member is experiencing “the situation, others’ presence, and an awareness of oneself in company” (Kuyvenhoven, 2009, p. 61). Interruptions are tolerated and can be incorporated into the story creating an atmosphere suitable to sharing personal connections and discussions. It is a level of participation that includes everyone. The book gives many examples of this type of participation where the format of the story was very informal. One notable example I would like to explore later is the class meeting format where a student is selected as moderator and a number of students come up to the front of the class one by one and tell the class a story or summarize a news article. Other examples are much less structured where the class was simply socializing and
through that were telling short accounts of recent events or jokes and riddles they had heard of recently. Kuyvenhoven points out that talking with stories served an important role in socializing the classroom creating a strong learning space where all the students were encouraged to have a voice. The classroom studied is located in BC, Canada and nearly 35% of the students in the school were identified as ESL (English as a Second Language) students. The students told stories in English but were encouraged to tell stories about life in the country they came from. This created many situations where the children had a concept in their mind but had no word to refer to it and resorted to native words for those concepts. Very rarely this created situations that alienated the student. Nearly all of the time through verbal prompts by the teacher or other students, the storyteller was encouraged to search for other ways of describing this concept. The final result in these cases was that the storyteller overcame a difficulty in communication and the listeners learned both a new concept and a little bit about a different culture. In a specific example of this, a student told a story of his sister riding a tricycle in the house and crashing into a madhami (a common butter/yogurt churn in Indian kitchens) and breaking it. The audience did not know how to respond until the teacher prompted an explanation.

2.5.2 Thinking with Stories

In thinking with stories, the listener is mindfully interacting with the story and the teller. The nature of this interaction is an active dialogue between the listener’s mind and the story’s content. This prompts the listener to form associations or recall personal memories, typically within the mind of the listener but sometimes out loud. At this level of participation the interaction is between the listener and the storyteller. Kuyvenhoven mentions that the majority of research on storytelling as pedagogy is focused on this form of storytelling where the story is chosen with a specific purpose of advancing the curriculum. Three main ways the storytelling
teacher used this level of interaction were to help students think about concepts, to encourage students who were learning to read, and to facilitate the teaching of writing. Clearly thinking with stories lends itself very well to the language arts curriculum but there are examples where it can be useful in communicating and thinking about the nature of science. In a specific instance, the teacher told a story called “The Flying Head” where a monstrous head terrorizes a village and in the end a brave woman kills the monster by tricking it into eating a red-hot rock. This was followed by asking the students to think about what ‘a hero is.’ The author notes:

“Children made meanings and drew applications from the story, considering what it means to ‘be heroic.’

‘Pender suggested that the stupidity of the monster diminished the woman’s status as a hero, implying that an adversary must be wily if a conquest is to be a heroic one. Tych contended that the woman’s heroism was an act of ‘standing up for herself.’ Thus, a hero is a person of independent character. Azun, who was well informed about current issues and events in the Middle-East, connected a recent Palestinian suicide bomber with the woman’s act.”

(Kuyvenhoven, 2009, p. 160)

Two of the students brought up the same question of whether the suicide bomber was a hero or a monster. One student applied the ideas of the story to bullies on the playground and how those who were bullied felt like the terrorized villagers. My take away from this example is that a story is able to invite deep thinking about the multifaceted nature of a single concept. The thinking and follow-up discussion that the story prompted created a dynamic and collective learning experience for the students. It also highlighted opposite points of view that made ‘a hero’ into “a complicated, situated, social, and personal idea” (Kuyvenhoven, 2009, p. 160). Another important point from the book is the difference between thinking about a told story
versus thinking about a story that the students read. Both kinds of thinking can prompt deep analytical thought about a concept but the told story implicitly communicates that learning is a socially shared pursuit and that knowledge is stored in hearts and minds. “The usual authority of text is absent; there is no print refuge, substitute, or weapon” (Kuyvenhoven, 2009, p. 161). These properties make me believe that this level of interaction with a story has great potential in teaching the nature of science, specifically about the tentative nature of scientific theories and getting away from the discourse of science as law.

2.5.3 Imagining with Stories

The final and innermost level of participation is imagining with stories where the listener is aware of only the storyworld excluding the situation, the teller and the other listeners. The listener sits alone in a deep imaginative engagement and explores the story world mentally loosely guided by the teller. At this level of participation, the listener “develops the abilities necessary for conceptualizing, connecting, and understanding a story’s meaning, implications, and applications” (Kuyvenhoven, 2009, p. 65). The author observes that during these kinds of storytelling sessions the students, once drawn into the story world, lose sense of their surroundings, often sitting in uncomfortable positions and stop responding to minor distractions such as noises made when reacting to the story. This is often referred to as the ‘magic of storytelling’ and can be thought of as an immersive experience. It is not a phenomenon unique to storytelling, in other forms of media it is described as a magic circle or a suspension of disbelief, but it can be achieved without any extra materials simply by preparing a suitable story and telling it by heart. Through the use of interviews, the author was able to identify five main points about the students’ experience during these immersive storytelling sessions. First, the story world is a real place, evoking a full spectrum of sensations and emotions; second, the listeners had to ‘make
pictures’ in order to get into the story world; third, the story world and the world out there were organized differently with their own internal logic and phenomena; fourth, the boundary of the story world is fragile and can be easily disrupted by external interruptions, sometimes making the interruptions more memorable than the story itself; fifth, students in the story world feel a sense of wonder resulting in a very visceral experience. These five properties of imagining with stories make this level of interaction useful for communicating certain aspects of the nature of science. For instance, creating a story where the audience can take the internal logic of the story world and create tentative story world knowledge to understand the tentative durability of scientific knowledge in the real world.

2.5.4 Other ways of characterizing stories that teach

Kuyvenhoven (2009) characterized stories in terms of what effect they had on the listeners. This was the aspect of storytelling I focused on, although in my research I came across other ways of classifying stories of different kinds. A source that shows great potential is *Teaching Mathematics as Storytelling* by Rina Zazkis and Peter Liljedahl (2009). In this book, stories were characterized by the intent of the teacher in sharing these stories. Despite the alternative focus on math education, I felt that the conceptual nature of mathematics is a good match for the concepts behind nature of science. The different types of stories allowed me to think of the examples that my participants put forth in terms of their intended effect. This will form a good resource for future studies on breaking down the elements of a story and how to select pedagogical elements before putting them together creatively and effectively. I will include the types here as a comparison but will focus on Kuyvenhoven’s characterization due to the time and scope of this project. I will also associate each with one of Kuyvenhoven’s characterization to increase the depth of my analysis when looking at my data.
HUMANISTIC SCIENCE THROUGH STORYTELLING

<table>
<thead>
<tr>
<th>Characterization by intent</th>
<th>Characterization by effect</th>
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<tbody>
<tr>
<td>Stories that set a frame or a background</td>
<td>Imagining with stories</td>
</tr>
<tr>
<td>Stories that accompany and stories that intertwine</td>
<td>Imagining with stories</td>
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<tr>
<td>Stories that introduce</td>
<td>Talking with stories</td>
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<td>Stories that explain</td>
<td>Thinking with stories</td>
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<td>Stories that ask a question</td>
<td>Thinking with stories</td>
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<tr>
<td>Stories that tell a joke</td>
<td>Talking with stories</td>
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Table 1: Comparing ways of characterizing stories

2.6 Summary of the literature

In summary, the literature shows coherent focus on the social and cultural issues present in science education. Due to the privileged position of science, science education receives significant attention worldwide regarding the transmission of scientific knowledge. Challenges to that transmission are also well studied in a variety of ways and on a variety of scales. Similarly, narrative pedagogy is a well-established practice with some amount of research. Despite a wealth of resources on stories for classroom use and how to do storytelling, I could not find any direction for current research into storytelling-as-pedagogy. There is a recent upsurge on the use of narrative in health care and other care giving professions which could be an interesting avenue of further resources for teachers. I could not find any paper that directly speaks to stories and nature of science.
3. Methodology

3.1 Procedure

This is an ethnographic qualitative study project in which I studied science educators. By taking an ethnographic perspective, I treated those teachers as a subculture in the school culture. I focused on this subset of science teachers because I was interested in the influence they have on the science education culture and I was interested in understanding their opinions about science education to promote more widespread inclusion of humanistic science content. In this research, I started by performing a literature review to explore the field of research and find some data collection instruments. Then I decided to focus the research with the goal of exploring a classroom pedagogical tool that I can take to my students during and after the master of teaching program. The tool I used was storytelling-as-pedagogy and I investigated the opinions of teachers about using stories in the classroom. This was done using informal interviews with questions aimed towards the use of storytelling and the informal assessments of the educators on their familiarity with nature of science in their audiences. The interviews will be transcribed and analyzed to form a conclusion on the effectiveness of using storytelling-as-pedagogy to influence the teachers’ attitudes towards implementing a humanistic science curriculum.

3.2 Instruments of Data Collection

Most of my information will be coming from informal interviews with the participants of this study. They were semi-structured in that I had a list of interview questions in mind to get the participants thinking and talking about stories and science education, but remained informal through my tone and rhythm of the conversation. I realize post-interviews that my contributions to the conversation influenced the things that my participants spoke about. Each participant also
had a different relationship with me. Some I had known through my journey in science education, others I had met for the purpose of interview and research.

3.3 Participants

For the purpose of the study, I intended to find three middle school science teachers. To find my participants, I researched science teachers and educators who were known to use storytelling in the classroom. In the end, I was able to find and interview three educators, only one of which taught in an elementary classroom. The sampling method is best described as mixed, using convenience and opportunistic sampling while keeping in mind to obtain maximum variation. I used a very opportunistic and convenient sampling simply due to the constraints of the MT program and decided to find a wide variation to generate findings that were widely generalizable. I will describe each participant in turn.

Participant A is an experienced teacher with approximately 40 years of teaching experience. The participant is an exemplary teacher in the public school system, having received many teaching awards for very novel and socially conscious projects. This teacher has an expertise in literacy and has experience bringing storytelling into the classroom. The participant is currently teaching a junior classroom of approximately 30 students and while does not have science expertise, does teach the science curriculum. Due to geographic limitations and time restrictions, the interview was conducted in a public space.

Participant B is an experienced lecturer teaching in the post-secondary education system for about 20 years. All of the participant’s experience has been in the post-secondary system but mostly interacts with students who are just entering post-secondary education. As a post-secondary lecturer, the participant has an informal assessment on the views and beliefs of students coming out of the public education system who have to take a physics course whether or
not they intend to continue down the path of science education. As a physics educator in the post-secondary system, the participant has also been through the science education pipeline and holds many views shared by research scientists. This interview was conducted in the participant’s office on campus. The location influenced the interview by focusing the discussion through the lens of scientific culture.

Participant C is an experienced lecturer also teaching in the post-secondary education system. This participant has been teaching a course on Aboriginal perspectives for 8 years and is also a post-doc actively doing pharmacological research at a hospital. While a research scientist, the participant has had an unconventional route to the culture of science. As an educator, the participant acts as a bridging person to help students cross borders and thus presented a very contrasting perspective on science education. While not an elementary educator nor a subscriber of the scientific pipeline, the participant represented an outsider view that I was unaware of at the start of the study.

3.4 Data Collection and Analysis

I based my analysis in what the participants said with a focus on the implicit values communicated about science culture. My coding process started with reading over the text a few times to get a holistic sense of the participant then coding the responses more analytically using the guidelines for ethnographic research described by John W. Creswell (2007). Creswell described a spiral analysis process starting with a simple organization of the data to describe the culture-sharing group. In this study, the data studies are transcripts of interviews organized through the lens of ethnography. By considering the participants as part of the science educator culture, I can organize the transcripts to create a culture portrait by categorizing the data as behaviour, beliefs, or language and finding patterns within those aspects.
3.5 Ethical Review Procedure

Prior to commencing the interview process each participant was given a consent form, which they were each required to read and sign (see Appendix A). The face-to-face conversations were recorded on digital devices and transcribed after the interview. The consent form was carefully reviewed with all participants. The participants were invited to pose questions before, during and after the interviews which were answered in a thorough and professional manner whenever possible.

The participants were assured of their anonymity and informed that they would appear as a pseudonym in the study. Before conducting the interview the participants were reminded that their participation in this research project is entirely voluntary and that they could opt-out of either individual questions or the entire project at any point in the interview process with no consequences to them. The participants were offered access to the transcribed interviews and were welcomed to redact any data they felt did not properly represent their approach and philosophy as educators. Finally, the participants were told they would be informed of the completion of the research project and that they can obtain a copy of the project from the researcher upon request.

3.6 Limitations and next steps

This research will not be generalizable due to the small sample size. Some readers will also argue that the research is not valid as an ethnographic study due to the small sample size. The sampling is also voluntary and very local. My only response to this criticism is that my personal experiences going through science education also provide a rich source of data. Having gone through the pipeline model of science education, I have interacted with a great number of science educators. My own postgraduate studies in science have given me experience as a
scientific researcher and as a lecturing teaching assistant. This limits my world view to a positivist reductionist perspective of a rationally understandable world that can be broken down and reassembled but it also gives me many years of field work experience in university research. The limited time frame means that the qualitative analysis was not as deep and integrative as I would have liked. The mixed sampling method produced a lopsided participant pool with very limited representation of classroom teachers and no representation of a primary or secondary science teacher. In a study of the intersection of school and science culture, science teachers should be at the centre of the participant pool.
4. Findings

In this study, I tried to answer if using storytelling in the classroom is an effective way of making science education more human focused or have a wider appeal. I believed this could be achieved by teaching the nature of science through stories. To this end I focused my research questions on the design and selection of stories to teach the nature of science along with practical challenges in implementation. While the number of participants is small, I was able to speak to a wide range of views and values. After gathering all of my data, I realized that creating a portrait of science educators as a well-defined culture is a daunting task. I started with the concept of a scientific pipeline and how a student going through that pipeline will interact with a large number of educators who through their behaviours, beliefs, and language patterns shape the behaviours, beliefs, and language patterns of the student. While the participants had recurring patterns of concern in their responses, I feel like the variety of views is best organized as separate cases on an individual basis. Within each case, I will be able to talk to each of the categories and the participants’ views on those categories. The recurring patterns I was able to categorize from the interviews were 1) the constraints of the curriculum, 2) the inaccessibility of science and science culture, and 3) differences in ideology and culture. While the three categories are interconnected and interacting, there are enough distinctive elements to each that I feel comfortable separating them. Case A and B represent typical contributors to the science education pipeline with one near the beginning and the other near the end of this pipeline. Case C represents a contrasting case with a focus on the Aboriginal perspective located somewhere near but outside of this science education pipeline. By framing my research as a personal learning journey, I have also related each participant to a role in the archetype of the hero’s journey (Davis & Weeden, 2009). I find this framing to be useful to my articulation of how I view my
own learner’s journey through this project and can help me structure internally the process of critical qualitative research. The ordering of the cases does not reflect the exterior chronology of my interviews, or the interior chronology of the learner’s journey. The ordering of the cases reflects the steps that a student might go through in the journey of science education. The role each participant played in my own learning and growth will be discussed more in depth in chapter 5.

Case A: sage in school culture

Participant A took on the role of a sage for my position as a pre-service teacher. As someone who has a lot of experience in the school system, the participant was able to elucidate many challenges that the curriculum and school structure might place on my goals of a more humanistic science education. The participant’s perception of me as a researcher influenced the values underlying his responses. My own position and interview questions are value-laden which are sometimes mirrored in the responses and sometimes challenged. I get the sense that the participant intended to warn me to the challenges of operating within the school environment. The focus of my analysis was on the self-perceived challenges to my value of humanistic science education from the school culture.

Constraints of school and curriculum

As an experienced teacher, the participant was very clear about the limitations that exist for teachers in the classroom. These limitations were from administrators, parents, and the reliance on standardized tests. To lead into a discussion on storytelling, the participant described a school wide storytelling activity. Due consideration was given in terms of expressing the finance, resources, and assessment aspects of an undertaking like this. The participant compared the activity to persuasive writing and persuasive speaking and pointed out that storytelling is
suitable for all grades from kindergarten to grade 8. The participant also said: “Storytelling forces you to put ideas together in a linking sort of way and communicate a complete thought with a sentence.” The participant stated that this was beneficial for many students who responded to questions in one word answers. Students were encouraged to use props and to take on a role. The participant also observed great responses from the parents. Despite being very successful and reaching the younger grades, the project was not continued due to a lack of board representatives that could have brought news of the success back to the board of education. This personal account suggests that while the public school board is capable of making large scale changes, it is difficult to enact a systematic inclusion of storytelling across the board.

The participant shared details about the progression of the curriculum in Ontario and other places in Canada. Before the current curriculum documents, the province was guided by the Circular P1J1, a provincial curriculum policy document on the primary and junior years (Ontario Ministry of Education, 1975). By the participant’s account, this was when the teacher had “full autonomy” and looking through the document I can see how that might be the case. Focusing on my interest in science, the Circular P1J1 gives the following directive: “Understand the environment, both in terms of the nature of its parts and the patterns that characterize it as a whole” as well as four guidelines following which start with: “develop an awareness of…”, “develop an initial understanding of…”, “perceive the development of…”, and “develop concepts…”. Comparing this half page with The Ontario Curriculum, Grades 1-8: Science and Technology (Ontario Ministry of Education, 2007), I wonder about the many stakeholders who have shaped this change over the last three plus decades. The Circular P1J1 allows for a lot of freedom in how a teacher meets those objectives but the objectives are very shallow. And while it can help the student in understanding the parts and patterns of the natural world, it does not
acknowledge the process of science as something done by people. Thinking about this document highlighted other parts of the response that were related to the changes made to the curriculum. The participant mentioned that before the value of accountability was central to Ontario public education, our school system produced two generations of functionally illiterate children. This was due to the lax phrasing of the curriculum and the lack of accountability of the teaching staff. As another example on the influences on the curriculum, the participant points to the creation of charter schools in Alberta and traditional schools in BC in an attempt to focus on the fundamentals, and the popular support that these schools received. For example, some parents were camped out in front of newly opened traditional schools to be able to register their children. Because there was a lack of teacher accountability, students could go from one school to another and be completely lost. This created a lack of continuity for the students which severely impaired their learning.

This ongoing tension between accountability and autonomy is behind our current curriculum documents. On top of the curriculum, teachers in Ontario also have to contend with the EQAO and principals. To give me a better picture of the values of the school system, the participant said: “Now the three big questions are: is what you are doing accountable, responsible, and productive.” The feeling I got from the response was that this is a definite improvement over the old model where teachers were not held accountable but created a school culture that I, as a pre-service teacher, would not be comfortable going into initially. To illustrate one sacrifice from this focus on accountability, the participant described each student as “getting the same plate” and while he would like to integrate more subjects and allow students to direct their own learning, it can be difficult and effortful to do. Because of the results of the EQAO, each principal will be aware of holes in certain content areas in a classroom. If the scores of your
students are low in a certain area, say making an inference, the principal will be able to walk into the classroom and say: “I want to see what you are doing for making inferences each week.” To teach beyond the curriculum, a teacher must be able to teach to the EQAO and principal expectations, and be able to locate or create resources that can bring in connections. To paraphrase a part of the response: “The curriculum is like the surface of a lake and most teachers stay on the surface; they do not make those connections because they do not have that kind of freedom and do not have that kind of time.”

In a more optimistic tone, many of the examples provided show a lot of social consciousness and integration across the subjects. The participant often brings in current affairs to keep the students engaged with the world out there, and offered many examples in teaching science that were authentically integrating storytelling. Current affairs is an engaging way to encourage the students to talk with stories and the storytelling examples involving flight, space, and electricity seemed promising in encouraging the students to imagine with stories (Kuyvenhoven, 2009). One other related example is from a novel study unit. As the participant progressed through the novel, he encouraged the students to put themselves in the story world and to think and imagine with stories using prompts like: “If you were the main character, how would you achieve their goal of…” This can only mean that despite difficulties with covering the curriculum and justifying to administration, it is possible to teach the elements of nature of science that is beyond the curriculum with creativity, experience, and resources.

Inaccessibility of science and science culture

From the perspective of an educator who did not have an academic science background, the participant was very cognizant of certain public attitudes towards science. When asked about the nature of science, the participant mentioned many times that the average teacher is only
teaching the surface and has no interest in deep critical questioning of curricular content. The Ontario science curriculum document does have a preamble that covers elements of the nature of science, but very little of that makes it explicitly into the expectations of the curriculum. The participant wondered if the preamble was written by different people than the expectations. I get the distinct impression that while the preamble introduces the nature of science, the curriculum as a whole does not care about “peeling back the layers.” When pressed on strategies, the participant provided many examples of lessons from the topic of flight. In the breakdown of lessons, the participant touched upon basic concepts like Bernoulli’s principle, the fundamental forces involved in flight, experimentation skills, and connections to history and aerial combat. Once I focused more on how people developed flight, the participant spoke to the role of motivation through common human emotions like curiosity and the desire for exploration. This tells me that an experienced teacher is able and likely already does make science relatable through historical context, hands on activities, and by bringing in the role of emotions. However, in my original phrasing of the question on the nature of science, the participant expressed that teachers do not understand the nature of science. I believe this is due to administrative pressure on the fundamentals, the low curriculum expectations on teaching nature of science, and the lack of teacher resources that provides examples of nature of science.

**Differences in ideology and culture**

The participant is an expert on school culture and Canadian culture and has had much awareness of other cultures around the world. Because of my own science background, the participant viewed me as coming from a privileged perspective where I could see the value in teaching nature of science implicitly through stories. I got the sense that this is not common among the teaching force. The participant roughly estimates that only one in ten teachers would
have an idea about the nature of science and only one in a hundred would be integrating across subjects like math and social studies. Due to the emphasis on the value of accountability, a science lesson designed to address the challenges raised by Aikenhead (2006) would have to be designed to fit between the cracks of the specific expectations outlined by the science curriculum.

When asked about teaching the nature of science, the participant also expressed frustrations in wanting to teach holistically. He says: “I want to do more, but my hands are tied.” The participant desires to educate the whole child “socially, ethically, emotionally, morally, and academically” but has to fit those values in between the curriculum as well. While desiring to integrate across subjects, the participant believes that such integration will be seen as unnecessary. “We are still teaching insular pods by subject area,” which reminds me greatly of the philosophy of reductionism. The participant also offered suggestions of other media such as comic books or TV shows as a way to teach more holistically but not specifically as examples of integrating nature of science into the science curriculum.

**Case B: helper in science culture**

Participant B took on the role of a helper as a member of the scientific community and a member of the science education community. Considering my own background in post-secondary science, I was not surprised that this participant expressed many views that I previously held before starting on this journey of teacher education. By looking critically at the expression of these views, I was able to challenge my own behaviours, beliefs, and language patterns from a simulated outsider’s perspective. The focus of the analysis was on my own views on science and scientists that I recognized in the responses of this participant.
Constraints of school and curriculum

As a post-secondary educator, the participant came into contact with many people who went through primary and secondary education. While the participant could not speak directly to the constraints of school and curriculum, he was clear that in order to teach everything, you have to skip over things in the curriculum. This tension between depth and breadth was reiterated a few times. According to the participant: “The best teachers I have ever met have all done that. They just had the courage to say I can’t do this; there is too much in the curriculum to teach properly in the allotted time.” This directly relates to my research question on the practical constraints of teaching a more humanistic science curriculum. Also important are the roles of memorization and participation. The participant expressed that stories can be used as mnemonic devices to help students remember abstract concepts, and that an ideal situation involves participation of the audience. This idea of participation resulted in two pieces of advice, first to do storytelling activities with small groups of 5-10 students to allow participation with the story, and second to keep the storytelling activities short, partly due to time constraints and partly to not take away from the doing of science.

Inaccessibility of science and science culture

As an experienced science educator, the participant expressed many behaviours, beliefs, and language patterns that are very common among scientists. I recognize the very conventional path taken by the participant as the pipeline perspective of science education. The participant went to university to study physics and astronomy and after graduating entered into a PhD program followed by a position as an assistant professor immediately after graduation. Throughout PhD and the subsequent professorships, the participant was instructing a variety of courses with a focus on astronomy and optics. While not directly related to education in the
primary or secondary classroom, I believe the views expressed by this participant are representative of many science educators who have had a science background. When I asked the participant about his PhD project, he summarized his research very succinctly by including details and technical language but also by including elements of a narrative. The participant knew about my previous experience in the physics department and so could have felt comfortable using technical language in a response. I wonder if it is typical of scientists to have a mix of technical and colloquial language in autobiographical accounts with a general audience.

When asked about the use of storytelling in a science classroom, the participant emphasized its ability to “break things up” and the importance of bringing in a “human element” into the classroom. I got the impression that breaks are an important element of a science class from quotations like this: “I think it’s a really good idea to just do a little reset and allow your brain to jump back into the physics.” And while this reset does not necessarily have to be a story or anecdote (the example given was an informal survey on popular TV shows), it should at least include a human element. One benefit of telling a story or anecdote is that it has the human element and catches the attention of the students, changing the mood and waking them up. The participant shared that this inclusion of the human element is part of his philosophy of teaching. From the analysis, I saw evidence that this human element is not a central part of the products of science. At a few places in the response, the participant deemphasized the values of the scientist in the products of science and stated that most science “does not have to do with our brains and emotions and our life and what we live with every single day.” This is a belief I held throughout my science education. That no matter who does the science, they will get the same theory, and that no matter who uses the science, they will get the same result. However, I feel that this is inaccurate considering the list of key elements of the nature of science given by McComas
(2004) which states that the process of science is creative and subjective. Throughout the interview, I got the sense that science or maybe more specifically physics is very difficult and isolated.

In the interview, the participant gave a few example stories to illustrate elements of nature of science. I found in my analysis that the examples served to create a list of emotions regarding the process of science and science education. The participant stated that sometimes you have to suffer through science education and that by bringing in a human element, you can reduce the suffering. This suffering also exhibits itself as boredom in the science classroom where a story or anecdote can “wake up” the students. As a scientist, the emotions highlighted were more about passion, curiosity, and perseverance through the challenges of doing science. To illustrate the challenges, the participant offered the stories of Kepler and Galileo, the first of which was isolated by his boss Brahe and the second was oppressed by the church. From my interpretation of the interview and my own personal experiences, the narrative of science education seems to be: you have to persevere through science education which is boring and hard before you are able to let your curiosity and passion drive you; once you have suffered through science education, the only thing that will get in your way of doing science will be other people; if you get tenure, less people will have power over you, and then you can do very controversial research which is more valuable than safe research. This I feel is part of the challenges outlined in *Science Education for Everyday Life* (Aikenhead G. S., 2006) where the difficulty of science is overemphasized, and the value of science is focused on its products and not its process.

**Differences in ideology and culture**

In the story about Kepler, the participant expressed a value that I often hear espoused when I studied at the physics department: “the perseverance that a scientist has and the drive to
develop science theories for the sake of the science.” This seems similar to a particular view of stories as a vehicle of delivery for a bit of humour, a lesson, or a moral. The participant had a very didactic view of stories as serving a very clear purpose. The first example story was about the participant’s child doing experiments on gravity by throwing things down. This story was used to introduce terms like “repeat the experiment” and “revise the theory” and was designed to instruct the students on the “scientific method” which is described as the “dry subject matter underneath it”. This relates back to the previous section on the barriers that prevent an emotional connection (i.e. if the scientific method is dry, then why am I excited to be here?).

This idea of “science for the sake of science” makes sense to me even now. Consider similar justifications like art for the sake of art, or math for the sake of math. In a way, this statement of “science for the sake of science” translates to knowledge for the sake of knowledge. Without criticizing this implicit value, I do want to frame this as a cultural value that may not be shared by people in other cultures. Aikenhead (2001) points out that the values of Western science “encourages the unravelling of the mysteries of the natural world. In contrast, the Aboriginal perspective places value on learning to live with the mysteries of the natural world for the sake of survival.” This mismatch in values may have been expressed in the interview through a comparison between international students from China and local students educated here. The participant observed that students from China are less willing to critically challenge the authority of the professors. From my past experience, Chinese culture values the natural order and hierarchy of the world. Knowledge serves the purpose of being able to understand the natural order for the sake of supporting the hierarchy. The participant suggests that over time, these differences go away and both backgrounds produce equally qualified scientists. This makes me wonder about the validity of a phrase like “Western science” because possible differences in the
values of North American Western science and European Western science. In fact, the science practiced in research institutions in China are also “Western science” with many of the same behaviours, beliefs, and languages. While the specific words used changes from language to language, there is still a discourse on evidence, falsifiability, hypothesis, etc. as a way of knowing.

A final salient difference came from the question if scientists make good storytellers. The participant confirmed that there are examples of people who are good scientists and good storytellers, but these people are few and far between. The scientist’s attention to detail is a useful quality in storytelling but many other skills are not selected for in a science career. Key elements to storytelling were identified as paying attention to the expectations of the audience and being able to structure it effectively to hold on to their attention. The participant expressed that many of the best and most natural storytellers are authors of children’s books. They are experts at paying attention to the audience and understanding the expectations of the audience. These are however skills that are not selected for in a scientific career. I wonder if this is a reflection of the durable nature of scientific knowledge as described by McComas (2004). The audience is important in any endeavour for communication, but durable knowledge is more static and does not need the validation of the audience to make it valuable. I asked about suggestions for pre-service teachers and received many recommendations on websites, articles, and blogs. These seem like very reasonable suggestions to getting to know the human behind the theories but I later noticed this focus on written forms of transmission than oral forms. This was a cultural distinction that I was made aware of through the next person (participant C) in my learning journey.
Case C: trickster in Canadian culture

As an experienced border crosser, participant C took on a role of the trickster in my own expectations on science education and the nature of science. This participant is a medical research scientist but also an instructor on Aboriginal ways of knowing. Instead of the conventional path to practicing science, the participant went through an education in art and worked as an artist for many years before going back into school and pursuing a science career. The interview with this participant involved many instances of internal struggle. Many views expressed by this participant challenged my own world views and allowed me to frame my prior knowledge as a non-central aspect of the different ways of knowing that people practice.

Constraints of school and curriculum

As someone operating very far from the public school system, this participant did not speak directly to the curriculum. Many of her responses do relate back to the curriculum as a reflection of the Western culture that our school system operates within. The participant educates students on Aboriginal perspectives on ecological knowledge and was able to talk to the many differences between Aboriginal ideas on teaching. She stated clearly that in Aboriginal communities, “learning is social and experiential”. Early childhood education is done by the immediate parents, while in adolescence children are expected to spend time with the extended family or community Elders. As an educator on Aboriginal perspectives on ecological knowledge, she feels impossible not to take the lesson outside to be able to talk about nature. She says: “[Nature] is all around us. Some of it is manicured, but there are other things that we have absolutely no control over.” In my analysis I felt this to be a good metaphor for the students of the school system. In terms of their growth over the years, some of it is manicured but there are many aspects of personal growth that we have absolutely no control over.
To talk more about the manicured aspects of school, the participant C expresses a similar concern as participant A about the reductionist tendencies of subject areas: “we have all of these silos, and that’s how we perceive our knowledge.” Further signs pointing to this fragmentation are the out-dated notions of mind-body dualism and the arbitrary separation of things in an environment into biotic and abiotic. The participant points out Aboriginal knowledge is typically more holistic and looks at things in context, relating every element of an ecosystem with each other, including the stars, the moon and the sun. This idea of out-dated knowledge influencing our current lives only serves to highlight certain properties of using a written medium to pass on knowledge. I will go more in depth on this in a later subsection and in the discussions. Speaking as a medical researcher working with other medical professionals, this participant also points out some of the flaws in the focus on testing within the medical community: “So we have the SATs, we have the LSAT, we have the MCAT. We have all these different tests that are supposed to indicate whether or not you are going to practice this particular profession. But I know people who had great MCATs but have the worst bedside manners you have ever experienced.” This reminds me of participant A’s emphasis on the EQAO and how it has changed school culture. On the bright side, the participant does notice small changes happening in the system and gives the merging of biology, zoology, and botany into ecology and evolutionary biology at UofT as an example of this change.

In terms of teaching advice, the participant was unequivocal about “not privileging my own voice.” As examples, she uses quotes from other people, readings from Aboriginal authors, or bringing guest speakers into the class. Furthermore, as teachers we should refrain from telling your speakers what to talk about, and we should refrain from imposing our interpretations on what the students have read or heard. I feel like this is related to a deeper theme of meaning...
making which I will speak about in the discussions. Other advice about bringing in guest speakers were to bring a male Elder and a female Elder, and that there are usually budgets for these kinds of visits as well as designated roles in the school board who can either speak or help invite a speaker to the classroom. However, the participant warns: “expecting to glean something from all of the stories is unrealistic, and also it is disrespectful to ask for that.”

**Inaccessibility of science and science culture**

The participant works as a medical researcher operating in Western science as well as instructor on Aboriginal perspectives of ecological knowledge. She acknowledges a few times that she has a different perspective as many of the other researchers that she works with. Among the Aboriginal languages, science is not a word. Or more explicitly, science as a way of knowing is not distinguished from other ways of knowing in most Aboriginal cultures. In most Western cultures however, science is decontextualized in a lot of ways. As an example, she states that the objectivity of the researcher is often assumed in science and does not factor into the interpretations of the products of that research. By comparison, in arts, the identity of the artist plays a crucial role in the interpretation of their artwork. The participant goes on to say: “it’s ridiculous. Obviously we are not separated from the world we live in and the knowledge we have.” As examples, the participant offered brief anecdotes about Decartes, Galileo, and Darwin, all of whom were influenced by the church who wielded a lot of power in their time. The anecdote regarding Decartes was about him making a deal with the church so that he could keep studying. This reminds me of Fatima’s rules from the subsection on learning difficulties in chapter 2. Fatima’s rules is the tendency for students to learn by rote and going through the motions to get through a science course without meaningful understanding of the canonical science content (Aikenhead G. S., Science Education for Everyday Life: Evidence-based
Practice, 2006). This participant, through comparisons with Aboriginal perspectives, points out that science is decontextualized and falsely objective when in reality the knowledge produced is influenced by culture and society. There are other similarities between Western science and Aboriginal ways of knowing such as pattern recognition and the dual values of continuity and meaning making.

Historically, science as a way of knowing is recent compared to other indigenous forms of knowledge. The participant suggested a number of books by Aboriginal authors that talks about the interactions between these disparate ways of knowing. She offered an example of such an interaction from Our Knowledge is not Primitive where early European settlers to Canada relied on traditional botanical knowledge of the Aboriginal people to stay healthy and how later on, this knowledge was appropriated as Western scientific knowledge without proper respect, acknowledgement, or compensation to those who originally held this knowledge (Geniusz, 2009). Another example she gave which also speaks to the Western culture of measurement and testing is about a beach in BC where people would come and stomp on the sand during low tides to harvest clams. The people noticed the water quality decreasing and contacted the authorities. Then with no communication, a team of scientists arrived, measured a bunch of stuff, and left. The community then received a letter saying their water is fine and the quality has not been impacted. This shows that despite being able to benefit from each other, these two ways of knowing are often at odds. From my interpretation of this example, the term “water quality” has different meanings in different contexts. To the people living there, this water quality is part of their quality of life and directly connected to their health and diet. To the scientists who showed up, the water quality is the concentration of a list of chemicals found in a laboratory removed from the local context. I feel like this has a connection with the challenges of discrimination and
cultural alienation that Aikenhead (2006) reported as described in chapter 2 where students from certain cultures felt excluded from power structures partly through an inaccessible vocabulary.

**Differences in ideology and culture**

Many salient differences between the scientific culture and common Aboriginal cultures have been mentioned. As a self-identified bridging person, this participant is highly aware of many cultural artefacts from Western science’s search for objective truth. The assumed objectivity of scientists, the tendency for reductionism and the removal of the context and the social privilege of being a scientist have been illustrated in the previous two sections. The scientist is also under immense pressure to publish which through the peer review process, consolidates the knowledge and makes it static. In contrast, Aboriginal knowledge is transmitted orally and through that takes on a fluid nature. The participant shares: “Traditional stories are oral histories. They can encode new knowledge. The teller can emphasize new things during the story.” Both methods of knowledge transmission have measures to maintain continuity. Many Aboriginal cultures value recognition and gratitude and sharing an important story can mean sharing where the teller heard the story. Western scientific culture has a system for referencing previously published works. One difference I could see in this continuity came from the participant’s story on Darwin: “Darwin’s theories of life were highly controversial and sensational and because of that he felt uncomfortable publishing his findings. It was only when he was an old man and another scientist had come to the same conclusion that Darwin was willing to publish his research.” This shows that publication culture values giving recognition but also glory seeking and gaining recognition. One comment from the participant that I could not integrate is about the role of language in ways of knowing. She explained that traditional knowledge is passed on through stories but also by doing things and that this is reflected in the
language in that many Aboriginal languages are verb-based while many European languages are noun-based. The participant said that due to this linguistic focus, Aboriginal cultures value “how you are doing things all the time, and not who you are in relation to others.”

Also worthwhile to talk about is the value of community and inclusion. Participant B shared many stories of scientists who generated knowledge while working in isolation. Participant C had a similar observation about the elderly in Western societies: “in the west, we relegate our elders to bring retired people who are often lonely and socially isolated. Whereas in indigenous communities, the elders are the centre of the community, you lead the community.”

As I mentioned earlier, Elders in a society take on the role of teachers, raising children and passing on knowledge gained from a lifetime. This is a very interesting contrast between how Western societies treat scientists and the elderly and how Aboriginal societies treat their Elders. An Elder is a designation in a community rather than an automatic label. They are the keepers of oral knowledge but they are also leaders in the community and responsible for the knowledge they have. The participant explained that in most aboriginal cultures not all knowledge is meant to be shared. Stories serve a purpose and sometimes are sacred. The keepers of knowledge are responsible for knowing which story to tell in what context for the continued survival of the community.
5. Discussions

My own background in Chinese culture gives me an affinity for Chinese ways of thought. Chief among them is the philosophical tradition of Taoism as represented through the yin yang. From my own understanding of the Tao Te Ching, the yin yang is a descriptive metaphor for opposite forces acting in dynamic balance against each other. Through this balance, both forces emerge in the real world to complement each other and as time passes, the balance shifts and the opposites turn into each other. While very abstract, I find the yin yang to be a useful mental tool for finding balance both in life and in my thoughts, and that it has helped me immensely in my attempts to make sense of the complexities of life. My early interest in books and later interest in science have also combined to lead me to the reductionist narrative theories of Joseph Campbell in particular the concept of the monomyth as first described in *The Hero with a Thousand Faces* (1949). In this book, Campbell describes the prototypical myth that bears resemblance to many narratives found around the world. Despite criticisms from the literary world, I have found the monomyth to be another mental model useful in my attempts of meaning making. The monomyth has similarities to the yin yang but goes into more detail about elements common to many narratives around the world. In the monomyth, the hero departs from a known world to enter into an unknown world. Compared to the status quo of the known world, this unknown world is filled with challenges and allies along the hero’s quest and by journeying through the underworld, the hero returns to the known world bearing gifts and boons. This journey has been used to describe the learner’s journey from unconscious incompetence, to conscious incompetence, to conscious competence, and finally to unconscious competence (Davis & Weeden, 2009). These two mental models are at the core of my philosophy of life and play a role in my interpretation and analysis of the findings.
More specific to this research, I find my inquiry paradigm to ultimately be social constructivist in nature. On top of that the research started with postpositivist leanings in the beginning and as the research progressed, moved into pragmatism instead. At the start, I was motivated by a sense of sadness at my stalled career in science. I intended to become a teacher to fix what’s broken with science by producing more enlightened scientists. To this end, I decided to assume knowledge about the failures of science education, partly confirmed by the research collected by Aikenhead (2006), and propose a tool to fix those failures, with later intentions to develop the tool and quantitatively test it in classrooms to show its effectiveness. As my research journey progressed, I saw more and more opposing forces in tension within the general Western society that I lived in and with the specific classroom culture I intend to join. The trickster figure participant revealed that in the framing of my problem, my world view was very limited and unaware of the diversity that existed out there. From then on, my goal became to understand and to make sense of the complexity and variety I was exposed to in this research and from that understanding guide my future actions and decisions in the field of education. As paraphrased by the trickster figure participant: it is foolish to look for simple solutions in complicated problems. So instead of making it my goal to fix science, I have decided to use my findings to better understand of the world and myself as a student of science and, in the future, an educator of science.

From these theoretical perspectives, I challenged my prior belief that science is the only valid way of knowing to arrive at a more nuanced picture of human’s journey in meaning making. From this picture, I will describe how this research project has affected my understanding of science, my own life, and teaching as well as how I can grow in life and in teaching. I will also take a wider look at current society where science is often at odds with a
culture of denialism and use my new understanding to try and make sense of this possibly destructive tendency of modern Western society. I will then talk about the stories told in the interviews and offer suggestions on the use of storytelling in a science classroom as well as answer and critique my research questions. Finally I will review the limitations of this research and talk about possible directions for further studies.

5.1 Implications and Recommendations

The three participants each offered a very different world view highlighting the status quo in science culture, school culture, and general Euro-Canadian culture. These overlapping cultures enforce the status quo through a set of expectations and beliefs as communicated in their way of speaking. This way of speaking includes special words or meanings exclusive to the culture, lines of reasoning and justification, and narratives that propagate the language, beliefs and behaviours. Examples of this from science culture are experiments, theories, emphasis on curiosity and passion, and the scientific method. Examples of this from school culture include accountability, administration, and the curriculum. The participants reveal a world where scientists are isolated from general society to protect the objectivity and the rigour of their products, and where teachers are constrained by general society to enforce political and economic beliefs. Were I to become a scientist, I would follow my curiosity to a place of suffering, and driven by my passion, ultimately persevere despite the constraints of other people. Were I to become a teacher, I would follow my passion to a system constrained by tests and administrators, and if I persevered, will find ways to get through the cracks and teach to my passions while satisfying the constraints. These expectations as transmitted through my interviews can and will guide me in border crossing from science to teaching. Flipping it outward, if I were a student, I would go through school getting the same plate as every other
student as dictated by a fragmented curriculum. Upon deciding to enter into a science stream, I
would be taught the basic foundational skills, critical thinking and inquiry, and historical
accounts of dead white men to illustrate the humanity inherent in science. All the while being
told that science does not need other people and that competition and oppression is the expected
outcome of interactions with other people.

From my own perspective, the implication of these values is that a career in science is
filled with suffering where the feverish desire to understand is more commonly emphasized over
the fulfilling joy of discovery. As someone who struggles with addiction, this feverish desire
seems related to the tendency for science to value ground breaking new research over the safer
research of verification and monitoring which lacks the recognition and glory of a new
discovery. In my own interpretation of the history of science, this is the time when science is still
trying to prove itself as the default way of knowing by focusing on knowledge production rather
than the responsibility of knowledge management and application. The focus on written
knowledge gives scientific knowledge a sense of permanence and objectivity, which only serves
the status quo in Western societies of the importance of science. This importance is tied to the
value of intelligence through the message that science is difficult, which only serves to
emphasize the smart/dumb dichotomy of a post IQ test society. However, the participants are
aware of the political and economic forces that drive science and one participant was explicit
about the economic challenges of following a scientific career. This sets up a contrasting set of
descriptors of smart, high SES, important, productive science versus dumb, low SES,
unimportant, responsible non-science. This I believe is the status quo enforced by our collective
expectations of science and the underlying message of the Ontario science curriculum. There is
change happening, for example from Gardner’s theory of multiple intelligences, and the recent
focus on environmental science for conservation and stewardship. But without directly challenging the association between intelligence, science, and profit, the dynamic balance between what is considered science and what is considered non-science will fall apart. I predict that the hegemonic tendency of science to monopolize knowledge will lead to a reaction from non-science to reclaim the production of knowledge. I feel that this is the source of the recent culture of science denialism such as the anti-vaccine, anti-GMO, creationism, and climate change denial movements. In my opinion, a dynamic balance recognizes that science is one form of knowledge production, with explicit stated connections to non-science, that allow for meaningful knowledge transmission in both directions. Through such interactions, it becomes possible for science to become something greater and incorporate new ways of knowing and meaning making. Through my interviews, I conclude that this border crossing between science and non-science is currently constrained, deceitful, and one directional. A continuation of the patterns I perceived may result in a similar situation as the Third Wave movement in Mr. Jones’ classroom but played out in a much larger scale. This constrained and deceitful narrative can and may already have created an exclusive group that ostracises dissent and stifle its own progress.

**How the research has affected me**

Personally, my study of science stemmed from a curiosity to understand the world around me. Studying science satisfied my curiosity while justifying the anti-social behaviour of ignoring other people who were messy and dangerous and only served to get in the way. As my education progressed, I developed the self-identity of being a smart student. This identity was a great source of motivation and obligation. Through it, I gained confidence in my thinking and questioning skills and that made me feel ready to function in a complex modern society. This idea of a smart student however also worked against me when I inevitably became stuck when doing research. I could make sense of the topic of research but I could not make sense of the
struggle I went through. In science, my stalled research led to frustration and a feeling of helplessness, and eventually resulted in me dropping out of a PhD program in physics. The perseverance I learned from undergrad did not translate to a drive to get the research done that Kepler showed in his tower. My identity as a scientist was compromised and I spent two years as a private tutor. As a MT student, similar struggles happened all the time. I found it difficult to start any project and speed bumps would often derail my progress for weeks at a time. The difference however was in the community. Because I was part of a cohort of peers, there was no sense that I was “the chosen one” who could or was expected to do everything myself. In my road to complete this project, I have received immense support whether technical or emotional from my peers and knowing of the struggles they underwent, I was able to draw motivation from their perseverance. I now know that while I can call myself smart, that is a role that I take on rather than an identity. The knowledge acquired from my strong interest in science is not the only way of knowing but it is the way of knowing I am most proficient in. While I can wield my knowledge proficiently I must also be aware of alternate world views and not judge those views but instead interact with them and through this interaction, increase the breadth of my own world view. By paying closer attention to my language and the language of those around me, I can better challenge the exclusionary message of science as belonging to the scientists. Through this research I have also come to better terms with my own past experiences and current addictions and have become more able to talk about my own subjective experiences. This has allowed me to reconstruct a life narrative fractured by childhood trauma and the micro-traumas involved in changing cultures.

As someone poised to enter a teaching career, the implications of this research are limited. I understand better the immense power of the teacher’s voice and will be more willing to
encourage a diversity of views and opinions. My views on science have shifted from a tool to look at the future to a tool to look at the past. I am confident that I can integrate responsible accounts of knowledge acquisition and transfer in history. I am more prepared to bring in the voices of contemporary scientists and other knowledge keepers in any lesson without imposing my own interpretation or voice. I intend to challenge the status quo of science education by teaching the variety of emotions and social pressures involved in the doing of science, and by using authentic stories as tools of border crossing to give students the variety necessary to create their own world view. I feel like doing this within the school system will still be a challenge until I can develop a number of resources that contain historical accounts for specific purposes and authentic contemporary accounts that illustrate how scientists and other people come to know the world. On top of that, I will focus on the doing of science through the use of instruments and mathematical skills to allow the students to inquire and reach their own conclusions and hopefully find their own reasons for doing science.

**Role and use of stories**

The theme of storytelling and science in the interview questions prompted many stories about science. Most of these were historical accounts of specific figures or events related to Western science. Between the three people, they spoke to various degrees about Johannes Kepler and Tycho Brahe, Einstein and the quest to unify physics, Galileo is put under house arrest, Einstein and the atomic bomb, Feynman in the Manhattan project, Feynman ordering tea at Harvard, Descartes and the church, Darwin delays publishing his *Origins*, Wright brothers inventing the airplane, Wright brothers in a nursing home retelling their lives, Thomas Edison inventing the light bulb, and the sinking of the Titanic. Being the majority, most of these stories referenced can be used in a classroom through talking with stories. To think with stories, I would focus on the human or social aspects of the stories. Taken together, I view these stories as
portraying scientists as petty, driven, victimized, powerless, whimsical, oppressed, fearful, inventive, nostalgic, ambitious, moral, political, funny, careful, and curious. The unfortunate effect of using these stories is that students will also get the image of scientists as those from the traditional Western science history who are all white and male. There are many more stories out there involving scientists but very few of them involve scientists of colour or of other genders. A few of these stories shared are suitable with imagining with stories. I would emphasize the emotional and experiential aspect of each figure to encourage imagining with stories. The retelling of Wright brothers’ lives as old men is a perfect activity to frame an entire unit on flight.

Other stories were connected to science in some way but did not fit in the above category of canonical science history. There were suggestions of books containing stories such as the Curious George series, Gathering Moss and Braiding Sweetgrass by Robin Wall Kimmerer. Other media sources were Star Trek, superhero comic books, children’s books, YouTube videos, and scientist-bloggers. A few of the stories were personal or everyday such as baby in highchair experiments with gravity, grandmother working on vaccines to save people, Inuit children playing on ice floes, students learning traditional hunting and fishing techniques which are complicated, holistic, and a source of pride, and finally coming back from Mars as the only survivor. I believe these sources can form a growing set of inclusive and humanistic but didactic stories that can deliver specific elements of nature of science as outlined by McComas (2004). To create authentic storytelling experiences I would have to invite speakers who have lived these kinds of stories to tell. I plan on either inviting people in or using accessible technologies such as Skype™, telling the guest what the class is learning, and then allowing them to talk about anything they feel like. This strategy of connecting with guest speakers poses several challenges.
I would have to spend personal time finding suitable speakers to bring into a classroom. I would have to be able to assess the student’s learning from this activity. I would have to find the time in the school schedule to have a speaker talk and answer questions. I would have to find the budget for a speaking fee for the time and effort they put in. There are designated roles in the TDSB acting as bridging persons for the Aboriginal perspective. They can invite Elders to come in and talk to students about Aboriginal knowledge. While demanding a story is rude, I feel comfortable bringing in an Elder and asking them to talk about the land we live on for the benefit of the students. There are storytelling organizations in Toronto who would be able to find speakers on specific topics such as medical research, aeronautics, naturalists, or electricians. Being members of a storytelling organization, I would feel comfortable demanding a story from them. This list of sources and example will form a collection of contacts, books, multimedia, stories, and anecdotes that I can develop over time and share with teachers interested in the science curriculum.

Research questions
To tie this back to the research questions I will address each in turn. In terms of implementing a more humanistic science curriculum, I concluded that while teachers want to make learning more holistic they often feel restricted by the size of the curriculum and the time constraints of the school structure. Teachers also do not have explicit knowledge of nature of science despite knowing many aspects of lives of scientists. My recommendation for this is for the Ontario Ministry of Education to consider including explicit nature of science learning expectations in the curriculum while encouraging professional learning of this concept for teachers. To reduce the volume of the curriculum, expectations might have to be dropped or bundled together. As one of the participant stated many teachers find it necessary to skip over parts of the curriculum, which presents an avenue of research in curriculum content and
implementation patterns. For my own teaching, I intend to deal with curriculum expectations and time constraints through creativity and the help of other more experienced teachers.

My interview questions did not target if stories can be designed to shape the student’s images and attitudes, and I now feel that this question was flawed since stories obviously influence our images and attitudes. A better question to ask the participants would have been “how do stories used in science education shape the student’s image of the scientist and attitudes towards science?” From a question like this, I can understand better the dearth of diversity in historical accounts of science. The go to stories of science classrooms are from a pool of historical figures in Western science. Being subject to social forces, these historical figures have mostly been white and male. There are exceptions to this for example the crucial role of Rosalind Franklin in the discovery of the structure of DNA. As science becomes more modern and global, scientists will become more diverse as well. A curriculum with more focus on modern science should include a more diverse pool of scientists and stories involving these scientists.

For necessary elements for teaching nature of science, a respectful inclusion of other ways of knowing can play a role in making science education more humanistic. By acknowledging their value and validity, students from other cultures will feel more comfortable sharing traditional cultural knowledge providing a fertile ground for STSE connections, inquiry, and critical thinking. By framing ways of knowing as a cultural endeavour, exposure to other cultures will also help students understand the social nature of science and how scientific theories as well as traditional knowledge change over time.

The last question on using stories to encourage scientific thinking was also poorly designed. While the application of scientific thinking is an essential skill in science education, it is not central to nature of science or to making science education more humanistic. Some of the
stories shared were examples of scientific thinking but others simply focused on the human aspect of the lives of scientists. The participants seem to agree that stories can make scientific thinking more relatable, which indicates that a better question might be “how can stories encourage the application of scientific thinking in everyday life?” The answer to that question may shed light on learning difficulties found in relating to the scientific theories and facts as described in chapter 2.

5.2 Limitations

This study is subject to the usual limitations of small sample size and time constraint. Furthermore, as a qualitative researcher coming from a quantitative background, I am unfamiliar with the expectations and the implications of qualitative research. Creswell and the research courses served as a suitable introduction but this is still a first attempt at qualitative research. This limits the credibility and dependability of this project. My own learning journey played a big role in completing this project. This may take away from the transferability of this research and to this day, I still wonder if my project should have been through a phenomenological or narrative research lens.

5.3 Further Study

This project widened my own perspective on qualitative research and the social nature of science and science education. This research was conducted through a critical theory perspective but a study from feminist, queer, or post-colonialist perspectives are also suitable in studying the culture of science education. The conclusion that science communication is constrained, deceitful and one directional can be triangulated by performing a phenomenological study on the student’s construction of a mental schema of the scientist or perhaps through narrative research or case study on students and on teachers. I would also like to study the act of storytelling more
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in depth through grounded theory by bringing storytellers into the classroom and interviewing the teller and then audience members. Through this I can get a better understanding of the elements of storytelling and how they can be applied to a complex goal such as educating nature of science. As a self-identified scientist, I intend to continue my ethnographic research into the culture of science and counterculture movements reacting to it. Switching to a mixed-method study can give a more complete portrait as well as involving researchers from a social science background with more experience in qualitative research. Finally I would like to pursue action research to empower scientists and science educators to become better communicators. I believe this is one of the necessary steps to making the products of science more focused on benefiting humanity and the process of science more accessible for people who do not identify as scientists.
Bibliography


Appendix A: Letters of Consent for Interview (Template)

Dear (participant),

I am a graduate student at OISE, University of Toronto, and am currently enrolled as a Master of Teaching student. I am studying the use of storytelling as a tool for teaching the nature of science in elementary and secondary education. The purpose of this requirement is to allow us to become familiar with a variety of ways to do qualitative research. My data collection consists of a 45-minute interview that will be audio-recorded. I would be grateful if you would allow me to interview you at a place and time convenient to you, outside of school time.

The contents of this interview will be used for my research project, which will include a final paper, as well as an informal presentation to my classmates and/or potentially at a research conference or publication. I will not use your name or anything else that might identify you in my written work, oral presentations, or publications. This information remains confidential. The only people who will have access to my assignment work will be my research supervisor and my course instructor. You are free to change your mind at any time, and to withdraw even after you have consented to participate. You may decline to answer any specific questions. I will destroy the audio recording after the paper has been presented and/or published which may take up to five years after the data has been collected. There are no known risks or benefits to you for assisting in the project, and I will share with you a copy of my notes to ensure accuracy.

Please sign the attached form, if you agree to be interviewed. The second copy is for your records. Thank you very much for your help.

Yours sincerely,

Researcher: Ting Wang

Contact: 416-315-0690, twang@mail.utoronto.ca

Research supervisor: Katherine Bellomo
Consent Form

I acknowledge that the topic of this interview has been explained to me and that any questions that I have asked have been answered to my satisfaction. I understand that I can withdraw at any time without penalty.

I have read the letter provided to me by Ting Wang and agree to participate in an interview for the purposes described.

Signature:

Name: _________________

Date: _________________
Appendix B: Interview Questions

Background
Could you talk about your previous teaching experiences? What subjects and grade levels or age? How long have you been teaching?

Storytelling
What are your experiences when you tell a story in a classroom or in other contexts?

What do you think are the benefits of traditional storytelling (teller speaking evocatively, audience listening passively) in a classroom?

How would you describe the role of the storyteller in relating a story to an audience?

What makes a good storyteller? Do you consider yourself a storyteller?

Are scientists typically good storytellers in your opinion?

What are your thoughts on using stories in any format (written/oral) in a classroom?

What do stories accomplish in the classroom?

If you were to select stories specifically for the purpose of nature of science education, how would you select them?

Nature of Science
How would you describe what scientists do?

How well do you feel students know about the nature of science?

What would you advise teachers entering into K-12 education in terms of teaching the nature of science?

What do you think are the strengths and weaknesses of using stories to teach the nature of science?

Teaching
What is the purpose of science education from K-12?

Do you believe our currently implemented science education serves that purpose?

Wrap-up
Is there anything more you would like to say on the subject of storytelling and nature of science?