Investigation and analysis of nature of science perspectives

among key curriculum influences in British Columbia

by

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Abstract

In this study I investigated the Nature of Science (NOS) perspectives advocated among three significant influences on school science in British Columbia: the official curriculum materials – Integrated Resource Packages (IRPs); the teachers; and the textbooks since these three significantly influence student learning experiences.

I examined the Science 9 Integrated Resource Package (IRP) 2005 and two editions of B.C. Science Probe 9 by Nelson Publishing by using the protocol established by Chiappetta, Fillman and Sethna (1991) with the addition of a method from Green (2012) to investigate the nature of science in text. I used an interview protocol developed by Padayachee (2012) for exploring teachers' views of the nature of science.

Analysis of the perspectives indicates that there is alignment between NOS perspectives by teachers and those implied in the IRP. The agreement that hands-on, inquiry-based, and experience-oriented science learning is worthwhile acknowledges the value of science as a way of investigating, science as a way of thinking and science in the context science-technology-society. On the other hand there is partial alignment of textbook-based NOS perspectives with those discerned from IRP and teachers' views of science teaching. Textbook NOS perspectives emphasized science as a body of knowledge without reference to history, creativity or imagination.

The study's findings have implications on how complete understanding of the nature of science might be taught, learned and represented in various learning media.

Preface

This dissertation is original, unpublished, independent work by the author, David Savory. This research study was conducted with the approval of the UBC Research Ethics Board (Behavioural Research Ethics Board; UBC BREB Number: (H14-02721).

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List of Abbreviations

BCEP: B.C. Education Plan: government policy document (2012)

IRP: Integrated Resource Package: B.C. curriculum document

NOS: Nature of Science

SBK: Science as a Body of Knowledge

STS: Science-Technology- Society

STSE: Science-Technology-Society-Environment

SWI: Science as a Way of Investigating

SWT: Science as a Way of Thinking

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Dedication

This thesis is dedicated to my children Max and Maitri who woke me from my dogmatic slumbers and made me happier than I thought was possible.

CHAPTER 1: Introduction To The Study

Study Background

The Nature of Science.

In one of his seminal papers, Lederman (2006) cited the Central Association of Science and Mathematics Teachers (1907) and argued that for approximately 100 years the 'nature of science' (NOS) has been advocated as an important goal for students studying science. Schwartz, Lederman and Crawford (2003) reported that, "reform efforts around the world stress the importance of developing images of science that are consistent with current scientific practices and constructivist perspectives" (p. 611). In the same vein, the National Science Education Standards [NSES] (NRC, 1996) assert that "students should develop an understanding of what science is, what science is not, what science can and cannot do, and how science contributes to culture" (p. 21).

Driver, Leach, Millar, and Scott (1996) advanced five general reasons why NOS has historically been deemed worthwhile as seen in Figure 1:

1) Utilitarian: understanding NOS is necessary to make sense of science and manage the technological objects and processes in everyday life
2) Democratic: understanding NOS is necessary for informed decision-making on socioscientific issues
3) Cultural: understanding NOS is necessary to appreciate the value of science as part of contemporary culture
4) Moral: understanding NOS helps develop an understanding of the norms of the scientific community that embody moral commitments that are of general value to society
5) Science learning: understanding NOS facilitates the learning of science subject matter.

Figure 1 Reasons the NOS is Worth Studying

Given this long-standing interest in the promotion of the nature of science, it behooves us to clarify what the nature of science is. Lederman (2006) reported the following characteristics of science derived from his long-running research about the nature of science:

- The distinction between observation and inference
- The relationship and distinction between scientific laws and theories
- Scientific knowledge is, at least partially, based on and/or derived from human imagination and creativity.
- Scientific knowledge necessarily is partially subjective and can never be totally objective.
- Science as a human enterprise is practiced in the context of a larger culture and its practitioners (scientists) are the product of that culture. Science, it follows, affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded.
- Scientific knowledge is never absolute or certain; it is subject to change.
- Scientific knowledge is empirically based.

Figure 2 Characteristics of Science

Typically, the NOS refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent in the development of scientific knowledge (Abd-El-Khalick, Bell, & Lederman, 1998).

The need for people to become scientifically literate includes being aware of the NOS. Schwartz, Lederman and Crawford (2003) citing the American Association for the Advancement of Science (AAAS) (1993) and the National Research Council (NRC) (1996), wrote, “The current emphasis on scientific literacy extends beyond calls for knowledge of scientific concepts and methods of scientific investigations. Understanding tenets of scientific inquiry and nature of science (NOS) are at the core of scientific literacy" (p. 611). The broad view of scientific literacy explicitly includes aspects of the nature of science (Zeidler, Walker, Ackett, & Simmons, 2000). Lederman (1992) reported that in spite of decades' worth of attention from academic pedagogues, the development of an understanding of the concepts, principles, theories, and processes of science as well as the awareness of the complex relationships between science, technology, and society was not being realized.

To place the above position on the importance of NOS, it becomes imperative to examine the state of affairs through a local context by examining the nature of education in the province of British Columbia (BC) based on the recommendations of the 1988 British Columbia (BC) Royal Commission on Education.

The Nature of Education in B.C.

In 1988, The British Columbia (BC) Royal Commission on Education published an educational report called "A Legacy for Learners: Report of the Royal Commission on Education" which was "initiated in response to important changes that have taken place in British Columbia society since 1960" (1988, p. 2). Royal Commissions on education are infrequent undertakings, in this province and elsewhere in Canada, "occurring about once every generation and generally regarded to be important educational milestones, events that signal a point of departure in our thinking about education and its importance in our lives" (1988, p. 2). A Legacy for Learners: Report of the Royal Commission on Education pointed out that since 1960, when the work of the previous Royal Commission on education was tabled in the Provincial Legislature, educational and social concerns changed in many ways. The energy and activism of the 1960's raised consciousness about individual rights and equality of opportunity issues. In the 1970's, we learned first-hand about energy shortages and threats to our environment. In the 1980's, we became more conscious of problems related to health, the economy, and our role in the international world. (1988, p. 2. In 1988 the Royal Commission reported that "disagreements over various aspects of provincial educational policy have sharply divided British Columbians and in some cases to the extent that the quality of schooling for children has been imperiled" (1988, p. 3). No longer the beneficiary of "unqualified public support", public schooling was "forced to compete with other social services, particularly health, for its share of funding" which has had "unfortunate effects on the morale of school professionals and the public they serve" (1988, p. 3). The goal of the Royal Commission in 1988, was to "foster a new educational accord in British Columbia" and "leave a legacy of value for our children and the future they represent" (1988, p. 3).

In addition to addressing learners, the Royal Commission made a number of very interesting assertions. It acknowledged, "the fundamental place of teachers in the learning environment" and added, "their relationship with children and parents is by far the most important and critical one in education" (1988, p. 37). However, the Commission also claimed, "teaching has always been a complex and demanding activity but never more so than today" (1988, p. 37). It cautioned that, "the boundaries of knowledge have exploded and many of the basic tenets of teaching and the values that traditionally supported them can no longer be taken for granted" (1988, p. 37). More ominously, it reported, "the provincial education system bears the scars of an often bitter conflict that has raged far too long" (1988, p. 37).

Problem Statement and its Educational Significance

Abd-El-Khalick, Bell and Lederman (1998, p. 429) reported that student teachers/teacher candidates felt they had to "cover the content that their mentor teachers had assigned them within predetermined time limits" and in the words of one teacher candidate, "there was no scheme to teaching the NOS; I did not address it much. I was on a treadmill in my student teaching and I was flying through content. It is just a kind of survival. I did not teach science the way I envision myself teaching it in the future. I was relying on the textbook and going with the basic curriculum." (1998, p 429).

Research indicates that neither teachers nor students typically hold helpful views of the nature of science (Driver, Leach, Millar, & Scott, 1996; Lederman & Lederman, 2004; Schwartz et al., 2002). In this thesis, my interest focuses on the views of the nature of science (NOS) in the curriculum, the resources the curriculum recommends, and in the practice of the teachers. . Based on my review of the relevant literature, there appears to be no study that analyzes the perspectives of these three key players in BC high school science. Therefore my study investigated and analyzed the perspectives of the NOS in curriculum documents, among science teachers, and in the recommended textbooks found in BC classrooms. In this study, I explore the view of science presented to high school students in their secondary science classes.

Study Context: Purpose and Research Questions

Purpose.

The purpose of this study was to analyze the perspectives of the NOS as a way of understanding the convergence and divergences in the perspectives of NOS that BC students experience in their science classes.

Research Questions

1. What view of the nature of science, is conveyed in the Science 9 Integrated Resource Package (IRP) 2005?
2. What are the views of the nature of science held by practicing teachers?
3. What is the view of the nature of science in the recommended textbook B.C. Science Probe by Nelson Publishing?

Significance of the Study

This study will provide insights into the role and interests of the three players: the government who determines the curriculum; the teachers who teach the curriculum; and the textbook publishers who interpret the curriculum and create content to assist teachers in teaching the curriculum. The degree of agreement among these three players would be worthwhile to determine, given the history of confrontation and conflict that has often characterized the relationships between and among the above players.

Researcher Background

I am a long time science educator who has spent over twenty-five years teaching science to children and youth as well as to adult learners. Some of this time was spent in a traditional science classroom, and I also taught in informal science education settings such as – provide examples here. I was also an educator in an immersive nature-focused professional development program for science-phobic elementary teachers. In addition I was a sessional instructor in UBC's teacher education program and taught science education to elementary teacher candidates. My teaching follows a hands-on, experiential learning approach with an emphasis on question-oriented exploration.

Thesis Contribution

Three of the major players in modern schooling are the government, which determines curricular expectations, teachers, who attempt to meet those expectations, and textbooks, the main resource of many classroom teachers. I believe it would be worthwhile to explore the needs and interests of each of these players and then explore the consonance or dissonance between and among them. I will now explain why.

In his 1854 novel "Hard Times" Charles Dickens introduces the headmaster Gradgrind with the following words which he utters on the very first page, "Now, what I want is Facts. Teach these boys and girls nothing but Facts. Facts alone are wanted in life. Plant nothing else, and root out everything else. You can only form the mind of reasoning animals upon Facts: nothing else will ever be of any service to them" (p. 1). Dickens presents a businessman-turned-teacher who sees students as pitchers who are to be filled with facts. This has proved to be a very enduring belief that persists to this day even though educators have through curriculum theorizing over the last one hundred years educators have worked to supplant it. Bobbitt maintained that, "Education is now to develop a type of wisdom that can only grow out of a participation in the living experiences of men and never out of mere memorization of facts" (2009, p. 10). This living experience is important because there is an interesting tension between the curriculum-as-planned and the curriculum-as-lived (Aoki, 1993, p. 257). I believe it would be interesting to delve into the world of great curricular expectations and look carefully at those expectations, the assumptions that underlie them, and the implications that flow from them.

Teachers tend to approach teaching and learning with preconceived notions of what it means to teach and learn (Ausubel, 1963; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Nashon, 2013). Giroux declared that teachers are often reduced to the "status of high-level technicians carrying out dictates and objectives decided by experts far removed from the realities of classroom life" (1988, p. 121). It would be interesting to delve into the teachers' world to look at their expectations, assumptions, and the implications involved.

Teachers draw upon a number of supportive resources including textbooks in their teaching. Chiappetta and Fillman claimed, "The role of textbooks in the U.S. educational system cannot be over-emphasized. Textbooks help define school subjects as students experience them. They represent school disciplines to students" (2007, p. 1847). I believe it would be interesting to determine the extent to which textbooks reinforce the curriculum and support instruction by defining school subjects.

I chose science, specifically the nature of science, as the litmus test for determining the agreement among the three major players in B.C. education because personally I always enjoyed science learning and teaching and as we saw from Fig 1, science has a number of compelling features as follows: science is a utilitarian, technological force capable of both positive and negative social effects; science knowledge can help citizens participate more knowledgeably in a democracy; and the normative forces in the scientific community could be extended to the rest of society. Put simply, science matters to all of the educational players in this province.

I chose the province of B.C. as the context for my study not only because it is where I live and work but also because B.C. has a very rich and interesting political history, some of which played out in the province's classrooms.

My hope is that this study can draw these elements together analytically to ultimately generate recommendations to guide the stakeholders through the current curriculum transformation. This present moment is a good time for reflection on the state of science teaching and learning in B.C. as classroom teachers throughout the province embark on implementing a new Kindergarten to Grade 12 curriculum beginning in the 2015/16 school year.

Thesis Overview

This thesis is organized into five chapters. Chapter 1 presented the introduction to the study, problem statement, research questions, and the study's significance. Chapter 2 continues with a theoretical framework and a literature review. Chapter 3 describes the methods used to collect and analyze data in order to answer the research questions and concludes with comments on the study's ethical considerations and limitations. Chapter 4 presents data from the BC Ministry of Education's Science 9 IRP, from interviews with practicing teachers and from Science Probe 9 and an analysis of the data. Chapter 5 answers the research questions and provides recommendations and suggestions for further research. Finally, Chapter 6 presents the study’s conclusions and implications on educational theory, practice and research.

CHAPTER 2: Theoretical Framework and Literature Review

In this chapter I will discuss the Nature of Science (NOS), what science is, and how it proceeds before I examine the philosophical underpinnings and implications for science education. This will be followed by focusing attention on how NOS is represented in the Integrated Resource Package (IRP, B.C. Ministry of Education policy document, and textbooks. I will conclude this chapter with a review of interview-based studies on teachers' understanding and representation of NOS in their teaching.

What is Science?

In "History of Western Philosophy", Bertrand Russell stated, "Almost everything that distinguishes the modern world from earlier centuries is attributable to science" (1946, p. 512). He added, "In the sphere of thought, sober civilization is roughly synonymous with science" (1946, p. 36) and further claimed, "the men who founded modern science" (Copernicus, Kepler, Galileo, and Newton) had two great merits, immense patience in observation and great boldness in framing hypotheses (1946, p. 514). Most importantly however, Russell maintained, "It is not what the man of science believes that distinguishes him, but how and why he believes it. His beliefs are tentative, not dogmatic; they are based on evidence, not on authority or intuition" (1946, p. 514). If, according to Russell scientific beliefs are tentative, one must question the basis on which they are subject to revision.

Karl Popper (1963) answered this by attempting to determine the difference between science and pseudoscience (p. 44). The difference is not due to an empirical method, that is, observation and experiment, nor is it due to the explanatory power of their respective theories, or even an "incessant stream of confirmations" (1963, p. 46). He concluded that, "the criterion of the scientific status of a theory is its falsifiability, or refutability or testability" (1963, p. 48).

Imre Lakatos (1978) complained that Popper ignored the "tenacity" of scientific theories; "scientists do not abandon a theory just because facts contradict it" (p. 4). This is because the "selection pressure" works on "research programmes" rather than individual predictions from individual theories. This echoes Kuhn's (2012) "paradigm shifts" when the "puzzle-solving" in the normal science of one paradigm gives way to puzzle solving in a different one (2012, p. 38-39, p. 84).

Kuhn's work, which was very influential in the science and science education communities, focused on the competition between rival ideas and how they were resolved. There is a difficulty in that different paradigms usually leave different problems unsolved, which means appeals must be made to criteria external to the whole debate (1970, p. 110) and indeed to rationality itself.

Current thinking on the philosophy of science appears to be founded on the work of Thomas Bayes, who, in 1763, published, "Essay Towards Solving a Problem in the Doctrine of Chances". Bayes' work ushered in a revolution in the understanding of the confirmation of scientific hypotheses two hundred years later (Strevens, 2012, p. 5). First, it is assumed that the scientist uses subjective probabilities that reflect the scientist's level of expectation that a particular hypothesis will turn out to be true. It is also assumed these subjective probabilities behave mathematically like other probabilities. Significantly, scientists are assumed to learn from the evidence and update their subjective probabilities in a mathematically exact way as new evidence comes in (Strevens, 2012, p. 5). Subjective probability and plausibility go hand-in-hand and comprise a very important part of the evaluation of rival hypotheses. I turn now to John Dewey and Joseph Schwab who defined science in ways that had implications for the teaching and learning of science.

Experience, Experiments and Expertise

I begin with an exploration of Dewey's view on the nature of science and continue with Schwab's elaboration. From there, I look at some of the pedagogical implications of these views of the nature of science.

Dewey (1916, p. 121) believed that thinking, inquiring, and investigating were all closely related. He was an ardent proponent of "experience," a word that comes from the Latin "experientia" which denotes trial, proof, or experiment (Jay, 2005, p. 10). According to Dewey (1916), science and science education have important roles to play in the lives of citizens in a democratic society. The function which science can perform in the curriculum is what science has performed for the human race: emancipation from local and temporary incidents of experience, and the opening of intellectual vistas not obscured by the accidents of personal habit and predilection (p. 186).

Dewey also claimed, "Command of scientific methods and systematized subject-matter liberates individuals; it enables them to see new problems, devise new procedures and in general, makes for diversification rather than for uniformity" (1984, p. 6). There is generally broad agreement that public awareness of science is a good thing. Tate (2001) for example, describes the case that "economic access and full citizenship depend crucially on math and science literacy" (p. 1015).

In Schwab's view (2004, p. 103-104), science was not a process for revealing stable truths about the world. Rather, science required a flexible process of inquiry consisting of the following components: formulation of a problem; the search for data that will suggest possible solutions to this problem; the reformation of the problem to include the possible solutions; a determination of the data necessary to solve the problem; a plan of experiment that will elicit the data desired; an execution of the experiment; and accumulation of the desired data.

According to Doll (2012, p. 64), Schwab "would like to make all education—especially formal schooling—practical in the sense of dealing with these particular and personal states of affairs" (p. 64). Schwab's notion of inquiry advocates "putting the student in very direct contact with the problems and practices within a field" (p. 64). It is with Dewey's and then with Schwab's work that personal experience becomes an important part of education.

Significantly, the idea that science education ought to reflect the practices of scientists within the scientific community as a form of enculturation was endorsed by Richard Rorty who also supported Dewey's (1916) philosophical pragmatism. What education and pragmatism share is the Rortyan notion of "solidarity". Rorty claimed that our intellectual history features a transition from solidarity to objectivity, wherein our sense-making narratives have shifted from contributing to a community to something non-human and abstract (2011, p. 367). For pragmatists like Rorty, "the desire for objectivity is not the desire to escape the limitations of one's community but simply the desire for as much intersubjective agreement as possible, to extend the reference of 'us' as far as we can" (2011, p. 369).

Lederman (1992) has long been vocal in his promotion of awareness of the "nature of science" with respect to understanding the concepts, principles, theories, and processes of science as well as the awareness of the complex relationships between and among science, technology, and society. As I mentioned previously, Lederman (2006) claimed that NOS has been advocated as an important goal for students studying science for approximately 100 years, and many researchers believe that NOS has significant important instructional implications for the teaching and learning of science (Hodson, 2009).

Based on the literature presented thus far in the chapter, I find there is a sense of what ought to be known in addition to the "usual" curricular content and the why. Research findings on the nature of science suggest that science teachers should explicitly guide students in developing a proper understanding; since implicit or incidental guidance is insufficient (Abd-El-Khalick & Lederman, 1998, p. 419; Schwartz, Lederman & Crawford, 2004, p. 614-615). But, to meet this need, a broad framework for teaching and learning science that accomplishes more than just the transmission of a few key ideas is required. I submit that, following Dewey and Schwab, the use of experience and scientific inquiry should stimulate curiosity, critical thinking, metacognition, and self-regulation and would also promote scientific literacy and understanding of the nature of science.

To summarize the literature reviewed here on the nature of science (NOS), I believe Niaz and Maza (2011) present a consensus on the NOS as depicted to in Figure 3:

- Scientific theories are tentative.
- Laws and theories serve different roles in science
- There is no universal step-by-step scientific method
- Observations are theory-laden
- Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, creativity and skepticism
- Scientific progress is characterized by competition between rival theories
- Scientists can interpret, the same experimental data differently
- Development of scientific theories, at times is based on inconsistent foundations
- Scientific ideas are affected by their social and historic milieu

Figure 2 NOS features

The implication is that creating familiarity with these characteristics would be the foundation for understanding what science is and how it proceeds, that is, being scientifically literate. According to Zeidler, Walker, Ackett, and Simmons (2000), "If teachers support the notion that scientific literacy entails, at least in part, the ability of students to engage in active dialogue as they ponder evidence, apply critical thinking skills, and formulate positions on various topics, then informal discussions and formal debates that challenge students to use multiple views and competing evidence in rendering decisions becomes central to a broader view of scientific literacy that explicitly includes aspects of the nature of science" (p. 344).

I will now discuss the curriculum of British Columbia, teachers' interpretation of that curriculum and the support given by textbooks to teaching.

Curriculum in British Columbia

Curriculum is a Latin term that refers to a "race" or "course of study." The B.C. Ministry of Education defined curriculum in their report "Let's Talk About Schools"

(1985, p. 10 in section 2.3) as “what is to be taught, or the body of courses that comprises a structured school program.” The “A Legacy for Learners: Report of the Royal Commission on Education” defined curriculum as comprising of three things: 1. Intended Curriculum, “the curriculum as it is defined in official publications, regulations, textbooks and supplementary materials, and curriculum guide”; 2. Implemented Curriculum, “the curriculum as it is interpreted by teachers and brought to life in their classrooms”; and 3. Attained Curriculum, “outcomes of schooling” (1988, p. 27).

The Integrated Resource Package (IRP)

B.C.’s Ministry of Education curriculum packages, called the Integrated Resource Package (IRP), presents curriculum for the required areas of study from Kindergarten to Grade 12. These documents include prescribed learning outcomes (PLO’s) and suggested achievement indicators (SAI’s) for each grade and subject area and are readily available on the B.C. Ministry of Education’s website (http://www.bced.gov.bc.ca/irp/all.php?lang=en).

The IRP.

In advance of the Year 2000 Curriculum Document, “A Legacy for Learners: Report of the Royal Commission on Education” declared:

> The Government of British Columbia believes that education is a long process embracing many facets, including personal development, career preparation, the enhancement of creativity, self-discipline, mature judgment, and a broad range of life skills, not the least of which is curiosity—the love of learning.” (p. 1)

The report also claims the study of science should encourage participation in scientific inquiry by drawing on concepts and processes inherent in the disciplines of biology, chemistry, and physics. Science should present students with opportunities to engage in discussion about relationships within the sciences themselves—and among the sciences, technology, and society (p. 30):

In response to the Legacy for Learners Report the BC government concluded:

> it is timely to clearly evaluate where we are going in education and to select the most appropriate and cost-effective means of meeting our objectives which were defined as including the development of a population that is 'well prepared to meet the rapidly changing challenges of everyday life in the 21st century (p. 1).

The Integrated Resource Package (IRP) is a government document that declares the following on the cover page, "this Science Grade 9 document has been provided to assist school districts, schools, and teachers in preparing to deliver Science Grade 9 in 2007/2008, the first of year of prescribed implementation." The prescribed learning outcomes are presented as being the "legally required content standards for the provincial education system" (p. 7). Similarly "required attitudes, skills and knowledge- what students are expected to know and be able to do- for each subject" (p. 7) are outlined. There is a large section on student achievement, which "contains information about classroom assessment and measuring student achievement, including sets of specific achievement indicators for each prescribed learning outcome" (p. 7). These are not mandatory however, "they are provided to assist teachers in assessing how well their students achieve the prescribed learning outcomes" (p. 7). There is a section called the "Classroom Assessment Model" which "contains a series of classroom units that address the learning outcomes" (p. 7). There is another large section toward the end of the document on learning resources which lists recommended learning resources and includes the texts that I examined in this study.

Teachers

In the 1930s, B.C.'s economy, which was based on the extraction of resources for export to foreign markets that were drying up, was in poor shape (Kilian, 1985, p. 30). George Weir, the head of the University of British Columbia's (UBC) Education department blasted a right wing report from businessman George Kidd which Weir characterized as an "attempt to condemn the youth of British Columbia to intellectual serfdom at the caprice of certain capitalistic parvenus" (Kilian, 1985, p. 32).

A generation later, postwar B.C. was booming economically. With their "sense of mission" and "devout belief in the future greatness of B.C." the ruling Social Credit party "built a respectable school system" but also "harbored a deep distrust of educated people" (Kilian, 1985, p. 33). In fact, the British Columbia Royal Commission on Education (1960) concluded, "what the public was willing to pay for the education of their children and youth did not make the profession of teaching an attractive one" (Kilian, 1985, p. 33). In 1966, the BC Government introduced a bill that required major changes in school financing that froze spending and compromised the autonomy of school boards (Kilian, 1985, p. 37). The government also sought to divert money from teachers' pension plans to pay for dams on the Columbia and Peace rivers. The BC Teachers Federation (BCTF) responded by levying their members to fund an anti-government publicity campaign that would coincide with the run-up to the next provincial election (Kilian, 1985, p. 37). Hence, so began the adversarial relationship between the BCTF and the BC Government that continues to the present day.

According to Macdonald and Werker (1976, p. 2), it was clear by the late 1960's the authority patterns were changing in B.C. education. They report that in 1968, the BCTF presented a number of recommendations that challenged traditional authority roles in calling for "greater parent and teacher involvement and authority" (p. 2). By 1971, the Official Opposition the National Democratic Party (NDP) and the British Columbia School Trustees Association (BCSTA) weighed in with their own recommendations that were countered in 1974 by new legislation from the government (p. 3).

Since the 1980's, education in B.C. has come down to "school effectiveness", "funding for schools", and the relationship between the two (Let's Talk About Schools, 1985, p. 7). This report cited Gallup and other information sources that suggested the large majority of British Columbians generally and educators specifically believed that existing levels of financial support were inadequate for meeting community needs (p. 8). Interestingly, the report also pointed out that the issue of governance was a source of concern for the public as well as for educators.

Kilian (1985) pointed out that although B.C.'s problems were not unusual, compared to other jurisdictions, the treatment of those problems by elected officials was very unusual as they advocated for education by attacking it (1985, p. 218).

Teaching

If, as Mintzes, Wandersee and Novak (1998) claim, the goal of the education is the creation of "shared meaning", the task for the teacher is to "conduct an instruction which provides rich environment for students where they have opportunity to actively involve in sharing, enlarging and changing the meaning" (Roswiati & Tonishi, 2008, p. 86). Nott and Wellington (1997, p. 395) suggest a number of dichotomies that show the multidimensional nature of science. These include: process-content; relativism-positivism; deductivism-inductivism; instrumentalism-realism; and contextualism-decontextualism. Nott and Wellington found that beginning teachers views' on the nature of science changed as they experienced classroom-life as these experiences changed the way they thought about science.

Abd-El-Khalick, Bell And Lederman (1998, p. 417) asked "what are the factors that mediate the translation of teachers' conceptions of the nature of science (NOS) into instructional planning and classroom practice?" and found that explicit references to the NOS were rare in their planning and instruction. The author's concluded this was because teachers' viewed the NOS as less significant than other instructional outcomes as they were preoccupied with classroom management and routine chores. The teachers studied also felt discomfort with their own understandings of the NOS as they believed they lacked resources, experience and time for teaching the NOS. What is interesting however, is that they all possessed views of the NOS which were "consistent with current reforms" (p. 432).

The Textbook

Roswiati and Tonishi (2008, p. 87) reported that, “a key feature of effective teaching is the selection of instructional materials and teaching aids that meet the need of students and fit the constraint of teaching and learning environment.” They add that the textbook is a very common teaching aid used in science classrooms all over the world, largely because “well chosen textbooks help students to understand how information and ideas can be organized” (2008, p. 87.) According to Dee-Lucas and Larkin (1990), science texts tend to present information in either of two ways, “proof first” or “principle first.” The proof first organization develops a proof or argument that builds to a conclusion, usually in the form of fundamental concept, principle, or law. In principle first organization, a content or principle is explicitly stated, then the supportive evidence is presented. According to Dee-Lucas and Larkin (1990, p. 712), the principle first structure is more effective for long-term retention and understanding by young readers because it provides a scaffold for additional information.

Textbooks figure in instruction in another way. “It is also acknowledged that science textbooks have important implications on the ways science is taught (i.e., inquiry-based or teacher-directed) and on the type of the classroom learning environment that is usually created (i.e., student- or teacher-centered) as well as on the ways that science knowledge is being assessed” (Valanides, Papageorgiou, and Rigas, 2013, p. 259). Reinders and Balcikanli (2011, p. 270) explain that textbooks are “collections of texts and tasks structured by the author in a way he considers best for teaching and learning a foreign language and in addition, most textbooks define the progression of such learning." They go on to add that textbooks "do have the potential to foster autonomy in a number of ways … through a focus on learning skills and through strategy instruction." However a major concern raised Abd-El-Khalick, Waters & Le (2008) is that the textbook becomes the curriculum.

Summary of the Chapter

I have presented some of the current and historical thinking around the nature of science. I have also presented some of the pedagogical implications of these ideas. Finally, I presented and discussed views on the nature of science held by the government, teachers, and disseminated by textbooks. The next chapter focuses on the methodological framework that I employed to collect and analyse the data for this thesis.

CHAPTER 3: Methodology and Research Design

I am interested in determining views of the nature of science and will do so by examining and interpreting verbal utterances as well as textual claims. To answer my research questions, I chose a hermeneutical approach for the study because the research questions ask for meanings of a phenomenon with the purpose of understanding the human experience (Crist and Tanner, 2003, p. 202).

I will first re-state my research questions and justify my choice of a hermeneutical approach for my study.

Research Questions

1. What view of the nature of science, is conveyed in the Science 9 Integrated Resource Package (IRP) 2005?
2. What are the views of the nature of science held by practicing teachers?
3. What is the view of the nature of science in the recommended textbook B.C. Science Probe by Nelson Publishing?

To critically examine curriculum and textbook documents as they exist and as they are interpreted by teachers and publishers, a mixture of methodologies was used to comprise a hermeneutical approach. I will now explain what I mean by a "hermeneutical approach."

Hermeneutical Approach

A hermeneutical approach allows the researcher to interpret without the need to establish and use pre-existing categories for understanding. Conversely, Gadamer cites Heidegger who said “our first, last and constant task in interpreting is never to allow our fore-having, fore-sight and fore-conception to be presented to us by fancies and popular conceptions” (Gadamer, 1976, p. 266). Thus a “hermeneutic circle” (1976, p. 266) is required, an iterative “spiral of inquiry” that focuses the interpreter’s investigation into details both specific and general. Most importantly, the researcher can focus on details that emerge from the exploration rather than seek to explain them with respect to categories presented by “fancies” and popular conceptions.

Gadamer (1994) maintained, “the problem of hermeneutics is the phenomenon of understanding and the correct interpretation of what has been understood” (pxxi). He added, “the task of hermeneutics was first and foremost the understanding of texts” (p. 392) and claimed that rather than being a standard method, hermeneutics was, for its originator Schleiermacher, more of an art or a technique for “avoiding misunderstanding” (p. 185).

Dilthey, one of the early hermeneutical thinkers is regarded by Ricoeur (2007) as having determined that the hermeneutical problem was to give interpretation and “the science of the spirit” a validity comparable to that of the natural sciences (p. 5). Gadamer pointed out that this is “not a problem of method, that is, it isn’t concerned with a method of scientific investigation” (1994, pxxi) because it is not concerned with “amassing verified knowledge”. It is not an attempt to understand things scientifically but a way to understand scientific understanding and connect it with other human understandings and the "totality of our experience with the world" (1994, p. xxiii). The interpreter begins the project by claiming what is to be understood is not only the exact words and their objective meaning but also the individuality of the author (Gadamer, 1994, p. 186). Thus interpretation has a grammatical component and a psychological one.

The method could also be divided into an examination of what is common, using comparison, and what is unique, by intuition (Gadamer, 1994, p. 190). Either way though, it is an art because it cannot proceed by "the mechanical application of rules" (p. 190).

Ricoeur admitted "we have to guess the meaning of the text because the author's intention is beyond our reach" (1976, p. 75) but allowed that "if there are no rules for making good guesses, there are methods for validating those guesses we do make" (1976, p. 76). Ricouer (1976) claimed that validation is not the same as verification and that the goal is a probable interpretation rather than a true one (p. 78). Ricoeur concluded, "the logic of validation allows to move between the two limits of dogmatism and skepticism" and "it is always possible to argue for or against an interpretation, to confront interpretations, to arbitrate between them and to seek agreement, even if this agreement is beyond our immediate reach" (p. 79). Thus one validates an interpretation by testing it against competing interpretations, not by verifying it empirically. Ricoeur concluded by borrowing from the Nichomachean Ethics, "We must be content to indicate the truth roughly and in outline" and to "look for precision just so far as the nature of the subject admits" (Ricoeur, 1981, p. 222).

Gadamer (1994) suggested that, for Schleiermacher, the act of understanding is the reconstruction of the production" (p. 192), although we ought to be careful to realize that the “artist who creates something is not the appointed interpreter of it” (p. 193). Gadamer (1994) notes that our goal is to “understand a writer better than he understood himself” (p. 192) and adds, “The real meaning of a text, as it speaks to an interpreter, does not depend on the contingencies of the author and his original audience” (Gadamer, 1976, p. 296) and “It is enough to say that we understand in a different way, if we understand at all” (p. 297). Ricoeur (1981) adds that hermeneutical interpretation is sharply opposed to explanation which is objective and scientific (p. 165).

Gadamer (1994) claimed, “to understand a text always means to apply it to ourselves and to know that, even if it must always be understood in different ways, it is still the same text presenting itself to us in these different ways” (p. 399). He added, “Let us remember, rather, that understanding always includes an element of application and thus produces an ongoing process of concept formation” (p. 404).

Gadamer had an impact on Rorty (2010), who wrote in “Philosophy and the Mirror of Nature,” that hermeneutics is an attempt to set aside the “classical notion that the universe is made of simple, clearly and distinctly knowable things, knowledge of whose essences provides the master-vocabulary which permits commensuration of all discourses” (p. 90). Rorty quotes Gadamer in saying “hermeneutics is not a methodology of the human sciences but an attempt to understand what the human sciences truly are, beyond their methodological self-consciousness” (p. 90). Rorty’s reaction was a project he called “edification” which consisted in the “hermeneutic activity of making connections between culture and another” (p. 91). This pursuit frequently involves attempting to interpret “incommensurate aims and incommensurate vocabulary to aid us in becoming new beings" (p. 91). Let me back up and say a little about the relationship between education and edification.

Rorty (1999) observed (pp. 114-115) that education involves two simultaneously competing imperatives: an enculturation, wherein students are expected to converge onto necessary social understandings; and an individualization, whereby they diverge from those understandings according to their personal needs and interests.

John Dewey took up the mantle raised by Pierce and James in reforming and reconstructing philosophy by "demystifying and defending the most reliable mode of inquiry in modern culture, namely, critical intelligence manifest in the community of scientists" (West, 1989, p. 72). Richard Rorty (1999) was an important champion of both Dewey and pragmatism. Rorty claimed that the pragmatic assumption is that problems are made and can be unmade with a different set of vocabulary, assumptions and distinctions (p. xxii). The pragmatic programme is not historical, rather, it does not see the relevance of vocabulary, assumptions, distinctions and pronouncements from long abandoned contexts in immediate and local ones. He claimed "The core of pragmatism is the attempt to replace the notion of truth beliefs as representations of the "nature of things" and instead to think of them of successful rules for action" (1991, p. 65.) "Pragmatism without method is pursued without the traditional distinctions between the cognitive and the non-cognitive, between "truth" and "comfort" (scientific and theological products respectively) or between the propositional and the non-propositional" (1991, p. 76). "Inquiry is not meant to correspond to the intrinsic nature of reality but to serve the transitory purpose of solving transitory problems" (1999, p. xxii).

Moreover, “the goal of inquiry is not truth but agreement about what to do next” (1999, p. xxv).

I turn now to the manner in which this understanding and avoidance of misunderstanding is meant to occur, a case study using narrative inquiry and content analysis.

Study Structure

This study incorporated both case study and narrative inquiry approaches through the use of semi-structured interviews. In the case of the IRP and the textbook, a textual approach was employed.

Case Study

The term “case study” has a number of different meanings, Van Wynsberghe and Khan (2007) claim, “The past three decades of scholarship on case study research have produced more than 25 different definitions of case study, each with its own particular emphasis and direction for research. Eckstein (2002, p. 124) writes a “case” can be defined technically as a phenomenon for which we report and interpret only a single measure on any pertinent variable. Creswell (2002, p. 61) wrote that a case study is a problem to be studied, which will reveal an in-depth understanding of a “case” or bounded system, which involves understanding an event, activity, process, or one or more individuals.

Narrative Inquiry.

Narrative inquiry is a method for eliciting and examining teachers’ personal histories as well as their inner experiences (Bell, 2002; Connelly & Clandinin, 1990;

Lieblich, Tuval-Mashiach, & Zibler, 1998; Polkinghorne, 1988). According to Pinnegar and Daynes (2007) what narrative researchers hold in common is the study of stories or narratives or descriptions of a series of events. Within the framework of narrative research, researchers use a number of research approaches, strategies, and methods (Lieblich, Mashiach-Tuval, & Zilber, 1998). Case study and narrative approaches will enable this study to explore the lived experiences of teachers and generate a thick description of teachers' experiences (Crowe, Cresswell, Robertson, Huby, Avery and Sheikh, 2011).

The teachers' view of the nature of science can be examined through semi-structured interviews. Seidman (2006) recommends interviewing as a basic mode of inquiry because "recounting narratives of experience has been the major way throughout recorded history that humans have made sense of their experience" (p.23). Huebner claims (p. 177) that, "Education is the meshing of the unfolding biography of the individual with the unfolding biography of society" (p. 177). Rodriguez (2005) claims "there is something alluring in the way stories are told that can engage us to the point where we live vicariously the teller's experiences… this may be due in part to the our empathize with the teller's struggles." (p. 121) Since "it is good to rub and polish our brain against that of others" (Montaigne, 1987, p. 172), I thought I would attempt to mesh teachers' stories with the stories told by curriculum documents and textbooks. The purpose of in-depth interviewing is not to find answers to questions, nor test hypotheses or "evaluate" the term is normally used; it is to "understand the lived experience of other people and the meaning they make of that experience" (Seidman, 2006, p. 24).

Seidman (2006, p. 15) points out that the word “interviewing” covers a wide range of practices, from tightly structured, survey interviews with preset, standardized, normally closed questions to open-ended, apparently unstructured, anthropological interviews that seem like friendly conversations” (p. 15). This process can be fraught with peril (Chase, 2003, p. 273-274) because reports tend to be elicited by interviews rather than stories, whereby emotions are left out as chronological factoids are left in the transcribed text. Chase points out that in one particular study, she asked an interviewee five separate ways in a three- hour interview for the details of her experience (2003, p. 277). The task of the interviewer “is to listen for gaps, silences and contradictions and ask questions that encourage fuller narration” (p. 289). The extent to which an interviewee’s response represents his or her complete and true belief is an open question however. I, like Padayachee (2012), used Hoepfl’s (1997) justification of the interview guide in a semi-structured interview schedule because I wanted to ensure I collected data on specific topics while having the freedom to remain on a topic or move to another as naturally and gracefully as possible.

Textual Analysis.

Grbich (p. 190) defined content analysis as a “systematic coding and categorizing approach” to “ascertain trends and patterns of words, their relationships and structures” (p. 190). My approach, borrowed from Green (2012), is an enumerative one in which the goal is determination of the frequency and distribution of NOS-related key terms. The absence of textbook terms related to “Science as a Way of Knowing”, and the abundance of terms related to “Science-Technology-Society” for example, would indicate something significant about a textbook’s view of the NOS. In this case, the implication could be that students should be introduced to the sociopolitical context of science rather than the practical, investigative side of science.

The strength of this approach is that quantitative data analysis can be quite persuasive, even if the underlying reasons for the trends, patterns, and structures are elusive. Discovering, for example, that the mean height of a group of women is 155cm and 185cm for a group of men is more compelling than discovering the men are taller than the women, even if we have no explanation available for the difference.

The key to interpreting the data is seeing how much of it is surprising and how much of it is not. As mentioned earlier, I am approaching my analysis as a Bayesian in trying to create probable and plausible interpretations of the phenomena.

This study incorporated both case study and narrative inquiry approaches through the use of semi-structured interviews, and for the printed material data I utilized a textual approach. Now I will address how I selected my data sources.

Data Source Selection

Integrated Resource Package

I chose to work with the grade 9 IRP for a reason that was not particularly compelling: I taught Science 9 many years ago and am familiar with the content material as well as student, parent and teachers' reactions to this material..

As far as the students were concerned, Science 9 was "astronomy", "chemical formulas", "electricity" and "reproduction". Students enjoyed space science because of some of the movies that were available to watch. Teachers would sometimes show and discuss films like *Apollo 13* or *Star Trek* for example, and students enjoyed this. I remember my unit on stars took a turn when a student wondered why "no one studies Chinese constellations". Consequently, I then encouraged students to research cultural views of the night sky.

Students and teachers alike tended not to enjoy the "atoms and elements" portion of the course because there was more emphasis on balancing equations than on hands-on experimentation, which everyone would have loved. "Too much like math" was a common refrain from students.

Electricity was enjoyable to the students as they used batteries and bulbs to explore voltage, current, and parallel versus series circuits. They deemed it less enjoyable when they had to make calculations based on Ohm's law, however.

Students were titillated by the idea of being taught about reproduction but soon became bored by the tedious lab work connected to asexual reproduction of yeast and sexual reproduction at the cellular level. While reproduction connected to previously-taught material like cell-division and the material also formed the foundation for the subsequent studies of evolution and diversity in grade 11, for the most part, the subject matter was not the material students were hoping to study.

I will add here that I will also discuss and analyze the K-7 IRP in this study because it places topics like electricity and space science in a larger curricular context. With this wide view we can get a sense of how concepts are meant to deepen and connect to each other as students move from grade to grade. We can see, for example, that in grade 6, students experience space science within the context of "exploration of extreme environments" before they experience "constellations and the position and movement of stars" in grade 9. The "Topics at a Glance" page (p. 15) is especially interesting where it shows the intended learning outcomes related to "processes and skills of science." The manner in which investigative skills are meant to accumulate is very interesting to contemplate. In grade 6, students are to be proficient in "controlling variables" and "scientific problem solving" which are supportive of SWI and SWT respectively. In grade 9, students need to demonstrate "scientific literacy" and "application of scientific principles" which, although they may seem to be supportive of higher-order NOS goals, are actually more supportive of SBK. Suggested achievement indicators for these two goals include being able to "describe a scientifically literate person" (p. 61) and "giving examples of scientific principles that gave rise to technologies" (p. 61) such as electricity and appliances. Whether teachers and textbooks promote understanding of these goals from an NOS perspective is what I will explore more fully in subsequent sections.

Participant Teachers.

The request for teachers was sent out using the researcher's my social media contacts. The posting mentioned views on the nature of science to be determined in a short interview at the coffee shop of the interviewee's choice. The first four teachers who responded to the request were interviewed. All of those I interviewed were known to me, but I did not know any one particularly well as they were "friends of friends".

*TextBook***.**

The role of the textbook in the classroom has always interested me. I myself have always been resistant to "teaching the book" as I believe that the text ought to be a supplement to the teaching and learning that happens as a result of the interaction between the student, the teacher, and an experience-able phenomenon. For example from

– include the years you taught the course - , I taught a course at UBC called “Physical Science Beyond the Textbook” whose goal was to promote student-centred, experiential teaching.

The textbooks I chose for analysis were two very commonly used in schools. This is because they are recommended in the Learning Resources accompaniment to the IRP (2005) document, having been “tailored” for use in this jurisdiction by consultants and reviewers from B.C. The B.C. Science 9 text for example, is described as a “comprehensive text resource [that] offers a high degree of correlation with the new curriculum. The content is current, accurate, and highly relevant for the students of British Columbia” (p.7). The emphasis on content is quite interesting and appears to imply an emphasis on SBK.

The Science 9 IRP explicitly states four overarching curriculum goals. These are science-technology-society-environment; skills; knowledge; attitudes. When I read through the IRP, the following questions come to mind: Is there an implied view of the nature of science in these goals? Teachers in the public school system come from a variety of backgrounds and have various levels of commitment to science. Do these teachers share a view of the nature of science? Does this view come through in their teaching? Do teachers share the view of the government? How do textbooks portray the nature of science? Do textbooks support the views of teachers and the government? These questions comprise the focus of this study. My hope is that by determining the view of the nature of science held by the government, teachers, and the I can provide a sense of the agreement among the stakeholders in the public education system. I will now discuss the ways in which data will be collected, analyzed, and interpreted.

Data Collection

The three types of data I gathered for this study required three different gathering practices. For the view of the nature of science, as conveyed in the Science 9 Integrated Resource Package (2005) text was extracted from curriculum document. Teachers' views on the nature of science were taken from transcriptions of audio interviews. The view of the nature of science in the recommended textbook B.C. Science Probe 9 by Nelson Publishing (one published in 1995, the other in 2007) was determined via coding and sorting of the content. I will first discuss my data collection including how I prepared for the data collection from the IRP and textbook, and then how I recruited the teachers for interviews.

Data Collection Preparation

IRP and Textbook.

Before the data were collected, I operationally defined my terms and established how I would identify, mark, code, tabulate, and sort occurrences of these terms to ensure I coded the data consistently. To that end, I followed the protocol from Chiappetta, Fillman and Sethna (2004) in their study of textbooks and applied it to curriculum documents and interview transcripts. Padayachee in her 2012 study followed this protocol as well. Then I looked for patterns and trends.

Operational definitions from Chiappetta, Fillman and Sethna (1991, 2004, p. 2-4) and examples are as follows:

1. The knowledge of science: the intent of the text is to present, discuss, or ask the student to recall information, facts, concepts, principles, laws, theories, etc. This type of

text reflects the transmission of scientific or subject matter knowledge, in which the student receives information. It presents information to be learned by the reader.

Textbook material in this category:

a. Presents facts, concepts, principles and laws.

b. Presents hypotheses, theories, and models.

c. Asks students to recall knowledge or information.

2. The investigative nature of science: the intent of the text is to stimulate thinking and doing by asking the student to "find out". This type of text reflects the active aspect of inquiry and learning, which involves the student in the methods and processes of science such as observing, measuring, classifying, inferring, recording data, making calculations, experimenting, etc. The instruction can include paper and pencil as well as hands-on activities.

Textbook material in this category:

a. Requires the student to answer a question through the use of materials.

b. Requires the student to answer a question through the use of charts, tables, etc.

c. Requires the student to make a calculation.

d. Requires the student to reason out an answer.

e. Engages student in a thought experiment or activity.

f. Accesses information from the Internet.

However, if a question simply asks for recall of information or is immediately answered in the text then it comes from Science as a Body of Knowledge.

3. Science as a way of thinking: the intent of the text is to illustrate how science in general or a scientist in particular went about discovering ideas. This aspect of the nature of science represents thinking, reasoning, and reflection where the student is told how the scientific enterprise operates. This type of text also presents the scientific method(s) and problem solving.

Text in this category:

a. Describes how a scientist experimented.
b. Shows the historical development of an idea.
c. Emphasizes the empirical nature and objectivity of science.
d. Illustrates the use of assumptions.
e. Shows how science proceeds by inductive and deductive reasoning.
f. Gives cause and effect relationships.
g. Discusses evidence and proof.
h. Presents the scientific method(s) and problem solving steps.

4. Interaction of science, technology and society. The intent of this type of text is to illustrate the effect or impact of science on society. This aspect of scientific literacy pertains to the application of science and how technology helps or hinders humankind. It involves social issues and careers. Nevertheless, in the presentation of this type of material, the student receives information and generally does not have to find out.

Text in this category:

a. Describes the usefulness of science and technology on society,

b. Stresses the negative effects of science and technology on society,

c. Discusses social issues related to science or technology, and

d. Brings out careers and jobs in scientific and technological fields.

Interviewees.

Four teachers responded to a request put out on Facebook for interviewees. (See Appendix for recruitment form and letter of consent.) The only selection criterion for participation in this study was the teachers must be certified to teach in the Province of British Columbia. Interested candidates were instructed to email me directly to set up an interview date, time and location. The interviews were conducted in quiet public areas suggested by the participants outside of their homes and workplaces. The interview date and time were chosen by the interviewees.

Textbook.

The textbooks chosen for study were: 1) BC Science Probe 9, 1995 and 2) BC Science Probe 9, 2007 and were chosen because they were recommended by the B.C. Ministry of Education's Science 9 Instructional Resource Package (2006). For example, this document states with respect to the BC Science Probe 9 textbook that, "This 587 page comprehensive text extensively covers all aspects of the new Science 9 curriculum".

I have presented how I the process of data collection preparation and will now present how I collected the data for my study.

Data Collection

IRP

Following from Husserl's distinction between "noetic" and noematic" meaning, Ricoeur (1976) distinguishes between "what the utterer means to say" and "what the utterance means" (1976, p. 12). Because a document shows an "intention to communicate" (1976, p. 18), one of the reader's jobs is to "recognize that intention" and we may take what is written at face value. While the IRP document possesses "surplus meaning" as Ricoeur would say, as a public set of expectations for teachers and students, it has an obviously intended meaning and can be taken literally. The assumption here is that extracted elements from this document will adequately represent the government's position. The concern that other elements not extracted for analysis could represent another position is of course a possibility and is a limitation I will address later.

Curriculum documents, as statements of expectation, were interpreted at face value as plainly declarative text. While the IRP itself acknowledges there is room for interpretation by teachers (for example on p. 7 "Achievement indicators are not mandatory; they are provided to assist teachers in assessing…") the "surplus of meaning" is irrelevant because the document of this nature would leave nothing significant unsaid. There is more that is said that can be ignored than there is unsaid that should be discovered, it seems to me.

Consider, for example, the IRP's "overriding goals" (p. 12) as shown in Figure 4:

GOAL 1: Science, technology, society, and the environment (STSE) – Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.

GOAL 2: Skills – Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

GOAL 3: Knowledge – Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

GOAL 4: Attitudes – Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

Figure 3 IRP Goals for Science Education

There is surely no reason to doubt that these goals are not accurately stated and that the other, real goals, remain undeclared and yet are available for us to discover in the text. The challenge for us is to determine whether these goals are consonant with the goals of teachers and textbooks, using the operational definitions from Chiappetta, Fillman and Sethna (1991, 2004).

Teachers.

Conversational analysis is predicated on assumptions such as, “Our exchanges do not consist of a succession of disconnected remarks and would not be rational if they did. They are to some degree at least cooperative efforts and each participant recognizes in them a common purpose or set of purposes or at least a mutually accepted direction” (Grice, 1989, p. 26). Grice goes on to describe “maxims” that assure us conversations are ways of sharing meaning: be informative, be truthful, be relevant and be perspicuous (avoid obscurity and ambiguity, and be brief and orderly, p. 26-27.)

Grbich (2013, p. 230) points out that conversational analysis grew out of ethnomethodological work by Garfinkel (1996) who claimed “ethnomethodology is respecifying Durkheim’s lived, immortal ordinary society, by working out preposterous problems” (p. 5). By this he meant the goal is to understand the order in everyday activities (p. 7). Garfinkel acknowledged that his conversational analysis arose from work done by Schegloff (1986), who maintained that “talk-in-interaction is the primordial site of human sociality” (p. 101).

Interview methodology.

I conducted semi-structured interviews which allowed for flexibility and for the probing of individual experiences without the rigidity of a structured interview. This protocol included a series of standard questions asked of each individual participant and allowed for open-ended questions to explore individual insights, perspectives, and experiences. These interviews were audio recorded and transcribed. Once the transcript of each interview was completed, it was emailed to the participant to ensure it accurately represented the interviewee's views.

Transcription. Transcription of audio records was done without paraphrases. While "ums", "uhs", pauses and false starts were omitted in the transcription process, I made a conscious effort to not add words to the transcript. If researcher bias in any way limited my interpretation of the transcription process, it would only be due to the subtraction of data, which I hope is preferable to any additions based on my own beliefs and point of view.

Textbooks.

My methodological analysis of these textbooks is an amalgam of two approaches. Using Chiappetta, Fillman and Sethna's (1991, 2004) procedures for textbook analysis, I scanned textbooks and noted the presence or absence of content related to the nature of science. Using Green's (2012) approach, I coded these notes using markers and keywords that I could count quantitatively in an *Excel* spreadsheet.

I modified this approach using a procedure developed by Green (2012) where keyword terms are searched in the document and situated in various chunks of content. If, for example, "science as a way of thinking" is presented in a textbook, what content does it appear with?

Textbook Procedure

I read each and every word of the Science 9 textbooks. NOS content was identified, recorded, and annotated. The presence or absence of NOS was identified through the use of markers or keywords or concepts associated with related terms such as science, scientist, research, researcher, law, theory, test, discover, invent, design, experiment, explore. NOS content was classified in accordance with Padayachee's (2012) terminology, into "science as a body of knowledge" (SBK), "science as a way of investigating" (SWI), "science as a way of thinking" (SWT) and "science, technology, and society" (STS).

These data were recorded in an *Excel* spreadsheet along with specific quotations and information on topics being covered. Highlighting all the cells and choosing "data>sort" was a very useful operation because it was easy to (for example) see the relationship between presence of NOS content and subject matter.

Noting and Coding

The phrase "they must find indirect methods to measure" is enough to qualify the whole page as having SWT content on that page, even though this content is surrounded by decontextualized SBK facts such as "There are more than a dozen ways to measure interstellar distances, that is, the distances between stars, within the universe."

Green (2012) himself notes that there may be a perceived lack of precision with this coarse methodology, this approach does provide some eye-opening broad strokes which help establish the quality of the NOS presentation (p. 193-194).

I have presented how I collected the data for my study. I will now address how I analyzed the data.

Data Analysis

The curricular expectations were summarized in a table to illustrate their relevance to the nature of science. Key points were extracted from the interview transcriptions to illustrate the teachers' views of the nature of science. A summary table showing quantitative data on the relative abundance or absence of terms related to the different views of the nature of science was compiled and presented. I will now elaborate on the analysis in the following sections.

Analyzing the IRP.

For reasons I explained earlier, the analysis of the IRP is less of an analysis and more of a re-rendering of the terms in the document to bring them into line with Chiappetta, Fillman and Sethna's (1991) NOS framework. If for example, the IRP presents a prescribed learning outcome such as "perform experiments using the scientific method" (p. 39) and lists suggested achievement indicators such as "formulate an hypothesis", "make a prediction" or "identify controlled versus experimental variables" (p. 39) the analysis is really a determination of how well these indicators fall within one of the four views of the nature of science. As it turns out, these indicators fit quite nicely into "Science as a Way of Investigating". Based on this finding, I suggest that the BC government is indeed interested in having students acquire this view of the nature of science.

Analyzing Teacher Interviews.

I analyzed the interview transcriptions by conducting a narrative inquiry. I began with keyword searches to situate myself in the text. I then extracted statements from the transcriptions that seemed to address particular questions about teachers' views of the NOS, and I pasted these statements into a word file. This file is included in Appendix number please. These extracted statements were then massaged into what I hope is a “thick” (descriptive) narrative summary that it is also a valid interpretation of the interviewee’s view of the nature of science.

Analyzing Textbooks.

The task of analyzing the textbooks is slightly different from the task of analyzing the IRP. Like the IRP, the terms in the text needed to be re-rendered according to Chiappetta, Fillman and Sethna (1991; 2004). Where the analysis of the IRP simply involved determining the Ministry of Education’s view, the analysis of the textbooks had to determine the extent to which important material was adequately dealt with in the text: if the IRP were to declare “students should be able to describe matter” then the task would be to determine a number of key terms such as “mass”, “volume” and “atoms” to search for and count in the document before judging whether or not that would help a student meet curricular expectations.

Following Green (2012), quantitative measures were used to analyze the textbooks. I determined the percent of NOS content relative to the total content in the textbook’s main sections. This measures emphasis given to including content that addresses NOS in the textbook. I looked at the greatest number of consecutive pages without NOS content. If NOS content and issues did not appear in large blocks of the text, readers could assume they were of little relevance. I also looked at the distribution of NOS content relative to the other content in the book to determine if NOS content was being associated with particular subjects.

Following Green's (2012, p. 194) quantitative analytics, I measured:

1) Percent of NOS content in the textbook. This measures emphasis given to including content that addresses environment-economy linkages/ecological sustainability in the textbook. Content that is frequently encountered, is likely to be perceived as important.
2) Greatest number of consecutive pages with "merely" SBK content. If references to SWI, SWT or STS do not appear in large blocks of the text, students may well assume they are of little relevance for understanding science.

Validity of the Study

In the research, I employed triangulation (Mathison, 1988) of multiple data sources to increase the creditability and validity of the results. In accord with Gadamer's (1994) recommendation, the goal is not amassing verified knowledge (pxxi). Rather it is the use of a "hermeneutic circle" (1976, p. 266) that is, an iterative "spiral of inquiry" that focuses the interpreter's investigation onto details both specific and general whose goal is to avoid misunderstanding.

Throughout the study, I exercised my independent status as researcher and not that of an employee of the Ministry of Education nor Nelson Publishing. It was made clear to all participants in the consent document (Appendix A) that they had the right to withdraw from the study at any time.

Limitations

The greatest limitation of the study will be reliance on interpretation in the determination of the applicability of terms to a given utterance.

Consider the following three statements made on three successive pages in a section on the colour of stars in the Nelson Science 9 textbook (1995):

- "Scientists have found when a chemical is heated…" (p. 310)
- "Astronomers have found one of the best ways" (p. 311)
- "Astronomers call the brightness of a star its magnitude" (p. 312)

The first statement links empirical claims to illustrate a way of knowing, The second statement makes a value judgment, and the third is a flat declaration. The first statement shows how astronomers infer the chemical makeup of a star from chemicals they have experimented with on earth. This illustrates the NOS. The second statement simply declares a technique scientists have found works which also illustrates the NOS although not as strongly as the first statement. The third statement simply states what scientists believe and doesn't promote the nature of science at all.

Summary of the Chapter

This study uses a hermeneutical approach to a case study with a study structure involving both case study and narrative inquiry approaches. Both quantitative and qualitative analyses were applied because, as Mathison (1988) points out, "good research practice obligates the researcher to triangulate, that is, to use multiple methods, data sources, and researchers to enhance the validity of research findings" (p. 13). This study attempts to look at the nature of science from three perspectives in the generation of three data sets to determine the views of the nature of science of teacher in the IRP, and in the selected textbook.

CHAPTER 4: Data and Analysis

In the previous chapters I provided background information pertinent to this study and laid out a plan for investigating views of the nature of science in the IRP and from teachers and a textbook. Through the use of Padayachee's (2012) terminology, I will present the data as derived from the IRP, the teachers, and the textbook. I will now present the collected data on the views on the nature of science in the Science 9 IRP.

Data – Views on the Nature of Science in the IRP

The BC Science 9 IRP curriculum lists 23 prescribed learning outcomes (PLOs) in a table on p. 30. Each of the PLO's is prefaced with "It is expected that students will:" I include the PLO's here along with their code according to the NOS coding protocol of Chiappetta, Fillman and Sethna, (1991; 2004, p. 2-4). I am using Padayachee's (2012) terminology, "science as a body of knowledge" (SBK), "science as a way of investigating" (SWI), "science as a way of thinking" (SWT) and "science, technology and society" (STS). I will now present the data collected on the nature of science in the IRP, discuss the data and draw some conclusions based on the data.

Figure 5 presents the Prescribed Learning Outcomes (PLO) from the Integrated Resource Package (IRP) (p.39-40) and what it is expected the students will be able to do in the Process of Science and the connection to the Nature of Science (NOS).

PLO A1 demonstrate safe procedures→ SWI
PLO A2 perform experiments using the scientific method →SWI
PLO A3 represent and interpret information in graphic form → SWI
PLO A4 demonstrate scientific literacy →SWT
PLO A5 demonstrate ethical, responsible, cooperative behaviour →SWT
PLO A6 describe the relationship between scientific principles and technology → STS
PLO A7 demonstrate competence in the use of technologies specific to investigative procedures and research → STS

Figure 4 Process of Science Connection to the NOS

Figure 6 presents the Prescribed Learning Outcomes (PLO) from the Integrated Resource Package (IRP) (p. 42) and what it is expected the students will be able to do in Life Science: Reproduction and the connection to the Nature of Science (NOS).

PLO B1 explain the process of cell division → SBK
PLO B1 relate the processes of cell division and emerging reproductive technologies to embryonic development → SBK
PLO B3 compare sexual and asexual reproduction in terms of advantages and disadvantages → SBK

Figure 5 Life Science: Reproduction Connection to the NOS

Figure 7 presents the Prescribed Learning Outcomes (PLO) from the Integrated Resource Package (IRP) (p. 46) and what it is expected the students will be able to do Physical Science: Atoms, Elements, and Compounds and the connection to the Nature of Science (NOS).

PLO C1 use modern atomic theory to describe the structure and components of atoms and molecules → SBK PLO C2 use the periodic table to compare the characteristics and atomic structure of elements → SBK PLO C3 write and interpret chemical symbols of elements and formulae of ionic compounds → SBK PLO C4 describe changes in the properties of matter → SBK

Figure 6 Physical Science: Atoms, Elements, and Compounds Connection to the NOS

Figure 8 presents the Prescribed Learning Outcomes (PLO) from the Integrated Resource Package (IRP) (p. 46) and what it is expected the students will be able to do in Physical Science: Characteristics of Electricity and the connection to the Nature of Science (NOS).

PLO C5 explain the production, transfer, and interaction of static electrical charges in various materials → SBK PLO C6 explain how electric current results from separation of charge and the movement of electrons → SBK PLO C7 compare series and parallel circuits involving varying resistances, voltages, and currents → SBK PLO C8 relate electrical energy to power consumption → SBK

Figure 7 Physical Science: Characteristics of Electricity Connection to the NOS

Figure 9 presents the Prescribed Learning Outcomes (PLO) from the Integrated Resource Package (IRP) (p. 48-49) and what it is expected the students will be able to do in Earth and Space Science: Space Exploration and the connection to the Nature of Science (NOS).

PLO D1 explain how a variety of technologies have advanced understanding of the universe and solar system →STS

PLO D2 describe the major components and characteristics of the universe and solar system → SBK

PLO D3 describe traditional perspectives of a range of Aboriginal peoples in BC on the relationship between the Earth and celestial bodies →STS

PLO D4 explain astronomical phenomena with reference to the Earth/moon system → SBK

PLO D5 analyse the implications of space travel →STS

Figure 8 Earth and Space Science: Space Exploration Connection to the NOS

Conclusions: the View of the Nature of Science in the BC Science 9 IRP

There are 23 major prescribed learning outcomes listed for the grade 9 science IRP. Thirteen of those 23 are the expected learning outcomes such as "use modern atomic theory to describe the structure and components of atoms and molecules" and "explain astronomical phenomena with reference to the Earth/moon system". These outcomes appear to fall squarely into the designation SBK. Three PLOs promote SWI, two PLOs promote SWT, and five PLOs promote STS. While the IRPs (Science 9) do not explicitly present a view of the NOS, these documents do very clearly declare the government's curricular expectations of – include what those are based on the data.

Applying the operational definitions of views of the NOS (from Chiappetta, Fillman and Sethna, 1991; 2004, p. 2-4) to the IRP, there appears to be a significant overlap between the IRP's four goals for scientific literacy (STSE, skills, knowledge, attitudes) and the four views of the nature of science (STS, SWI, SBK, SWT): the IRP declares that science as a way of investigating, as a way of thinking, as a body of knowledge and in the context of technology-society are all important parts of science education in the province of British Columbia.

If one looks however for the nine criteria for defining the nature of science used by Niaz and Maza (2011), one finds they are not specifically addressed in the science 9 (or K-7) IRP. For example, Niaz and Maza point out that there is a distinction that ought to be made between theories and laws and nowhere in the IRP curriculum can this distinction be found. A keyword search for "theory" in the K-7 IRP yields references to the "theory of divine intervention" and to the "particle theory" for example and not to "observation is theory-laden" or "theories are tentative." Similarly, searching in the Science 9 IRP yields references to "atomic theory", "kinetic molecular theory" and "tectonic theory".

Thus it seems that the emphasis in the IRP is on SBK, SWI with nods to STS and very little to SWT. This seems to suggest that the government believes students should begin their scientific apprenticeship with simple, lower-level understandings. This may in fact be developmentally appropriate. It may not make sense to familiarize young people with the role science has in modern society before they have any sense of what science is.

What is not particularly clear in the grade 9 Science IRP is the rationale for the presence or absence of particular PLOs. The IRP states (p.13) that, “students in Science 8 to 10 are building on skills and processes that they have been developing from Kindergarten through to Grade 7. These include skills such as observing, classifying, predicting, inferring, and hypothesizing. Scientific reasoning, critical thinking, and decision making are also part of that foundation.” We do not know if these PLOs are developmentally appropriate because they are connected to cognitive milestones. We also do not know if the Ministry is working from the goals it has for adults and reverse engineering an educative process for getting students to those goals. The K-7 IRP does not offer any additional insight. The progression of learning outcomes does indeed seem clearly sequential. It seems reasonable to assume that children should be observing and classifying as they are directed to do in kindergarten before they are designing experiments and fair testing as they are expected to do in grade 5. Whether or not this sequence is developmentally appropriate, it appears there is meant to be an implicit evolution of learners’ scientific thinking; they begin by absorbing science knowledge and then are directed to investigate, after which, in their teen years, they reflect on their thinking and the impact of science on other aspects on modern life.

Data – Teachers

The four teachers interviewed were all experienced teachers with 10, 12, 19 and 24 years teaching experience. All reported that they enjoyed their work with their students and their colleagues. Three of the four had science backgrounds in botany, geology and chemistry, respectively. One teacher did not have a science background.

The teachers' enjoyment of science teaching is derived from the subject itself and from the opportunities that present themselves to take the teaching where students would like it to go. As NG explained, "So much more is coming from the kids, and I'm hearing more about what their knowledge already is, and they're taking it in directions I hadn't thought of" (personal communication, Feb 8, 2015). There seemed to be willingness on the part of the teachers to let their lesson planning be determined by students' interests. Student-centred teaching certainly seemed to be a priority although this can be counteracted by the reality that there are other priorities acting in an equal and opposite directions.

Conversely, the challenges in the teaching of science include the need to "coax people into trying to do stuff" (NN, personal communication, Feb 2, 2015) and the intensive labour required because "you have to prepare all your own materials, set up your labs, you have to clean up, as opposed to just coming into your classroom and just talking about a topic like in social studies but with interactive activities there's a lot more materials that you're using" (MB, personal communication, Feb 5, 2015). Significantly, MM pointed out that "one of the things I find most frustrating is how so many publishers create a textbook completely based on the curriculum set by the Ministry and teachers are completely focused on teaching that program" (personal communication, Feb 16, 2015). Most significantly, when asked "So in terms of expectations about delivering a certain amount of content is the chief expectation having people ready for the provincial exam? Is that the number one concern, do you think?" MB replied, "That's the number one concern for the students because they feel like they want a certain grade to get into certain programs and there are such high expectations for that so their only goal was coming out with the highest result possible. That meant covering material." Thus opportunities for unstructured exploration and discovery can be limited by the need to "get through material" by presenting it for students to consume.

When asked about the skills they as teachers were attempting to impart to students, the interviewees provided some very interesting answers. NN pointed out, " I guess the one skill or maybe it's a habit of mind that you might need to persist a little bit through some discomfort in learning something." MM thought it is important to know "how to properly formulate a question." MB mentioned that " an important skill is being able to determine how to approach problems to solve problems and then how can they realistically go about using practical skills to go about solving the problem." I was expecting an emphasis on specific scientific skills like predicting or fair testing but the teachers seemed to be working toward higher-order thinking skills or habits of mind that are commonly thought of as inherent personality traits, not impartible skills. Certainly there is more of a connection to science as a way of thinking than to science as a way of investigating.

On the role of the textbook in classroom teaching, the interviewer was very surprised by the teachers' responses. While NN believed, "it's good to have an artifact in front of you that everyone can reference and have a common understanding around so if you don't understand, you can go back," MB declared that "we don't use textbooks in our class." NG said "we haven't had textbooks in forever. I have no idea the last time we used textbooks." Describing the typical view of the textbook, MM maintained that, "it provides your basal information for the curriculum that you'd be teaching…. it's a safe resource." MM continues, describing the value of the textbook to an inexperienced teacher that “They know it’s covering the curriculum. They know if they just do that the learning outcomes are going to be met.” When asked, “What do you use a textbook for?” NN replied, “Well for key vocabulary definitely.” It appears however, that for many teachers, textbooks are not being used to provide that basal information, the internet is. MB declared “we … try and use the library when we can and primarily we do a lot of computer-based research.” It appears that the textbook is an important piece of science teaching for an inexperienced teacher and that it becomes less important as the teacher gains experience with the subject matter and instructional strategies that help convey it.

Turning to teachers’ views of the nature of science, it was interesting to see how teachers understood the pedagogical implications of each of the views. When asked about science as a body of knowledge, for example, NN opined, “That would be the transmission model. That you as the science teacher, you have the body of knowledge, and we’re just gonna move it and we’re not gonna construct it together.” NG ventured, “I like that because it’s easy to teach.” MM thought “for teachers without a science background it would be intimidating to walk into because it’s a body of knowledge that they don’t have in their own backpack.” MB saw other implications, claiming, “That’s what I think a lot of the parents would consider, the students would consider that as well that science is a body of knowledge and there’s a certain amount of material, here’s my book, that’s the material, there’s what I have to know about science, or the chemistry or the biology.” It is quite clear to me from the teachers’ comments that the promotion of science as a body of knowledge is not desirable because it is not reflective of student interests or needs. The learner is reduced to a spectator, a historian in the construction, not even a spectator in that construction, let alone a participant.

When I asked the participants, “How do you/would you promote science as investigation?” two teachers became quite animated. NN, for example, declared, “Well I promote it right now, like what we are doing right now, is promoting the observable.” NN went further and said, “we just talked about what’s Google-able and what is investigateable, what we can do on your desk and you can show everyone what you are doing.” MB’s view of SWI can be determined easily: “Quite often we start off with that. Almost the first day of lessons… the scientific method is a great way to start off our junior science, you know, let’s explore which brand of cereal has the most iron in it…. Yeah, not just regurgitate a bunch of facts but come to a problem or an idea or a question with an idea of how to explore that. And very basically, by going by the scientific method. This happened, so how can I explain that? Or how could I test that out?” NG, however, was not clear how to promote SWI, until she participated in inquiry-based workshops, “previous to that, no, they didn’t get to investigate, at all. Not nearly enough…. I couldn’t figure out how before I did a few inquiry workshops and now I’m Oh! This is how I can get the kids to investigate more. How to investigate and still have it going somewhere in particular that’s gonna meet particular objectives.” MM had a problem with the way investigation is promoted in textbooks, claiming, “the investigation either comes at the end of the body of knowledge section, like here’s the facts, let’s investigate this thing but the investigations seem really hokey like they’ve seen them before on Saturday morning science shows so they already know what the answer’s gonna be ….”.

Shifting gears, the interviews turned to "How valuable do you think science is as a way of thinking or as a way of knowing?" NN reported that, "I think that's something that would be important to me, a solid basis in science makes you a better citizen." MB believed, "it's extremely valuable because I think a lot of the innovators are those people who are able to think outside of the box and are able to think like scientists." NG claimed, "I've never thought about it before…. They would be questioning, they would be thorough, they would test things, they would want to find out… collaborative comes to mind… they would want to find out what other people are learning and thinking and compare." When asked how they promoted SWT, teachers made suggestions similar to MM's: "I think just having the kids go through understanding the scientific process. Being able to come up with a hypothesis, gather the materials, walk through the procedures, what are the results, what can we say about the results." MB made some concrete suggestions, saying, "More of those science challenges, paper has only this much strength, give you something, let's see where you go with it…. More in terms of fascination and interest is the way we could promote it."

The interaction of science, technology, and society was a fascinating topic to explore because there were some very divergent understandings at work. NN believed that, "it's crucial that kids are able to negotiate that scientific information easily and well…" MB made a similar claim, stating, "Technology is something that we use within our society a lot and we take advantage of to make our life better or easier or more efficient and a lot of times there's a connection to science through research…. Definitely should not be taught as this is right and this is wrong but as a valuable way of exploring ethical issues and making your own decision which is the way we should be exploring at school.” Related to this was MM’s position; “I bring up scientific achievements. I try and find things that young kids have done. And talk to them like, these are kids that are a little bit older than you. They’re really not that old. But this is something that I think you should know about.” NG, on the other hand, stated that this is not something that would be relevant for grade one students.

When it came time to rank the views of the nature of science in terms of importance, MB ventured that “I’d say personally science as a way of explaining and exploring and researching topics is the way I would prefer to do it.” NN put it this way: “Well I think for your average kid who’s gonna be the average contributing citizen, it would be ways of knowing, number one. The interaction with society, number two. And then the knowledge and then the skills.”

NG and I wondered if the ranking of these views might correlate to a progression of understandings. Science teaching begins with science as a body of knowledge, that is, fundamental understanding about the natural world, such as the separation of “animals” into “mammals”, “birds”, and “fish.” After children have acquired fundamental concepts, perhaps we start to add additional complicating abstractions, such as when we talk about what classifying is and how cones, leaves, and rocks could be coded in a key in the same manner as animals. Perhaps once learners are familiar with investigation, they are able to consider social factors like the importance of technology; for example, the impact of the telescope to the study of space. Finally, perhaps the possibility of metacognition allows learners the possibility of connecting their own thinking with that of past and more recent scientific thinkers.

At this point we turned to what the teachers believed is emphasized in classroom teaching. It was very clear to me what their expectations were: as MB put it, "Unfortunately, it's a body of knowledge is gonna be number one or two because the end goal is kids looking for university and they want a high grade and the content is gonna get them there." NN put it this way: "they are getting knowledge first. Because for elementary, that's the easiest thing to just transmit. I can transmit information. And then the skills. But maybe I'm not as good at teaching the skills." The expectation, perhaps not necessarily coming from textbooks or curriculum documents, is that science teaching involves providing information for learners to *know* first and foremost. The most determined adherents to this idea may be parents whose interest is in insuring their children have whatever universities expect applicants should have.

NN made the interesting point however that teachers transmit more than information, they also model behaviour. Moreover, they teach much like they were taught. "I intended to be a science educator when I went back to school because that had been my own experience in elementary school." She continues, "We had a teacher specialist in elementary school who was fantastic, Mrs. Wilson, I loved her, she was great at teaching science, and so I just assumed that that role was out there. It's not but I've sort of made it my role at the school where I teach."

The issue of support was an interesting one. "What sort of support do you need to teach like you want to?" MB put it very well saying, "I think what we don't need is somebody giving us a book saying, here's how to do it, it's more a chance to collaborate with colleagues and Ministry officials who have ideas and other professionals within education and give us opportunities to get together and not as a single pro d day (professional development day) but as a learning team that meets together over a year once every two months and having that opportunity to get together to develop some resources together and share with your colleagues around the province or the country." NG agreed claiming, "we need more workshops and more information. And I just need to experiment more because it's a whole different way of teaching and I'm going into a place where I don't know for sure where this is gonna go. Experimenting with discomfort."

Conclusions: The Views of the NOS in the Teachers

The four interviewees were experienced teachers with 10, 12, 19 and 24 years of teaching experience. Only one taught science as a subject matter expert. One was a learning assistance teacher with a science background, and one was a grade 4 teacher with a science background. The most experienced teacher taught grade 1 and did not have a science background.

Collectively, what the teachers liked about teaching science was the opportunity to explore and investigate by asking questions. The teachers' shared enjoyment of teaching science is generally consistent with the skills they thought were important to cultivate which were persistence and wonder as habits of mind. This is also consistent with science as a way of knowing which they generally were well-disposed toward. NN claimed that "I think that's something that would be important to me, a solid basis in science makes you a better citizen."

They generally approved of and tried to meet the curricular expectations connected to SWI, accomplished by "promoting the observable" as NN noted.

Interestingly, all the teachers were well-disposed toward inquiry or to incorporating more inquiry into the classrooms. They all saw the value of hands-on activities in science education.

Based on the interview data, I suggest that the teachers seemed to place very little emphasis on STS in their teaching. Two claimed to make reference to technology and its role in modern life. One teacher in particular made a point of guiding students toward technological problem solving. None of the teachers addressed the social implications of science or encouraged debate about issues that have both scientific and ethical components (such as whether or not to vaccinate children).

Science as a body of knowledge was somewhat disparaged by the teachers interviewed for this study. NN stated, "That would be the transmission model. That you as the science teacher, you have the body of knowledge, I don't, and we're just gonna move it and we're not gonna construct it together." However, NG, the grade one teacher who did have a science background, stated plainly that she liked this conception because it made science easier to teach and assess.

To me it seems clear that teachers are of two minds about the NOS. While they understood and appreciated the need, interest, and value in promoting science as a skills-based way of investigating and way of knowing, they felt shackled to the instructional implications of the view that science is a body of knowledge that must be acquired for use in subsequent schooling. The teachers maintained that students' possession of this body of knowledge was easy to assess.

Significantly, the participating teachers were of one mind about the need for a textbook; they do not need it. None of the teachers relied on the Ministry recommended texts in their teaching. This does not mean that they were satisfied their teaching was exemplary. On the contrary, they were interested in a more collaborative kind of support such as workshop-based professional development rather than support via a textbook or a resource binder.

I will now present the data collected on the views of the nature of science in Science Probe 9, discuss the data, and draw some conclusions based on that data. A summary of findings is shown in Figure 10. As documented, STS comprises a small fraction of these textbook content. That is, less than 5% of the material in all Science Probe textbooks make reference to STS.

Data – Nature of Science in Science Probe 9

SP9 1995	# pages	% of book	Topics
STS	18	3%	STS
SWI	76	14%	process skills
			chemistry; matter, atoms, earth
SWT	94	17%	science: tectonics, earthquakes
SBK	352	65%	chemistry, human body, health
total	540	100	
SBK only	15, 15, 16, 16		

SP9 2007	# pages	% of book	
STS	19	3%	Astonomy
SWI	130	23%	Nature of Scientific Inquiry is SWI
SWT	49	9%	Astronomy
SBK	376	66%	reproduction, chemistry, electricity
total	574	100	
SBK only	35, 14, 11, 10		

Figure 9 Summary of Textbook Data

SWI appears on 14% and 23% of the pages of these textbooks and is usually clustered in a section on skills.

SWT appears on 17% and 9% of the pages and is usually associated with Earth Science and Space Science. These topics are presented in the text not only as facts and concepts to be understood but also as examples of how understandings arise and change. SBK comprises the bulk of these textbooks in the form of declarative statements without reference to historical context, controversy, creativity, imagination, or discovery. Life science content is consistently presented in this way, unlike Earth Science and Space Science as mentioned above. Moreover, textbooks frequently feature sequences of up to 15 consecutive pages of SBK content without any STS, SWI, or SWT references.

Analysis of the Nature of Science in Science Probe 9

I found the determination of the presence or absence of NOS content on a page to be a very interesting exercise. Consider the following three statements made on three successive pages in a section on the colour of stars in the Science 9 (1995) book:

> "Scientists have found when a chemical is heated…" (p310)
>
> "Astronomers have found one of the best ways" (p311)
>
> "Astronomers call the brightness of a star its magnitude" (p312)
>
> “Stars have a life cycle...” (2007 ed, 9425)

The first statement links empirical claims to illustrate a way of knowing. The second makes a value judgment about a form of knowing, and the third and fourth statement are fixed declarations without any context. The first statement shows how astronomers infer the chemical makeup of a star from chemicals they experimented with on earth. This makes a point not only about star composition but also how we know it. The second statement simply declares a technique scientists found that works and does something similar. The third and fourth statements simply state what scientists believe as a component piece of science as a body of knowledge. Importantly, statements three and four are equivalent because even though statement four lacks the qualifier "Astronomers think that…" at the beginning, this is implied throughout the whole book, rendering ALL the decontextualized information "SBK" if it is not marked at SWI, SWT, STS.

It is very interesting to note the subjects where the historical context and where contributions from individual people are identified. Astronomy is always presented this way in the textbook reviewed for this study. Chemistry, whether its Mendeleev and his index cards or the atomic theory from Democritus to Dalton is similarly presented. Conversely, life sciences are not presented in the text in this way. In the 2007 Science Probe text for example, we learn about the relationship between DNA and proteins but there is nothing about Watson and Crick the discoverers of DNA, for example.

It is abundantly clear that of the four categories of messaging about the Nature of Science, Science as a Body of Knowledge comprises the vast majority of those messages. The bulk of the textbook is simply information presented without reference to origin, context, controversy, creativity or imagination.

SWT content appears to be associated with some subjects more than others. Certainly it appears in "Science and You" where references to how scientists work are explicitly made so readers could imitate this work. SWT content figures prominently in "Changes in Matter", "Drifting Continents", "Solar System", "The Stars." It does not appear at all in any of the biological topics "Nutrition", "Body Systems", "Fitness and Health", "Fishing". There is virtually nothing in "Energy" or "Simple Machines."

Science as a Way of Investigating is relegated to a separate section devoted to the skills scientists possess and Science-Technology-Society is usually addressed with respect to the technology associated with space exploration or the chemistry of hairstyling.

Conclusion: The Nature of Science in Science Probe 9

Most of the content in the examined textbooks is decontextualized, declarative of science as a body of knowledge. Open one of these books at random, close your eyes and point to a sentence, and it will most likely be something like, "Cepheid variable stars and red shift are the two most useful techniques for measuring distances in space"" (BC Science Probe 9, 2007, p. 421). This sentence is presented in a section devoted to the difficulties of measuring space since "Scientists cannot measure the distance to a star directly by laying down metre sticks or by driving to it" (p. 420).

That said, the Nature of Science is a significant part of the Science Probe textbooks. There is, for example in the Science Probe 9 text, a four page section devoted to "Doing Science: Experimenting" (p. 24-28) that presents information on "the two main types of tests that may or may not support an answer: controlled experiments and correlational studies."

The distribution of NOS content was patchy however. SWI, SWT and STS content tends to be was concentrated in early chapters on what science is and how it gets done and is sprinkled through chapters on chemistry, earth science, and astronomy. The content on the human body was delivered in a decontextualized, declarative manner without reference to how any of that knowledge was generated, by whom or when. This is simply science as a body of knowledge.

In contrast, the section on earth science made claims such as "Scientists estimate …magnetic reversals have occurred more than 170 times" which could just as easily have been rendered as “Magnetic reversals have occurred more than 170 times…". The addition of “Scientists estimate” at the beginning of a claim gives the content more of an NOS perspective.

I have examined the official expectations in the B.C. Ministry of Education’s curriculum documents. We have seen that these documents reveal that the Ministry is interested in promoting science as a way of thinking, science as a way of investigating, science-technology-society, and science as a body of knowledge. I have summarized the teachers’ views of the nature of science and presented their interest in science as a way of investigating and science as a way of thinking. We have also learned teachers seem less committed to science-technology-society and science as a body of knowledge, although they understand the forces at work. I have analyzed two textbooks recommended by the Ministry’s curriculum documents and pointed out their tendency to emphasize science as a body of knowledge and science as a way of investigating. I will turn now to an examination of the effective implications of these views have on each other.

CHAPTER 5: Discussion Of Results

This chapter presents a discussion of the study's results. One of the teachers interviewed for this study made a comment that I will use as a reference point for this discussion. When asked about incorporating open-ended, hands-on, student-centred teaching into her practice, she conceded she was "experimenting more… experimenting with discomfort." I would like to proceed by following up "experimenting with discomfort" with following three themes: (1) "experientia", the relationship between experiment, experience and expertise; (2) expectations that exist in the teaching of science; and (3) edification, how can we move forward in comfort, rather than discomfort, on the basis of intersubjective agreement?

"Experientia"

As I mentioned previously in chapter 2, Dewey (1916, p. 121) believed that thinking, inquiring, and investigating were all closely related. He was an ardent proponent of "experience," a word that comes from the Latin "experientia" which denotes trial, proof, or experiment (Jay, 2005, p. 10). Jay points out that "experience" is both a verb and a noun; it is the act of acquiring something and can be the thing itself (2005, p. 12). And what is the "thing" to be acquired?

Dewey answers this by declaring that the "traditional view of education involves the transmission of bodies of information and skills that have been worked out in the past" (1938/1963, p. 17). A criticism of this view is that the scheme is one of "imposition from above and outside" (1938/1963, p. 18). It also implies a deficiency or gap that must be overcome (1938/1963, p. 19), and it "forbids active participation in the development of what is taught" (1938/1963, p. 19).

Much more palatable is the progressive relationship between personal experience and education (1938/1963, p. 20-21). "Experience and education can not be directly equated" (1938/1963, p. 25). Experiences should be agreeable, interesting, and linked cumulatively (1938/1963, p. 26). The effect of an experience is that it promotes future experiences (1938/1963, p. 27). Every experience borrows from those that came before and lends to those come after (1938/1963, p. 35). Guidance by the teacher amounts to the provision of a continuity of experience (1938/1963, p. 28). Guidance also involves interaction between external, "objective" expectations and the internal needs and interests of the learner (1938/1963, p. 42.)

Dewey's claim (1938/1963, p. 47) that the future must be taken into account at every stage of the educational process is a defining characteristic of American Pragmatism. It is not that everything taught should be of some value in the future but that "extracting the full meaning of present experience prepares us to do the same thing in the future" (1938/1963, p. 49). This is best achieved by having "study derived from materials within the scope of everyday life-experience" (1938/1963, p. 73).

This examination of experience involves observation, prior knowledge and judgement (1938/1963, p. 69). "Growth depends upon the presence of difficulty to be overcome by the exercise of intelligence" (1938/1963, p. 79). Guidance involves assisting in the identification of a problem relative to a present experience, gauging the capacity of the learner and arousing in the learner an active quest for information and production of new ideas" (1938/1963, p. 79).

The ultimate goal of experience is growth because “growth itself is the only moral end” (in Rorty, 1999, p. 29). Dewey also claims, “the aim of education is to enable individuals to continue their education—or that the object and reward of learning is continued capacity for growth…we are not concerned, therefore, with finding an end outside of the educative process to which education is subordinate” (p. 60).

Dewey believed that science education is supportive of personal growth. Dewey declares that the beauty of science is the “systematic utilization of the scientific method as the pattern and ideal of intelligent exploration and exploitation of the potentialities inherent in experience” (1938/1963, p. 86). Recall that he maintained “the function which science has to perform in the curriculum is that which it has performed for the race: emancipation from local and temporary incidents of experience, and the opening of intellectual vistas unobscured by the accidents of personal habit and predilection” (1916, p. 186).

Rorty claimed (1999, pp. 114-115) that education involves two simultaneously competing and imperatives: an enculturation, wherein students are required to converge onto necessary social understandings and an individualization, whereby they diverge from those understandings according to their personal needs and interests. Doll pointed out the challenge is to is “to devise an educational methodology which is based on the individual’s own assimilation of experience but which will not prescribe what those experiences are to be” (Truett, 2012, p. XX).

How then to specify experiences? Montaigne maintained one learns dancing by dancing and playing the lute by playing the lute. Moreover, “one learns judging and speaking well by exercising us in judging and speaking well” (1987, p. 171). Enter

Schwab who, according to Doll, “would like to make all education—especially formal schooling—practical in the sense of dealing with these particular and personal states of affairs” (Truett, 2012, p. 64). Schwab advocates “putting the student in very direct contact with the problems and practices within a field” (Truett, 2012, p. 64). With Schwab there is a definite emphasis on education (schooling) as the development of experience, not as the place or means by which information is transferred from one to another. In fact, information itself is but a means to practical decision making; and hence, education should be so structured that decisions can grow from personal and practical experiences (Truett, 2012, pp. 64-65).

The important thing for teachers to remember is that however much we want to “give an experience” to our students, the best we can do is help students “craft an experience” (Truett, 2012, p. 98). This “crafting” involves students summoning their own creative energy and thus helping direct the experience to “its own end” (Truett, 2012, p. 99).

Expectations and Enculturation

Returning to the notion introduced by Rorty (1999, pp. 114-115) that education involves an enculturation, that is, convergence onto necessary social understandings, I will now address the expectations surrounding the enculturation into the world of scientifically knowledgeable adults. This second theme in science teaching involves what students are required to actually do and understand. I will begin by describing the expectations laid out in the IRP. I will then turn to the needs and interests of teachers before I discuss the support they receive from recommended textbooks.

Science 9 IRP

The Science 9 IRP lists 23 major prescribed learning outcomes (PLOs) that are "legally required content standards" (Science 9, p.7). Thirteen of those 23 appear to fall squarely within the designation SBK. Three PLOs promote SWI, two PLOs promote SWT, and five PLOs promote STS. However the nine criteria for defining the nature of science used by Niaz and Maza (2011) are not part of the B.C. Government's expectations for science teaching. Although, for example, academic science educators may deem understanding the distinction between laws and theories an important part of understanding the nature of science and being scientifically literate, the government does not require students to know this distinction.

The IRP does expect students to know the collection of facts and concepts that correspond to SBK. The IRP also expects students to be able to demonstrate understanding of science process skills which are SWI. In other words, the applications of science/ process skills prescribed in the IRP match the operational definition of SWI (Chiappetta, Fillman & Sethna, 1991, 2004, pp. 2-4): observing, measuring, classifying, inferring, recording data, making calculations, experimenting.

Thus it seems that the emphasis in the IRP is on SBK and SWI with nods to STS and very little to SWT. This seems to suggest that the government believes students approaching the end of their engagement with formal schooling are well enough served by simple, lower-level understandings. This is interesting given the subsequent thinking of – tell us what that was - the Ministry has applied to curricular expectations.

B.C.'s Education Plan (2012) suggests the "curriculum will be redesigned to reflect the core competencies, skills, and knowledge that students need to succeed in the

21st century" by describing "fewer but higher level outcomes will create time to allow deeper learning and understanding" (p. 5). Deeper learning and understanding surely refers to process skills as well as content knowledge, as prescribed in the K-7 IRP, wherein it was declared there should be "integration of science processes through all grades" (K-7, p. 7). Two such skills, prescribed for grade 6, are "manipulate and control a number of variables in an experiment" and "apply solutions to a technical problem (e.g., malfunctioning electrical circuit)." These are in indeed higher order thinking skills connected to science as a way of investigating and science as a way of knowing and the extent to which this thinking is supported is what we turn to next.

The draft Science 9 curriculum (as of August, 2015) states some very interesting intentions. "While the Science curriculum has always been conceptual, the new curriculum highlights fewer concepts to allow for substantial inquiry time." Furthermore, "the level of facts and details in the new curriculum is left open to individual customization by the educator, allowing more time for in-depth exploration by students." These directives would surely be welcomed by the teachers I interviewed who expressed hopes that this would be the case with the draft curriculum.

The draft curriculum also states, "The familiar skills and processes of science remain an integral part of the Science curriculum and reside in the curricular competencies" (p.2 of the pdf of the August 2015 draft document). Previously these skills and processes were introduced a few at a time for each year; now they are introduced at kindergarten and grow in sophistication through Grade 10. This is interesting on a number of counts. First, it illustrates a emphasis on SWI. Second, this is a continued emphasis with SWI; in fact the same emphasis shown by the previous curriculum. Third, there is still no justification for this PLO associated with the related grade level.

There is a new overarching justification for the whole science curriculum however. The government's website promoting the draft curriculum states that "Science provides opportunities for us to better understand our natural world. Through science, we ask questions and seek answers to grow our collective scientific knowledge. We continually revise and refine our knowledge as we acquire new evidence. Building on a foundation of respect for evidence, we are aware that our scientific knowledge is influenced by our cultural values and ethics. The Science curriculum enables students to link traditional and contemporary Aboriginal understandings and current scientific knowledge and make meaningful connections to their everyday lives and the world beyond." This suggests that STS and SWT would feature prominently in science teaching, but similarly impotent declarations were made in the past.

The draft curriculum document goes further. "The current focus on competencies highlights the thinking, communication, and social and personal core competencies that students can develop through the new Science curriculum. The curricular competencies within the curriculum articulate the habits of mind of scientists, the attitudes of science students, the skills and processes of science, and the core competencies that help to develop scientifically literate citizens." Of particular interest to this thesis is this notion of "the habits of mind of scientists." The extent to which these habits are introduced to students will of course be determined by the support teachers receive to do so.

One of the teachers, NG, mentioned inquiry and professional development as a means for helping teachers help students develop scientific habits of mind. The draft curriculum website says, “Through the curricular competencies, the Science curriculum gives students the opportunity to develop the skills, processes, attitudes, and scientific habits of mind that allow them to pursue their own inquiries. Linking with the curricular competencies, the content strengthens this approach through a conceptual design that allows substantial time for inquiry.” It appears therefore, that the B.C. Ministry of Education has taken seriously the Deweyan notion that guidance-type teaching involves interaction between external, “objective” expectations and the internal needs and interests of the learner (1938/1963, p. 42). It also appears this new draft curriculum is attempting to add emphasis to STS and SWT goals which were somewhat underemphasized in the 2005 curriculum.

Teachers

Teachers are interested in the promotion of skills with activities but are thwarted by the usual difficulties including lack of time, lack of help, and lack of resources. The teachers interviewed for this study all understood the value of science as a way of investigating and science as a way of knowing, and they were excited about delving into this more deeply as part of school district and Ministry initiatives promoting inquiry.

There seems to be a perception that universities are the gatekeepers to a prosperous adult life, and they value SBK. Hence students and their pre-university teachers must fall into line, and they do. Although this is not a desirable state of affairs, this is how science has traditionally been taught. Teachers also find it easier to assess science when it is viewed as SBK.

Significantly, none of the teachers interviewed relied on Science Probe or any other textbooks for their teaching. One of the teachers claimed his school wants to "save on paper" and opted instead to use the library and the Internet as a source of information for student research. While it is helpful to have an "artifact for learning" as one teacher described the text, when creating common understandings with respect to things like vocabulary, none of the teachers stated that a textbook was necessary to their practice.

If the emphasis in the new curriculum is the development of scientific habits of mind, one wonders what place there would be for a static textbook acting more or less like a cross between an encyclopedia and a dictionary, especially when other, better, cheaper resources are available online. A recipe book describes opportunities to "go through the motions" and creates justifications for doing so, but there is simply no textual substitute for actually doing hands-on work. The same is true for science. It appears the textbook is now regarded by some teachers as intermittent support to be used as needed.

My findings would likely come as a surprise to Chiappetta and Fillman (2007) who claimed, "The role of textbooks in the U.S. educational system cannot be over-emphasized. Textbooks help define school subjects as students experience them. They represent school disciplines to students" (p. 1847). In their discussion of the examination of high school biology textbooks, they conclude, "High school biology textbooks are major curriculum resources that provide the subject matter content for a great deal of what is taught in biology classrooms, and to some degree how the content is taught" (p. 1863). This sentiment has been expressed time and time again in the relevant literature. Roswiati and Tonishi (2008) claim, "One of the teaching aids the teachers most frequently use is the textbook. It is well known that textbooks are ubiquitous and widely used in science classrooms. They are very important in determining what the students experience as they study science" (p. 87). This no longer appears to be the case. Other resources, such as the Internet, appear in many cases to have usurped the textbook. One of the teachers interviewed for this study opined this result was because textbooks are "expensive" and the Internet is "free."

Textbooks

One interesting finding of this study is that textbooks are playing a significantly reduced role in science teaching. Another is that the textbook's chief virtues no longer seems to be so virtuous. Chiappetta and Fillman (2007) also point out that in their analysis of five biology textbooks, "there appears to be a reasonable balance of the nature of science themes that can be recognized in the writing and activities. The textbooks frequently encourage students to investigate, whereby they are directed to think about a phenomenon or situation, respond to questions, or gather information" (p. 1863). The present study finds that this is not the case, at least for these two junior science textbooks. They also claim, "most of the five biology textbooks examined in the present study place a reasonable amount of emphasis on science as a way of thinking and how science is influenced by technology and society" (p. 1863), and this does not seem to be the case either.

It is clear that text committed to presenting science as a way of thinking occupies a small fraction of the textbooks recommended by the B.C. IRP. On the contrary, these textbooks present science as static knowledge to be transmitted for student consumption.

The activities are book-led or teacher-led opportunities to follow instructions and notice what happens. These activities boost the SWI messaging although most of the "investigation" is by-the-recipe confirmation inquiry (as Banchi & Bell, 2013 defined it) of ideas, theories, and laws that are unlikely to be interesting, surprising, or meaningful to students.

Clearly, the textbooks are limited in assisting with the realization of Government's goals that allow for deeper learning and understanding. Particularly when connected to critical thinking, and problem solving that characterize science as a way of knowing.

If a textbook is meant to be a container for all the desirable knowledge, then these textbooks, full of science as a body of knowledge, fit the bill. If a textbook is meant to support an instructional practice that encourages a certain kind of investigation, knowing and metacognition, then these textbooks are not helpful.

Abd-El-Khalick, et al (1998, p. 432) state that NOS claims must be made explicitly and that implicit, that is, tangential or digressive mentions made in passing, both in texts and activities are of no use in increasing awareness of NOS. Whether implicitly stated or explicitly, "Nature of Science" messages are of little value if the teacher does not refer to the textbook, and the students do not read it.

My finding does corroborate the findings of Niaz and Maza (2011) that, "Most textbooks in this study provided little insight into the nine criteria used for evaluating the presentation of nature of science (NOS)" (p. 26). It is clear that of the four views of the NOS, "Science as a Body of Knowledge" is the most common one in the textbooks studied. Decontextualized presentation of facts and concepts are simply declared without hints of history, impact, debate, imagination, or discovery. Very rarely are students invited to join the hunt for answers and never is imagination or creativity encouraged as necessary parts of the scientific process. Most commonly, information is presented simply for student consumption. Again, looking for evidence of one of the nine criteria, that, for example, "Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, creativity, and skepticism" (reference for this quote?) we discover there is emphasis on "observation" and "experimental evidence" and none at all on "argument," "creativity" or skepticism."

The BC Science Probe 9 text does indeed tackle the "law vs theory" distinction that Niaz and Maza (2011) describe as an important part of the NOS. A graphic on the bottom of page seven in a chapter entitled the *Nature of Science* summarizes the difference. I find it interesting that this is in the textbook because it is not a Prescribed Learning Outcome in the IRP. Therefore, I suggest that distinction is not something the government expects students to understand.

It appears that, at the high school level, textbooks mention the nature of science without doing so particularly forcefully and certainly not by way of encouraging readers to engage in science themselves. For example, the difference between a law and a theory is described in BC's Science Probe 9 (2005) is presented without examples from "real" science and certainly not from "kid" science; it is presented without meaningful context, like most of the content in the textbook (p. 7).

My findings indicate that the irrespective of whichever view of science emphasised in a textbook may be irrelevant given if teachers are not committed to using them. In the same vein, Carpenter et al. (2006.) in a description of publisher-funded studies on textbooks used in Britain made two important points: one, that textbook publishers and authors seem to have little appreciation of how students learn; and two, students are often motivated more by the desire to attain a degree rather an inherent love of, or interest in, course subject matter. At the same time, both students and instructors value textbooks, even though "there is no correlation between textbook purchase and the grade achieved." Klymkowsky (2007) wondered why, given that students view textbooks as references rather than learning tools, instructors do not assign books that are designed to be reference works, such as dictionaries of biology, both of which cost less than $20, compared with popular textbooks that can cost $120 or more (p. 190). Klymkowsky (2007) concluded that the issue of whether to use a textbook is complex, and "is dependent upon course and curricular goals. Students (and colleagues) expect a textbook; yet often, the textbook is not used, except as a reference" (p. 193). Stavrianeas, Stewart and Harmer (2008) went further and declared that physiology students indicated that "they enjoyed the online material, were almost unanimous in their praise for such pedagogical approaches to science education and yet, were reluctant to part with their textbooks" (p. 76). The authors concluded that there are different subgroups of learners in their courses: one subgroup may need to read the textbook "often" to do well in the course, while another subgroup appears to rely on other resources such as classes and assignments or perhaps even prior knowledge to do well in the course. It is very possible that science teachers now believe that a hands-on approach to materials-based science is preferable to print-based teaching based on a textbook or lecture notes.

Russell (1946) believed that scientific beliefs are tentative, not dogmatic" (p. 514). Furthermore, scientific beliefs are fluid and self-correcting which surely puts textbook authors and publishers in the difficult position of attempting to nail a nebulous, undulating jellyfish to the page if they believe they are attempting to represent the Truth, eternal, certain, complete and commensurate. I wonder if "textbook as dogma" might contribute, even in a small way to its demise. This would certainly not be a problem if the tentative nature of SWT were made explicit by the text. If a current thought is presented in the context of a constellation of explanations, laws, theories and models as the best one, yet probably not final one, the NOS is actually best served. Presenting the most current theory along with the evidence and justification for its value relative to what has gone before conveys both SBK and SWT which is surely a good outcome for a textbook. As mentioned earlier, this would not necessarily require a great deal of editing; recall the following three astronomical claims.

"Scientists have found when a chemical is heated…" (p. 310)

"Astronomers have found one of the best ways" (p. 311)

"Astronomers call the brightness of a star its magnitude" (p. 312)

These above statements all appear to be superficially similar, perhaps even somewhat interchangeable, yet the first is the most helpful for NOS purposes because it connects an experiment, an observation and a theory providing the reader with a sense of SWI, SBK and SWT. The second quotation provides SBK without saying how that knowledge was derived only that it had been derived somehow, scientifically. The third is simply SBK and conveys no sense at all of evidence or argument. Rendering the second two quotations to be more like the first would not be prohibitively onerous and would, I believe, make the text more interesting and enjoyable.

Noteworthy here is that "not only do textbooks constrain the possibilities for thought and action regarding ethical issues, they also require a certain kind of "subject" to partake in the exercises described within them" (Bazzul, 2015, p. 23). In other words, the textbook frames the thoughts and thinking that are acceptable within the community that the learner is attempting to join. SBK is therefore a kind of cultural capital to be acquired for personal gain.

However, "for students to develop a true understanding of the nature of science, the curriculum and the textbooks that support their learning must provide an accurate and balanced presentation of the nature of science" (Phillips et al., 2015, p. 149). This being the case, Phillips et al. concluded that what is required in future textbooks and learning resources "would be the inclusion of more content related to science as a way of thinking, as well as science and its interaction with technology and society to provide a more authentic view of the nature of science" (p. 161). This is exactly what I found as well.

Edification

Significantly, the idea that science education ought to reflect the practices of scientists within the scientific community as a form of enculturation was one endorsed by Richard Rorty who also endorsed Dewey's philosophical pragmatism. What education and pragmatism share is the Rortyan notion of "solidarity". Rorty (2011) claimed that our intellectual history features a transition from solidarity to objectivity, wherein our sense-making narratives have shifted from our contributing to a community to our place relative to something non-human and abstract (p. 367). For pragmatists like Rorty, "the desire for objectivity is not the desire to escape the limitations of one's community but simply the desire for as much inter-subjective agreement as possible, to extend the reference of 'us' as far as we can" (p. 369). I will return to the social nature of understanding later in this chapter, but I would like to turn now to key philosophical underpinnings and implications of this study.

The hermeneutic approach I employed to explore the current state of science education is one Rorty (1979) termed as "edification." Rorty proposed "edification" as the project of finding, new, better, more interesting ways of communicating with each other (p. 360). It can consist in the hermeneutic activity of making connections between our current context and another. The goal is to "remake ourselves or each other" (1979, p. 359) as we do so.

Edification is unlike systematic philosophy which puts epistemology at its centre (1979, p. 365, 368). The idea, traditionally speaking, has been to create or appeal to foundational knowledge that is complete, certain, and final and true for everyone and for all time. It was meant to support arguments and lines of reasoning that would be justified, certain and commensurable. Science has proceeded and been successful with the goal of creating knowledge that met those criteria.

Rorty (1979) however, claimed this type of thinking is obsolete and what we should emphasize is thinking that takes us out of our old selves by the power of strangeness, to aid us in becoming new beings (p. 360). As new beings, our goal is not to continue with the old goal of seeking truth but to determine intersubjective agreement and to contribute to humanity's ongoing conversation about what to do with itself. The goal of this study is to present one side of a strange conversation about science and education; a conversation that examines scientific understanding as a model for working together, rather than a source for valid facts, theories, and laws. Where then are the points of intersubjective agreement that will help us move science education in B.C. forward?

It is clear that teachers and Ministry officials share many of the same goals for science teaching. They both wish to see graduates borrowing from the scientific community and demonstrating higher-order thinking skills. Whether this should happen so young people can participate in the economy or achieve self-actualization (or some other reason) is largely beside the point; the point being that critically-thinking problem solvers are an important part of any community.

Teachers are being asked by the government to adjust their instructional strategizing to accommodate the needs of individual students, and I wonder if these adjustments are coming at the expense of the structured content in the textbook. Certainly the rise in student-centrism has come at the expense of teacher-centrism and textbook-centrism. This makes a certain amount of sense; as Reinders and Balcikanli (2011) put it, "Teachers may expect popular textbooks published by major publishers to present the state-of-the-art in teaching, but this clearly does not extend to skills for self-directed learning" (p. 270). Most important for us in this context, it seems fairly clear that the disavowal of the textbook is not because of a shortcoming in the textbook's view of the nature of science as this is not the teachers' most pressing concern.

Recall that science teachers need to explicitly guide students in developing a proper understanding of the nature of science since implicit or incidental guidance is insufficient (Abd-El-Khalick & Lederman, 1998, p. 419; Schwartz, Lederman & Crawford, 2004, p. 614-615). If the textbook is of limited value in presenting all the facets of the nature of science, then teachers will obviously require other forms of support to guide students effectively.

At this point, it is worthwhile drawing upon the perspective of a biologist who is a researcher, textbook writer, and university instructor. Jocelyn Krebs, Professor of Biology at the University of Alaska Anchorage and lead author of *Gene*, who when asked how textbooks ought to be used responded, "I can tell you how I use it myself, which is admittedly more as a resource. I want to give students the big picture and then send them to the book to get the details. The book has to reinforce what you are covering in class, where you have to leave out a lot of details" (2011, p. 1217). When asked, "How much do students need to know about the historical perspective and the classic experiments in molecular biology?" Krebs replied, "Historical anecdotes make great teaching tools—there are a number of classic experiments like Meselson and Stahl that are easy to understand, beautifully illustrate the scientific method, and have great stories associated with them. I usually give only a few of these examples, because there is so much else to cover. But I think it is important for students to have a sense of history and progress in science, because it helps to emphasize that our understanding is always changing" (2011, p. 1217). In response to the question "Should university education aim at teaching rational thinking and scientific method instead of facts?" Krebs replied,, "I think many courses already do that. Some factual basis is essential for any course, naturally, but teaching students how to think about science and how to evaluate the scientific literature is much more important than learning a vast array of facts—many of which will soon be out of date anyway" (p. 2011, p. 1219).

What is most significant about Krebs' opinions stated above is that the use of historical anecdotes to illustrate the scientific method or particular aspects of SWI, SWT or STS relegate the reader to the role of a spectator in the evolution of understandings. The role of Krebs' textbook is not to encourage readers to go off and do science of their own, it is to provide the depth of knowledge a practicing scientist might need. It is certainly true a scientist spends a great deal of time reading, but it is not clear that making a university student read a textbook is a way to prepare them for evaluating scientific literature.

Why this is important is that university science learning is the end game; it is what primary, elementary, and secondary science education is leading to. If SWT is not really being emphasized at the end of scientific training why should it be emphasized at the beginning?

One piece of the story which is conspicuously absent so far is the view of the nature of science held by the student. Kang, Scharmann and Noh (2004) sought to compare the views of the nature of science held by Korean students in grades 6, 8, and

10. Their study was interesting on a number of fronts. They found for example, that Korean "students tend to regard science as making or inventing something useful to improve the quality of our lives" (p. 323). Students in many other cultures believe this as well, but Korean students continue to believe this as they get older which sets them apart from other cultures, according to the study. The study concluded that "only a small number of students, regardless of grade level, were found to have an appropriate understanding of the NOS" (p. 331). This is noteworthy because "10th graders still need further development of their views on the NOS because 10th grade may be the final year of formal science learning for approximately half of the Korean school-aged population" (p. 331).

van Griethuijsen et al. (2015) reported that "international studies have shown that interest in science and technology among primary and secondary school students in Western European countries is low and seems to be decreasing" (p. 581). Their results revealed that students in countries outside Western Europe showed a greater interest in school science, in careers related to science, and in extracurricular activities related to science than did Western European students. The authors also found that "non-European students were also more likely to hold an empiricist view of the nature of science and to believe that science can solve many problems faced by the world" (2015, p. 602). Moreover, analysis revealed a strong correlation between interest in science and having such a view of the Nature of Science. Interestingly, they concluded that "the results from this study suggest that the answer to the problem of decreasing interest in Western Europe would be to develop teaching materials that present scientific research as collaborative, creative and as beneficial for society" (2015, p. 602). Thus it would seem that hands-on, student-centred, inquiry-based science teaching is effective in introducing students to the NOS, and it is enjoyable for students as well.

In summary, it appears that the NOS is indeed being addressed in both the curriculum-as-planned and the curriculum-as-lived; teachers are in favour of the curricular expectations laid out by the government. The NOS is being promoted (although possibly a little more incidentally than explicitly) in curriculum documents but also in instructional strategies as imagined by Dewey and Schwab and implemented by teachers who appear to enjoy this approach. The Nature of Science does not seem to figure prominently in science textbooks which are becoming irrelevant because they support an outdated instructional program.

CHAPTER 6

Summary, Conclusion and **Implications**

In this the final chapter of the thesis I present a summary of my findings by revisiting the questions that guided my study. I will then present my recommendations for further research and finalize this thesis with conclusions.

Research Questions

1. What view of the nature of science, is conveyed in the Science K-7 Integrated Resource Package (IRP) 2005?
2. What are the views of the nature of science espoused by practicing teachers?
3. What is the view of the nature of science is implicated in the recommended textbook B.C. Science Probe by Nelson Publishing?

Summary

Research Question #1: What view of the nature of science, is conveyed in the Science K-7 Integrated Resource Package (IRP) 2005?

The K-7 IRP recommends a well-rounded view of the nature of science, encompassing all four views described by Chiapetta, Fillman and Sethna (1991, 2004). In fact, these four views correspond very closely to the four goals in the IRP's curriculum overview (p. 12). The goals are as follows: 1) Science-Technology-Society-Environment; 2) Skills; 3) Knowledge; and 4) Attitudes. STSE corresponds very closely to STS in that "Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology" (IRP, p. 12), and according to Chiapetta, Fillman and Sethna (1991, 2004), "This aspect of scientific literacy pertains to the application of science and how technology helps or hinders humankind. It involves social issues and careers" (p. 3).

The goal "Skills" demands "students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions" (IRP, p. 12). This goal is a combination of SWI and SWT. It is SWI to the extent that students utilize apparatus, charts and tables, make calculations and reason out answers" (Chiapetta, Fillman & Sethna, 1991,2004) and SWT when students "describe how a scientist experimented, show the historical development of an idea, emphasize the empirical nature and objectivity of science or present the scientific method(s), and problem solving steps" (p. 3).

"Knowledge" is a fascinating goal. The IRP dictates "Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge" (p. 12). Chiapetta, Fillman and Sethna (1991, 2004) characterize SBK as text "presents facts, concepts, principles and laws, presents hypotheses, theories, and models and asks students to recall knowledge or information" (p. 2). At first look it would appear that this goal and SBK are one and the same. Simplifying here somewhat, the Ministry is mandating that "Students should know things" and Chiapetta, Fillman and Sethna ask us to note where texts present things to know.

“Attitudes” is another interesting curricular goal; “Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge” (IRP, p. 12). This goal is unusual because it seems to assume that students are removed from the creation of scientific knowledge, and they are in fact some distance from it but still need to be respectful of it. Teachers are not encouraged to inspire and excite students so they investigate and think like scientists. Rather they are to encourage students to respect the process, without necessarily being encouraged to engage in it themselves. One “attitude” they are encouraged to demonstrate is “ethical, responsible, cooperative behavior” (IRP, p. 38) which, is desirable in science learning as well as every other form of learning!

On final observation, all four of the Science 9 IRP’s curriculum goals appear on page 11 of the IRP. The assumption is that each goal is important and developmentally-appropriate for students of all ages.

In summary, the Science 9 IRP illustrates emphasis on science as a body of knowledge and on science as a way of investigating but science as a way of thinking and science-technology-society are to be explored as well.

Research Question #2: What are the views of the nature of science held by practicing teachers? The participating teachers conveyed the impression of being committed to science as a way of investigating and science as a way of thinking for two reasons. The first reason is that teachers believe these are valuable habits of mind for students to possess, and another is that orienting teaching to the promotion of these habits of mind is enjoyable for students and teachers alike. One of the teachers (NG) reported on what was enjoyable about teaching science this way, “So much more is coming from the kids and I’m hearing more about what their knowledge already is and they’re taking it in directions I hadn’t thought of” (personal communication, Feb 8, 2015).

As far as science-technology-society is concerned, it is fair to say that the science-technology interaction does receive requisite coverage in textbooks but science-society does not. The practical impact of technology is so obvious it is difficult to ignore; one cannot discuss “communication” for example, without bringing up computers, cellphone, social media, or the Internet. The social side of this technology is only discussed insofar as it is practically useful; it is not “age appropriate” to critically analyze any part of science, technology, and society or to compare competing worldviews, for example. This appears to fly in the face of the STSE goal of developing an understanding of the “nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology” on page 12 of the Science 9 IRP and page 11 of the K-7 IRP.

Although it was deemed by NG to be “easy to teach this way,” science as a body of knowledge was generally disparaged by the teachers interviewed for this study. The need to convey content via the “transmission model” as NN called it and to help students hurdle obstacles such as provincial exams and university entrance was dealt with somewhat grudgingly by the teachers.

Research Question #3: What is the view of the nature of science in the recommended textbook B.C. Science Probe by Nelson Publishing? The nature of science according to the two recommended textbooks was science as a body of knowledge, that is, decontextualized facts connecting one fact to another. Rarely were students' needs and interests considered, nor were history, imagination, discovery, or exploration. Space science was the rare exception, where the facts included the personalities, technologies, and controversies associated with individual thinkers. Most of the other content, especially the biological science content, was presented in a declarative manner that included no history, no imagination, no exploration, and no discovery.

A clarification should be made here. Consider a statement such as, "One very common chemical change is what happens to metals that contain iron, especially when they are wet" (BC Science Probe, 2005, p. 129). This is a simple declaration that, as explained above, contains no history, imagination, exploration, or discovery. This statement is the lead-in to a paragraph on rusting in a chapter on chemical changes in the non-living environment. Consider the statement, "Imagine you are Alfred Wegener in the early 1900s. You are excited about your new hypothesis that today's separate continents were once joined together as Pangaea" (BC Science Probe, 2005, p. 129). This is an invitation to think like a scientist and promote SWT. Much of what is ostensibly SWT and SWI text is actually SBK however. Now consider, "Hess suggested that the new ocean crust is constantly moving away from the ridge as if it is on a huge and very slow conveyor belt" (BC Science Probe, 2005, p. 227). The subject of this sentence and the related paragraph is not Harry Hess and his scientific thinking; rather, it is the age of the rocks on the ocean floor.

Much of the content in the textbooks examined for this study is presented in the above described way. The context for scientific facts and concepts does not broaden the view of science to show the nuances of scientific thinking; it is simply more facts to know. Hess's conveyor belt is not presented as a visual aid to understanding the spreading of the sea floor nor as an imaginative solution to a phenomenon not previously understood, it is presented as another "thing" to know. Simply rewording much of the texts would accomplish a presentation of science as a way of thinking but it appears the choice was intentionally made to present the material as a body of knowledge. Thus it appears the presentation of material in a science textbook analyzed in this study is determined more by editorial choices rather than pedagogical ones.

Conclusions

For many years I was in charge of a professional development program for "science-phobic" elementary teachers. As they entered this program, these teachers thought they needed more science knowledge. They believed that being able to anticipate any question a student could ask would put them in command of their science teaching. This of course is an impossible aim because there is no way to acquire all the information needed to anticipate any question a student could ask a teacher. A more productive aim turned out to be "modelling curiosity." If a teacher was asked a difficult question by a student, a helpful response might be "Well I don't know- how could we find out?" This validates the student's question, but more importantly it opens up a constructive and collaborative dialogue similar to what would happen in a community of practising scientists. Teachers in this professional development program realized that engaging in this type of collaborative inquiry was constructive as well as authentic and enjoyable. What crystallized for me was the belief that teaching should provide opportunities to celebrate imagination and curiosity in students, teachers, scientists, and community members. I believe an important goal in teaching ought to be enabling and empowering people to be boldly imaginative and collaborative. Although it is a significant part of Science as a Way of Thinking, in my experience imagination is rarely promoted and never celebrated in curriculum documents and textbooks.

Richard Rorty (1999), invoking John Dewey, claims that the goal of primary and elementary schooling is, first and foremost, “familiarizing young people with what their elders take to be true” (p. 118). Socialization comes before individuation which is introduced gradually and in later grades. Individuation can and should involve inciting doubt and stimulating imagination. The two goals for this individuation are our continued growth as individuals and as members of a community. Growth is not possible without imagination of what might be possible.

Of course, teachers are socialized to be particular kinds of educators by their elders, and teachers’ views on the NOS seem to derive from how they were taught. NN specifically expressed the desire to follow in the footsteps of a teacher she loved. There is evidence in research that this desire is quite common among teachers and that beginning teachers tend to bring preconceptions of science instruction to their own teaching (Nashon, 2005).

Although science education serves many useful social purposes, it is also true that there are many social forces at work to constrain and steer science education. Presentation of the NOS is complicated by the accommodation of points of view of stakeholders such as parents, university officials, and employers. Clearly there are more players than just the government, teachers and textbooks in the delivery of science in B.C.’s classrooms. This was made clear by NN and MB who maintained that the transmission of facts and concepts was the expectation as far as parents were concerned, especially parents who hope their children will go on to university. MB also brought up provincial exams and other standardized tests that appear to be another selection pressure point which tends to force teachers to emphasize SBK at the expense of the other perspectives.

Looking specifically at the role of the teacher, it appears they are in the difficult position of having to meet the expectations of the Ministry of Education, the job market, students, parents, and university officials. Recall that the B.C. Ministry of Education mandated in the 2005 IRP that "scientific literacy is an evolving combination of science-related attitudes, skills and knowledge students need to: develop inquiry, problem-solving and decision-making abilities as citizens; become lifelong learners and maintain a sense of wonder about the world around them" (p. 11). It seems clear that the government's view of the NOS involves Science as a Way of Investigating, Science as a Way of Knowing, and Science-Technology-Society.

Let us look at "skills" a little more closely. One of the four major goals in science teaching is "students will develop the skills required for scientific and technological inquiry, for solving problems" (IRP, 2005, p. 11). It seems clear that whether the skill is classifying, sorting, communicating or titrating, the expectation is that students ought to actually do these things having instruction to do so beforehand and been assessed afterward. How about during as well?

The B.C. Ministry of Education and the teachers appear to share a similar view of the Nature of Science. This may seem surprising giving the adversarial relationship that exists between the B.C. government and teachers.

Teachers seem to support the notion that students should acquire skills, being generally in favour of science as a way of investigating and knowing. They were well-disposed to allow students to experiment and acquire skills but expressed concerns about the practicalities of preparation time, resource availability, and assessment problems.

My own experience as a science educator at a science museum and as a parent indicate to me that children enjoy opportunities to experience hands-on with respect to science learning. This allows children to acquire skills incidentally while having fun. For example, my own children have spent hours exploring the cause-and-effect relationship between the creation of carbon dioxide gas and thrust by putting vinegar and baking soda in a plastic film canister and watching it “launch”. Thus engaged, it was very easy to nudge them toward being systematic and thorough in their own attempts to determine their own favoured result.

Teachers do not often use activities like this in their teaching however. The difficulty a teacher might have replicating this scenario in his or her own classroom could come from not being aware of this activity, not having access to the resources, not being sure how to run the activity logistically, and not being sure how to justify the activity to colleagues, administrators, or parents. As someone who brought this activity into my child’s class, I can confirm that the teacher approved of this activity, enjoyed learning about it, and now uses it herself having been shown how to teach it..

This particular activity does not appear in any of the textbooks analyzed in the study so a teacher could not stumble across it accidentally and use it; it would have to be the result of a specific search. This highlights a significant shortcoming in the recommended texts. That is, students learn about elements of the nature of science by reading about them rather than being encouraged to do them themselves. Reading what a prediction is surely much less impactful than being told by the teacher what it is. Teaching as telling has less impact than a student doing the activity/experiment him or herself. For example, having the students read the instructions for an activity like "pop rockets" and then asking them to predict what might happen before being encouraged to try the experiment. Studies, for example, Taylor and Bilbrey (2012), show the relative effectiveness of this kind of activity.

If governments and teachers are committed to students understanding the nature of science by actually engaging in science, you would never guess this by looking at the Science Probe textbooks, recommended by the government and recognizable to the teachers. The approach of the textbooks is to simply declare what science is and how it proceeds without any kind of urgent encouragement to the students, which is unfortunate since surely is this not the point of education?

Teachers already engage in a minimum of 25 hours of professional development per year, so it is clear that they have the green light to grow as individuals. Many B.C. teachers have degrees and qualifications beyond teaching certification requirements. These credentials are often attained through weekend and summer courses such as the one with which I was involved. The tension between socialization as convergence onto a point of view and divergence as development of an individual point of view is just as relevant to teachers as it is to students. While we want teachers to meet expectations, we also want to allow them latitude to meet those expectations as they wish.

Teachers understand all the above mentioned points which is why they have turned away from textbooks to look elsewhere for support. They could use help, not from textbooks which they tend to avoid due to the lack of helpfulness, but from one other, their teacher colleagues. The solution may be release time for the collegial sharing of ideas. As MB states:

> I think what we don't need is somebody giving us a book saying, here's how to do it, it's more a chance to collaborate with colleagues and Ministry officials who have ideas and other professionals within education and give us opportunities to get together and not as a single pro d day but as a learning team that meets together over a year once every two months (personal communication, Feb 5, 2015).

NG claims to "need more workshops and more information. And I just need to experiment more because it's a whole different way of teaching and I'm going into a place where I don't know for sure where this is gonna go. Experimenting with discomfort." This sentiment is interesting because this new way of teaching- this seismic shifting of practice, this re-culturation- will indeed create discomfort for teachers and for everyone involved in science education.

My findings seem to corroborate Rudolph's (2000) claim that "building an understanding of the nature of science from the divergent daily practices of science instead, provides not only a more authentic portrayal of those practices that make up 'science', but also allows for a more natural integration of nature of science concerns with the traditional school science curriculum" (p. 404). He goes on to add, and I agree,, "This curricular approach, however, requires the perhaps difficult step of abandoning any notions of a universal ‘nature of science’ and embracing the diversity of the particulars” (p. 404). Again we see stakeholders having to address potential discomfort.

Interestingly, the B.C. Ministry of Education is (as of 2015) finishing off the revision of the mandated science curriculum. The government website declares that while there are significant changes to the curriculum, important aspects of the 2005 one are retained. For example, the familiar skills and processes of science remain an integral part of the Science curriculum and reside in the curricular competencies, presumably promoting SWI. Moreover, the usual areas of science (i.e., biology, physics, chemistry, and Earth/space science) are still represented in the new curriculum, representing SBK.

The website also announces the following new approaches:

- Each grade has four areas of science: biology, physics, chemistry, and Earth/space science. This replaces the existing curriculum that organized the subject by biology, physical sciences, and Earth/space science.

- While the Science curriculum has always been conceptual, the new curriculum highlights fewer concepts to allow for substantial inquiry time.

- The level of facts and details in the new curriculum is left open to individual customization by the educator, allowing more time for in-depth exploration by students.

- A glossary of terminology, as well as examples of some science concepts, is hyperlinked into the curriculum to support non-specialist educators.

These last two points illustrate the unease the B.C. Ministry of Education exhibits regarding teachers. There is a grudging respect for them due to their ability to customize their teaching; not many teachers are thought to be non-specialists who need to “spruce up” their vocabularies. If I appear to be intemperate, recall that the 2015 revision of the 2005 curriculum revision I explored in this thesis was predated in 2012 by the B.C. Education Plan.

The B.C. Education Plan (2012) claimed to outline a new approach to education in this province. It meant to ensure “Personalized Learning for Every Student” such that “every student’s needs are met, passions are explored, and goals are achieved. This means student-centered learning that’s focused on the needs, strengths and aspirations of each individual young person” (p. 5).

There are assumptions implicit in some of the component strategies in its “response” to the “challenge” that I sought to address. The reason I do so is that as someone interested in experiential science education, I am interested in the B.C. Education Plan’s implications for science teaching.

There appear to be three major themes in this plan, leading from the 2005 curriculum to the 2012 version. The first is, “The world is changing, yet the educational system is not” (p. 3). The world is frequently described using active terms such as “dynamic” and “evolving”, and the educational system is described in terms that suggest it is sluggish and resistant to change.

The second theme is, “Students need flexibility, freedom and choice and the educational system does not currently provide these things”. Moreover, students need personal attention to meet universal curricular expectations.

A third theme is, “Teachers need to be regulated to be effective”, and by “effective” the Ministry means adaptable and responsive to student needs. The Ministry is suggesting that teachers are doing things like not using their Pro-D days effectively and must be watched to ensure we get the service we want from them. Teachers are positioned as that part of the “educational system” that is resistant to change.

In summary, it appears the Ministry assumes that all that stands between students and success are teachers who need to be regulated; they need to know what the curricular expectations are, and they need to be accountable to all the stakeholders if those expectations are not met.

The B.C. government suggests the “curriculum will be redesigned to reflect the core competencies, skills, and knowledge that students need to succeed in the 21st century” (2015, p. 5). Alberta (2014) is also embarking on a “Curriculum Redesign”, a “reimagined system that will empower Alberta’s young people to become the leaders of tomorrow in our communities, workplaces, and society.” In Alberta, the emphasis is on stakeholder collaboration and little mention is made of teachers. What is odd about all this re-visioning of the curriculum is that it was predicated on changing the pedagogical practice of teachers who, seem to be more or less on the same page as the government.

American historian Richard Hofstadter (1963) wrote that if there is one slogan or sentiment that could be said to have dominated American thought about the role of education, it is that “Americans expected of education what they expected of religion, that it is practical and pay[s] dividends” (p. 299). He suggested that “the belief in mass education was not founded primarily upon a passion for the development of mind, or upon pride in learning and culture for their own sakes, but rather upon the supposed political and economic benefits of education" (p. 305). Education was viewed as preparation for participation in the economy. The same would be appear to be true of education in British Columbia. Hofstadter also pointed out that dissatisfaction with education as a business goes back at least as far as 1870, when William Franklin Phelps who would go on to become president of the National Education Association, declared elementary schools,

> are mainly in the hands of ignorant, unskilled teachers. The children are fed upon the mere husks of knowledge. They leave school for the broad theater of life without discipline; without mental power or moral stamina. . . . They afford the sad spectacle of ignorance engaged in the stupendous fraud of self-perpetuation at the public expense. . . . Hundreds of our American schools are little less than undisciplined juvenile mobs. (Hofstadter, 1963, p. 303).

As noted earlier, the period between the 1980s and the 2010s was tumultuous in British Columbia. In advance of the year 2000, the 1988 Sullivan Commission Report "A Legacy for Learners" declared, "The Government of British Columbia believes that education is a long process embracing many facets, including personal development, career preparation, the enhancement of creativity, self-discipline, mature judgment, and a broad range of life skills, not the least of which is curiosity—the love of learning" (p.).

This apparent distrust of teachers, together with a desire to save money, maintaining educational physical plants, and a desire for community integration paved the way for the privatization of BC Education, as it had been done in places like Texas. There "Pearson, one of the giants of the for-profit industry that looms over public education, produces just about every product a student, teacher, or school administrator in Texas might need. From textbooks to data management, professional development programs to testing systems, Pearson has it al, and all of it has a price. For statewide testing in Texas alone, the company holds a five-year contract worth nearly $500 million to create and administer exams (WiredAcademic, 2011). The role of the teacher has been reduced to that of an auditor who ensures expectations are being met and nothing more.

At this point, we can revisit the value of the textbook in the classroom. Perhaps the problem with the traditional textbook is that it, by itself, is not as hyperfunctional as we like our assistive resources to be. Perhaps a student text and a teacher's guide do not fulfill the perceived needs of the teachers as far as the people who provide resources for them are concerned. Perhaps the choice is between a comprehensive learning resource and nothing at all. I would never have predicted that the comprehensive learning resource backed by a very large multinational would have been supplanted by nothing at all.

But other changes are afoot. Education appears to be reverting not to what Bertrand Russell (1930, 1968) called "education for training in the capacity of enjoyment" (p. 31) but to the system of apprenticeship first developed in the later Middle Ages in which a "master craftsman was entitled to employ young people as an inexpensive form of labour in exchange for providing food, lodging and formal training in the craft" (Wikipedia.) The disgorgement of students from schools into the community, while initially touted by progressives who are committed to Deweyan "understanding deriving from activity," happens because it saves school districts money they would normally spend maintaining their physical plants. In the U.K. there are headlines like "Graduates paying to work for free" on top of stories about young people paying large sums of money for work experience placement (BBC).

It seems that, whatever the government claims in documents, justifying changes to the curriculum, teachers, and the government are on more or less the same page with respect to the teaching of science. Both parties are interested in hands-on, inquiry-based, experiential learning that will round out students' view of the nature of science so it includes SWT as well as STS. Support to actualize these interests will not come from textbooks or other forms of media created by distant publishers. On the contrary, it seems that local groups of collaborators appear to be what is both requested and required.

In Contingency, Irony and Solidarity, Rorty (1989) wrote, "In my utopia, human solidarity would be seen not as a fact to be recognized by clearing away "prejudice" or burrowing down to previously hidden depths but, rather, as a goal to be achieved. It is to be achieved not by inquiry but by imagination, the imaginative ability to see strange people as fellow sufferers" (p. xvi). This emphasis on imagination and the conduct of what Rorty (1979) called "abnormal inquiry" (p. 363) reflects a modern philosophy, a more accurate sense of what scientists actually do and a way of engaging young people that is both enjoyable and effective. May we all do more of it!

Implications

This research raises a number of questions that would be interesting to pursue. What is the Nature of Science depicted in popular culture? What about within the community of practising scientists? Awareness of the NOS is going to be important for young people seeking to enter the community of scientific practice but how important is it for the general community at large? How well-versed in the Nature of Science must a citizen be if the goal is a citizen who can participate meaningfully in debates around scientific issues of the day? These are questions related to teaching theory.

Other questions relate more to the practice of teaching. How, for example, does student achievement relate to the use of the internet or the use of the textbook; which of the two drives a better result, if results are the key success factor? Which of these two resources is most cost effective, if cost effectiveness is the key success factor? Which would students find most enjoyable? If differences are observed between one resource and the other, then subsequent questions ought to address the qualities of the resources that account for the differences- are textbooks too static? Too dogmatic? Too expensive? Too boring?

There are other academic questions to consider as well. What are the instructional practices associated with socialization and with individuation? What is the relative placement of the practices throughout a student's school life? To what extent are teachers promoting students' self-formation and also the unique contribution each student could make to the solution of the problems in their communities?

I will close this chapter and thesis by predicting that the next two to three years will be interesting for anyone involved in education in BC. There are a number of innovations in the draft curriculum; it would be very interesting to witness how they are modified as they are put into practice. The extent to which the new curriculum actualizes some of the intended imperatives of the BC Education Plan would be interesting to analyze; it may not be particularly easy to reconcile "flexibility" and "accountability" for example. It may not be easy to implement a new curriculum that is "content-based but competency-driven" without a lot of professional development, for another example. I believe however that the BC Education Plan proclaiming support, interest, and expectation for instructional innovation is good news for anyone interested in science literacy, the nature of science, experiential learning, or inquiry.

This study was a fascinating opportunity for me to look closely at the social meaning-making that scientists, philosophers and educators engage in. I remain intrigued by Rorty's notion of intersubjective agreement as a goal for all three of these communities. And I am impressed at the extent of the role interpretation plays in their work.

As someone very committed to hands-on, student-led, experiential education, I am excited to learn that this is indeed the future of science education in British Columbia. I look forward to participating in this future!

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Appendices

Appendix A: Consent Form

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

Consent Form for Participation in a Study of

Views of the Nature of Science

Research Team

Principal Investigator:

Dr. Samson Nashon, Dept of Curriculum and Pedagogy, UBC Faculty of Education, 604-822-xxxx, yyyy@ubc.ca

Co-Investigator:

David Savory, grad student, Dept of Curriculum and Pedagogy, Faculty of Education, 604-220-xxxx, yyyy@gmail.com

This research is in support of David Savory’s master’s thesis which will ultimately be a public document.

Why are you doing this study and why do you need my help?

Most people agree science is a potent cultural force but it's not clear that everyone in the culture believes the same thing about science is, how it proceeds or how it should be taught.

This study focuses on the "Nature of Science" and how it is depicted in the BC Ministry of Education's curriculum documents, commonly used science textbooks and teachers' practices.

You are being invited to take part in this research study because as a practising teacher, your views on what science is will have a significant impact on the views of your students.

What happens if I say, "Yes, I want to be in the study"?

If you agree to participate, I will ask you for a two hour "window" that would be convenient for you to meet for an informal interview. The location will be somewhere convenient for you

It will be an interview in that you will be asked a series of questions about science and science education but it will be informal in that it will be a conversation where we can meander and clarify as we need to. The questions will take less than one hour to go through but more time has been requested to ensure we have adequate time for any "scene-setting" before the first question and "de-briefing" after the last question.

The session will be audiotaped and transcribed afterward so there is a faithful representation of your responses. The transcription will be emailed to you so you can read through them and approve them. That way we can be assured your thinking has been accurately captured.

What will happen with the results?

The results of this study will be reported in a graduate thesis which will be a public document and may also be published in journal articles and books. Participants who would like to see the results of the study are welcome to contact the investigators via phone or email, as above.

Is there any way being in this study could be bad for me?

We do not think participation in this study will cause any sort of harm. If any questions seem too personal, touch on sensitivities or cause upset, they do not need to be answered.

Will my privacy be respected?

Your confidentiality will be respected. Information that discloses your identity will not be released. Your opinions and beliefs will be attributed to a code known only to the investigators. Data will be kept on password-protected hard discs which will be stored in a locked cabinet.

What are the benefits of participating?

It is our hope that in determining what teachers, Ministry officials and textbook publishers all believe about science, steps can be taken toward a cultural centre of gravity and ultimately, a useful and productive unity. It is clearly in no one's best interest to have stakeholders working at cross-purposes.

Will I be paid for taking part in this research study?

We will not pay you for the time you take to be in this study. However, we will provide a Starbucks gift card and cover the cost of bus fares and parking, if applicable.

Who can I contact if I have questions or concerns about the study?

If you have any questions or concerns about what we are asking of you, please contact David Savory whose contact information is listed at the top of the first page of this form.

If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, contact the Research Participant Complaint Line in the UBC Office of Research Ethics at 604-822-8598 or if long distance e-mail RSIL@ors.ubc.ca or call toll free 1-877-822-8598.

I'm ready to consent!

Taking part in this study is entirely up to you. You have the right to refuse to participate in this study. If you decide to take part, you may choose to pull out of the study at any time without giving a reason and without any negative impact on your circumstances.

Your signature below indicates that you have received a copy of this consent form for your own records.

Your signature indicates that you consent to participate in this study.

____

Participant Signature   Date

____

Printed Name of the Participant signing above

Appendix B: Interview Protocol

David Savory: Views on the Nature of Science Interview Protocol (from Padayachee, 2012)

PART ONE: THE INTRODUCTION

1. Greeting and thank you for consent and participation
2. Tell me about yourself.
3. How long have you been teaching Sciences?
4. How would you describe the way you feel about being a Sciences teacher at this very second?.... Explain
5. What do you enjoy the most about Sciences?
6. What do you dislike about your duties as a Sciences teacher?
7. Moving onto the more serious part of the interview, briefly discuss what important skills a Sciences teacher needs to instill into learners?
8. Which of the above mentioned skill would you rank as being the most important?... Why?

PART TWO: THE ROLE OF TEXTBOOKS

1. How would you explain the role that the textbook has in your classroom?
2. How do all learners become accessible to the textbook?
3. How do you use the textbook in the teaching and learning of science?
4. What suggestions can you think of that can better the textbook in terms of its structure, layout and usability?

5. How would u describe the knowledge-base of the textbook?

6. What are your judgements regarding the activities that are evident in the textbook?

7. How do you incorporate moral and ethical aspects in your lessons, such as cloning, invitro-fertilisation?

PART THREE: SCIENCE AS A BODY OF KNOWLEDGE?

1. What is the role of "science as a body of knowledge" in the Sciences classroom?

2. How do you teach a topic like cellular respiration by promoting "science as a body of knowledge"?

3. Which topic from the recommended textbook best lends itself to promoting science as a body of knowledge?

4. How is science as a body of knowledge assessed formally and informally?

PART FOUR: THE INVESTIGATIVE NATURE OF SCIENCE

1. What do you understand by the "investigative nature of science"?

2. How do you promote the investigative nature of science in your science teaching?

3. How does the curriculum accommodate the "investigative nature of science"?

4. How would you rate the incorporating this aspect of science in the science classroom?

5. Which topic in the curriculum best lends itself to the "investigative nature of science"?

6. Can you relate an example of how you have included it in your teaching?

7. Are you familiar with the term "scientific method"?

8. Elaborate a little on your understanding of the "scientific method"

PART FIVE: SCIENCE AS A WAY OF THINKING

1. How valuable is "science as a way of knowing" to your learners in the classroom?

2. What aesthetic skills can a learner acquire by being exposed to “science as a way of knowing”?

3. Does the science curriculum lend itself to the historical discoveries that have been contributed by scientists, for example, in photosynthesis?

4. Have you included any contributions made by scientists in your lessons?... relate how

5. What is the role of skills such as “thinking, reasoning and reflection”?

6. Is there any significant place for the exercising of these skills in your science class?

7. Can the above skills be assessed either formally of informally? Explain

PART SIX: THE INTERACTION OF SCIENCE, TECHNOLOGY AND SOCIETY

1. Discuss your understanding of the interaction between science, technology and society?

2. How do you include this as part of your classroom activities?

3. How does this form part of the assessment for grade 10 learners?

PART SEVEN: CONCLUSION

1. From the four aspects of the nature of science that we have talked about thus far, i.e. knowledge, investigative skills, way of knowing and the interaction of science technology and society, how would you rank them according to their current position in the science curriculum (1-4, 4 the lowest)

2. Do you necessarily agree with the current curriculum with regard to the way the above 4 categories are positioned?

3. If not, how would you change it?

4. Why do you feel the no. 1 should be the most important?

5. Why is it that you have ranked no. 4 the least important?

6. What suggestions can you recommend be put in place so that teachers can best include these aspects of the nature of science in the grade 10 Life Sciences classroom?

7. Is there anything that you would like to add or ask before we conclude with the interview?

8. Thank you so very much for your time.

Appendix C: Teacher Tidbits from Interviews

What do you teach and how long have you done been a teacher?

NN: Learning assistance, 12 years.

MB: Chemistry and Math, 10 years.

NG: Grade 1, 24 years.

MM: Grade 4, 19 years.

What do you like about teaching science?

NN: I enjoy that aspect most that I get to collaborate that way, with the teachers and then the kids.

MB: I love it. Fascinating subject.

NG: What I like about it is lately I've been trying to do an inquiry approach which is what the new curriculum is geared towards and I like that a lot…. So much more is coming from the kids and I'm hearing more about what their knowledge already is and they're taking it in directions I hadn't thought of.

MM: Trying to stimulate that in the kids to start speaking out and asking questions. Just to wonder.

What don't you like?

NN: I dislike having to coax people into trying to do stuff.

MB: it's a little bit more labour intensive because you have to prepare all your own materials, set up your labs, you have to clean up, as opposed to just coming into your classroom and just talking about a topic like in social studies but with interactive activities there's a lot more materials that you're using.

NG: In the curriculum there's certain areas that I always thought were boring…. physical science.

MM: I think one of the things I find most frustrating is how so many publishers create a textbook completely based on the curriculum set by the Ministry and teachers are completely focused on teaching that program

Important skills:

NN: I guess the one skill or maybe it's a habit of mind that you might need to persist a little bit through some discomfort in learning something.

MM: How to properly formulate a question.

Role of a textbook:

NN: it's good to have an artifact in front of you that everyone can reference and have a common understanding around so if you don't understand, you can go back.

MB: We don't use textbooks in our class…. Our school has gone with the decision, partially environmentally to go with less paper and we're trying to avoid the photocopying which unfortunately for newer teachers is sometimes difficult, it's nice to have that back up, nice to have that resource, that textbook, so our textbook is more of a resource if they have to look up some material.

NG: Interesting because we haven't had textbooks in forever. I have no idea the last time we used textbooks.

MM: It provides your basal information for the curriculum that you'd be teaching…. it's a safe resource. They know it's covering the curriculum. They know if they just do that the learning outcomes are going to be met.

What do you use a textbook for?

NN: Well for key vocabulary definitely. I find the typical textbook doesn't have enough information in it so you do have to do some extra…

MB: we … try and use the library when we can and primarily we do a lot of computer-based research.

NG: I don't know if they need it but I think it would be helpful for them to have materials that help them consolidate and there are in other subject areas… there are in life sciences for example… but physical science, there's not that much

What do you think about science as a body of knowledge?

NN: That would be the transmission model. That you as the science teacher, you have the body of knowledge, I don't, and we're just gonna move it and we're not gonna construct it together.

MB: That's what I think a lot of the parents would consider, the students would consider that as well that science is a body of knowledge and there's a certain amount of material, here's my book, that's the material, there's what I have to know about science, or the chemistry or the biology.

NG: Yes, I like that because it's easy to teach.

MM: Well I think for teachers without a science background it would be intimidating to walk into because it's a body of knowledge that they don't have in their own backpack. All of a sudden they're gonna cling to the easiest resource which is the case for teachers who I have seen because that's gonna be a safe source, it's not gonna be wrong, they're gonna trust that as being a primary source of information….. It seems straight up like memorize this information, they are the facts, here's the test, we're recording data. It's not going to promote creative thought, stimulate thinking like I wonder what else could happen?

How do you/would you promote science as investigation?

NN: Well I promote it right now, like what we are doing right now, is promoting the observable.

NN: we just talked about what's Google-able and what is investigateable, what we can do on your desk and you can show everyone what you are doing.

MB: Quite often we start off with that. Almost the first day of lessons… the scientific method is a great way to start off our junior science, you know, let's explore which brand of cereal has the most iron in it…. Yeah, not just regurgitate a bunch of facts but come to a problem or an idea or a question with an idea of how to explore that. And very basically, by going by the scientific method. This happened, so how can I explain that? Or how could I test that out?

NG: Doing this inquiry approach. I'd say yeah, it's making a huge, huge difference. But previous to that, no, they didn't get to investigate, at all. Not nearly enough…. I couldn't figure out how before I did a few inquiry workshops and now I'm Oh! This is how I can get the kids to investigate more. How to investigate and still have it going somewhere in particular that's gonna meet particular objectives.

MM: I know when you look at the textbook, the investigation either comes at the end of the body of knowledge section, like here's the facts, let's investigate this thing but the investigations seem really hokey like they've seen them before on Saturday morning science shows so they already know what the answer's gonna be…. But if the kids wonder about it and you start throwing out what about this? What about this? If the kids come up with a question even if you know what the answer is this where the positive reinforcement of yeah, ask the question comes in. Yeah let's look at that. How hard would it be to find that answer? What do you think, could we test this? Have you ever tested it? Has there been consistent outcomes? For authentic, they genuinely want to know.

How valuable do you think science is as a way of thinking or as a way of knowing? How would you promote it?

NN: I think that's something that would be important to me, a solid basis in science makes you a better citizen.

MB: it's extremely valuable because I think a lot of the innovators are those people who are able to think outside of the box and are able to think like scientists…. More of those science challenges, paper has only this much strength, give you something, let's see where you go with it…. More in terms of fascination and interest is the way we could promote

NG: I've never thought about it before…. They would be questioning, they would be thorough, they would test things, they would want to find out… collaborative comes to mind… they would want to find out what other people are learning and thinking and compare.

MM: I think just having the kids go through understanding the scientific process. Being able to come up with a hypothesis, gather the materials, walk through the procedures, what are the results, what can we say about the results.

What's your understanding of the interaction of science, technology and society?

NN: I think it's crucial that kids are able to negotiate that scientific information easily and well…

MB: Technology is something that we use within our society a lot and we take advantage of to make our life better or easier or more efficient and a lot of times there's a connection to science through research…. Definitely should not be taught as this is right and this is wrong but as a valuable way of exploring ethical issues and making your own decision which is the way we should be exploring at school.

NG: (Do you discuss this with kids?) No. Not at all.

MM: I bring up scientific achievements. I try and find things that young kids have done. And talk to them like, these are kids that are a little bit older than you. They're really not that old. But this is something that I think you should know about. And the technology of hearing with the FM that's something where every class in my school has one.

Those four views of the nature of science, how would you rank them relative to each other in terms of importance?

NN:

MB: I'd say personally science as a way of explaining and exploring and researching topics is the way I would prefer to do it.

What do you think gets emphasized in classroom teaching?

NN: they are getting knowledge first. Because for elementary, that's the easiest thing to just transmit. I can transmit information. And then the skills. But maybe I'm not as good at teaching the skills.

MB: Unfortunately, it's a body of knowledge is gonna be number one or two because the end goal is kids looking for university and they want a high grade and the content is gonna get them there.

What sort of support do you need to teach like you want to?

NN: We’re pretty focused on the skills of science. That’s what they need the most help with, they feel, how are we going to set up this scientific inquiry? How are we gonna get it done?

MB: I think what we don’t need is somebody giving us a book saying, here’s how to do it, it’s more a chance to collaborate with colleagues and Ministry officials who have ideas and other professionals within education and give us opportunities to get together and not as a single pro d day but as a learning team that meets together over a year once every two months and having that opportunity to get together to develop some resources together and share with your colleagues around the province or the country.

NG: need more workshops and more information. And I just need to experiment more because it’s a whole different way of teaching and I’m going into a place where I don’t know for sure where this is gonna go. Experimenting with discomfort.