# Constitutions of Nature by Teacher Practice and Discourse in Ontario Grade 9 and 10 Academic Science

By Darren Glen Hoeg

A thesis submitted in conformity with the requirements
for the degree of Doctorate of Philosophy of Education

Department of Curriculum, Teaching and Learning
Ontario Institute for Studies in Education
University of Toronto

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## Abstract

This thesis presents an ethnographic study, based broadly on principles and methods of institutional ethnography, on the constitution of nature by nine Ontario Grade 9 and 10 Academic Science teachers. The intent of this methodological approach is to examine how the daily practice of participants works toward constituting nature in specific ways that are coordinated by the institution (Ontario public school and/or school science). Critical Discourse Analysis and general inductive analysis were performed on interview transcripts, texts related to teaching science selected by participants, and policy documents (i.e. curriculum; assessment policy) that coordinate science teacher practice. Findings indicate specific, dominant, and relatively uniform ontological and epistemological constitutions of nature. Nature was frequently constituted as a remote object, distant from and different than students studying it. More complex representations included constituting nature as a model, machine, or mathematical algorithm. Epistemological constitutions of nature were enacted through practices that engaged students in manipulating nature; controlling nature, and dominating nature. Relatively few practices that allow students to construct different constitutions of nature than those prioritized by the institution were observed. Dominant constitutions generally assume nature is simply the material to study, from which scientific knowledge can be obtained, with little ethical or moral consideration about nature itself, or how these constitutions produce discourse and relationships that may be detrimental to nature. Dominant constitutions of nature represent a type of objective knowledge that is prioritized, and made accessible to students, through science activities that attain a position of privilege in local science teacher cultures. The activities that allow students to attain the requisite knowledge of nature are collected, collated, and shared among existing science teachers. Activities are adapted to meet the knowledge requirements of the curriculum, which is institutionally coordinated by a system of management, based on accountability and performance. Thus, teachers come to see teaching practice that 'works' as contained in those science activities that engage students in learning nature as a specific representation (model/machine) or through science methods that control students learning so that they arrive at the correct knowledge. This allows teachers to assess and evaluate students' acquisition of the institutionally valued knowledge of nature. This system of coordination is sustained through discourse that enables teaching practices that aligns with institutional priorities of measuring performance, while at the same time, limiting teachers from being able to conceive of other teaching practices that might enable different constitutions of nature.

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# Chapter 1 : Nature in Ontario Grade 9 and 10 Academic Science

*What a piece of work is a man! How noble in reason! How infinite in faculty! In form and moving how express and admirable! In action how like an angel! In apprehension how like a god! The beauty of the world! The paragon of animals! And yet, to me, what is this quintessence of dust? Man delights not me: no, nor women either…* (Shakespeare, Hamlet, 1602/1992, p.32)

In this doctoral thesis, I present an ethnographic inquiry on how nature is constituted by teacher practice in Ontario Grade 9 and 10 Academic Science courses. In other words, I inquired as to how teachers speak and the types of lessons and approaches they enact in the classroom, and how these produce certain conceptions of, and human relationships with, nature. The way nature is constituted in school science is an important consideration, since science can be said to be about 'natural' phenomenon (Cobern & Loving, 2001). Relationships between humans and nature, therefore, define what and how humans, including scientists, perceive of the material and natural world (Harding, 1991). A system of Euro-centric scientific knowledge has been constructed around a relationship in which the human is viewed as separate from, dominant over and in control of nature (Cobern, 1991). Science knowledge can therefore be viewed as a originating from a socio-culturally constructed, human-centered, view of nature, and criticised on this basis. Learning this system of knowledge has been a priority in Euro-centric school science, potentially inculcating in students the same socio-cultural orientations to nature foundational to constructing this knowledge in the first place (Bowers, 1997). A human centered perspective foundational to scientific and modern discourses has remained an invisible background in many academic disciplines, left intact and unquestioned. Human-centered interests empowered by these discourses are seen by many scholars (e.g., Bowers, 1997; Dryzek, 1997; Orr, 2004) as initiating and sustaining environmental problems that threaten nature. There are therefore questions that must be asked about the effects of human-centered discourses in school science.

### The Bees

The following story may serve as an introduction to my interest in the constitution of nature by science, and school science. Over the summer of 1998, I worked as a lab assistant for Agriculture

Canada studying crop pollination of low-bush blueberries in the Annapolis Valley of Nova Scotia. This valley is Nova Scotia's most fertile and productive land, a flat plain surrounded by the Bay of Fundy on one side, and the low lying Appalachian mountains in the provinces interior on the other. I was conducting research to determine if honey bees were pollinating indigenous low bush blueberry. My task was to collect the pollen from bees returning to the hive after their morning nectar harvest. I wore a bee suit, the thick, white cotton garment that protects the bee keeper from being stung, a pair of thick leather gloves, and carried a 'smoker', which burns charcoal to produce a thick smoke that acts as a mild sedative, calming the bees. I had the scientific equipment I needed to do the job; a notepad, some plastic bags, vials, and a magnifying glass. The types of pollen collected were to be identified in the lab at the research station later, thus determining if the bees were pollinating the blueberry.

Although I understood the importance of this research, I was not enthusiastic as I approached the bee colonies that morning. Although lead scientist made light of the task, I had worked with bees enough that summer to understand that it would not be as easy as she claimed. I had to collect 20 pollen 'sacks', the visible, colorful bulb of pollen the bees carry on their hind legs. This meant sampling 20 bees, 10 times per bee colony, in 20 different fields over the next 2 weeks. Upon arriving at the blueberry field, a remote area with no sign of human presence, I parked my vehicle near enough to the bee hives so I could quickly leave, should I 'lose control' of the situation.

I could see several hundred bees circling the colony, waiting their turn to enter a hive, like airplanes circling an airport until a gate was available. There was a low, powerful buzz, reminding me of a resonant note from a large pipe organ in a church. It was the life-sound of thirty to forty thousand busy and seemingly content animals; a sound that was about to turn menacing. To collect the pollen, I had to squat near the hive entrance and grasp the returning bees with my fingers before they entered the hive, rubbing the pollen off their legs into glass vials. After inundating the hive with smoke, I grimly went about my task, taking position in front of the hive, my right hand positioned near the hive entrance, a specimen vial in my left hand. I grabbed a bee, and found that I had to break its hind legs in order to remove the pollen. Upset at myself, I sympathetically crushed the animal between my fingers, admonishing myself to be more careful next time. I grabbed the second bee, more gently, but still, unintentionally, killing it between the thumb and forefinger of the thick, cumbersome leather gloves. The sound of the colony seemed to change subtly, increasing in pitch and intensity, becoming alarming. A drop of sweat fell from my brow, and I looked longingly toward my vehicle. Reaching for another bee, I gauged the grasp correctly, only giving it an uncomfortable squeeze while taking the pollen and releasing it. However, the bee did not appear to appreciate my concern, and aggressively responded by trying to sting me through the gloves. The hum of the colony grew louder, the low pipe organ reaching a higher octave. I looked upward, and the air appeared thicker, with thousands of bees circling the hive. Anxiously I grasped another bee, again crushing it between my fingers in my haste to complete the task. I was then shocked when something hit me forcefully in the head. Unable to identify the object, I continued, collecting pollen from another bee, which managed to sting me in the finger through the seams of my gloves. I felt and heard the 'patter' of another object hitting me in the head. I realised these 'objects' were bees, circling the colony, that had organizing an aerial attack against me. Over the next 10 minutes, hundreds of bees gave up their lives to eradicate the threat they detected in their colony. Several were able to wedge their way into my suit, through seams I had not sealed well enough, or thrust their posteriors with enough force to drive their stingers right through the suit, into my flesh.

I felt as an intruder in an alien and uninviting world. I observed intelligence, and previously unrecognizable aspects of the' life' of the bees that I had not observed before, and certainly was not there to investigate. I was an objective, rational scientist, in the field simply to collect useful data about measurable and known phenomenon that would contribute to berry crop production, and therefore the betterment of (some) humanity. Yet, the bees suddenly seemed to have previously un-perceived qualities and characteristics that I could not measure or quantify, even, perhaps, a form of consciousness. I was supposed to be in control. Nature was supposed to bend to my will. Never had I felt so in awe of nature, and never had I felt so out of control of, and dominated by, nature. This role reversal, the new relationship I had with the bees, made me aware of intelligible essences (Aikenhead & Ogawa, 2007) I had not perceived before. The value I had for the bees changed, from one of scientific utility, to reverence for a powerful living organism with its own sense of agency and purpose. I had no scientific understanding to account for what I observed that day, and I realised perhaps I never would. I ran back to my car, chased by hundreds of bees. I was in panic, and feeling very alone due to the sense of disconnection I felt to civilisation in the alien world of the colony, and the knowledge that there were several thousand living creatures there whose immediate purpose was to eradicate the alien threat to their colony. I left the field quickly, chased for several miles in my car by the bees, but relieved that I had escaped that foreign world; that was, until realised I had 20 more fields to sample over the next two weeks.

This still vivid experience exemplifies how nature known through science was quite different from the natural inquiry I did as a child, exploring forests and streams around my home in suburban Halifax. In these explorations, my structured social existence was forgotten as I became lost in the interconnection I felt with nature during these experiences. I was another animal roaming the forest, engaged with nature and sensing the connected web of life of which I was an intrinsic part. I sensed there was a complex reality beyond what I could perceive or understand, yet I respected its mystery. Unfortunately, such experiences are becoming infrequent, as societies become increasingly urbanised (Latour, 2004).

In modern cities, many forms of nature are too remote to for citizens to be in frequent contact with.

My interest in nature helped me to excel in school science, yet I was never fully content as a science student, feeling my personal experiences overshadowed and seemed more authentic to me than the often abstract and reductive depiction of nature in school science, which represented an artificial and deficient experience in comparison. I grew to realise as I advanced in a university biology degree that science is based on what I considered a particular perspective on nature; a primarily unidirectional perspective from a human observer (the subject) with particular utilitarian interests towards nature (the object). Science told me that I could know nature by reducing it to its fundamental parts in order to understand the whole. Yet, in most of the scientific research in which I was involved, I realised I was manipulating nature to tell the story that I had pre-designed it to tell; the positivistic protocols of scientific observation and experimentation were privileging certain human valued aspects of nature while being disinterested in or incapable of producing other knowledge of nature.

An opportunity to teach school science presented itself, and I was attracted by the chance to develop science experiences that might be more meaningful to students than I received. Yet, the culture of school science was resistant to change, and disciplinary and professional expectations communicated to me through conversations with teachers, documents on professional conduct, the curriculum, and textbooks, seemed to reproduce the familiar and traditional type of science education that I was trying to change. Perhaps even more constraining than these texts, however, was my own inability to understand and practise science in ways other than that I was taught; to view nature through a human-centered perspective, to understand nature as a sort of machine that could be understood by reducing it down to and examining its smallest parts; that humans were in a dominant position over nature, giving us the moral authority to view it as a resource that we can control and use for our own purposes. Although I developed a science programme throughout my career that strained against the boundaries of school science, I never was able to exceed those boundaries. I realised both my own indoctrination as a science student, as well as my socialisation in a society that places high value on scientific ways of knowing were at the root of my inability to see how school science could be different. I observed similar phenomenon in the preservice science teachers I investigated for my Masters degree; although they wanted to implement lessons and teaching approaches that would overcome some of the incompatibilities of school science with environmental education, their vision of what was possible appeared to be constrained by reproductive elements in school science. It was in this research that I first became aware of reproductive social coordination of education. Further academic inquiry on social reproduction of nature in science education during my PhD degree has been the impetus for the doctoral study I am outlining here.

**School Science in Ontario and Nature**

Paul Hart (2003) suggests that children's school experiences act to shape their personal relationships with the social and natural world, and that these relationships frame their sense of responsibility to each other and nature. Since science is usually the 'default' school subject in which nature is taught (Steel, 2011), it is important to understand how students come to know nature in school science. Ontario school science is presently infused with goals to "educate all students about "the scientific and human dimensions of environmental issues" (MoE, 2008, p. 34). Commitments to Science, Technology, Society and Environments (STSE) and nature of science (NOS), signal commitments of the Ontario Ministry of Education to environmentally-minded science education reforms. STSE is a curricular domain focused on the relationships between science, technology, society and environments. This domain seeks to make often invisible STSE relationships apparent to students, enabling positive social and environmental agency. NOS inquires into cultural and sociological aspects of science, so students can gain understanding of what real scientists do, as well as the scope and limitations of science. The understanding how nature is constituted through school science practices fits squarely within NOS scholarship. These reforms could engage students in activities seen as beneficial to environmental sustainability, such as, for example, learning about nature outdoors, where students might develop inclusive and sustainable relationships with it (Hart, 2003; Orr, 2004). However some reports claim these reforms are poorly represented in many science classrooms in Ontario (Hoeg & Bencze, 2015; Steele, 2011), making it unclear whether reforms are effecting environmentally oriented science education for students.

Science education seems resistant to change, partly because of adherence to traditional research methods of science (Aikenhead & Ogawa, 2007; Hodson, 2009). These methods position nature as subservient to and separate from the individuals who study it, a relationship characteristic of *anthropocentrism.* Anthropocentrism, generally speaking, can be said to be orientations that place value on human concerns, issues and priorities, above all other, including nature (Kearny, 1984). Anthropocentrism appears to be a foundational assumption of modern Western science (Aikenhead & Ogawa, 2007), and science methods based on anthropocentric orientations produce scientific knowledge that describes, classifies and quantifies nature as an object (Harding, 1991). This is not the only way to know nature, however, and this constitution of nature can be in conflict with apparently more inclusive views of nature present among young students (Yoon, 2005). Also concerning is that orientations privileging and valuing the human, and devaluing nature, appear to be foundational to environmentally detrimental behaviours (Bowers, 1997). Many scholars suggest that science education based on anthropocentric ways of knowing nature may propagate socially and environmentally detrimental orientations (Bowers, 1997; Orr, 2004). *Naturecentrism*, usually posited as opposite to anthropocentrism in a spectrum of human orientations to nature, is more holistic, including humans as an interrelated part of nature, not separate from and dominant over it. Science education that includes nature-centric perspectives has been endorsed by scholars (e.g., Southerland, 2000; Taylor, 2010) as a means to foster socially and environmentally beneficial orientations, such as an appreciation of nature, communality instead of independence, and cooperation rather than competition. Naturecentrism in school science, in the extreme, might mean a turning away from practices that objectify nature, and instead allow students to engage with nature in ways that allow them to construct different forms of knowledge about nature than those that are typically valued in science, such as aesthetic, emotional and spiritual forms of knowledge (Southerland, 2000). More practically, the inclusion of some of these types of practices may work towards improved relationships with nature for school science students.

The ways nature is constituted by humans can be understood as sociocultural constructions; that is, as social phenomenon created and sustained by human interaction (Dryzek, 1997). In this study, I consider anthropocentrism and naturecentrism as reproductive sociocultural phenomena. That is, these phenomena can be thought to be a result of "mutually sustaining mental schemas and resources that empower and constrain social action and that tend to be reproduced by that social action" (Sewell, 1992, p. 19). A more specific sociocultural perspective from which to look at this phenomenon is as discourse. Discourse can be defined as systems of knowledge and practice that construct reality and provide a shared way of understanding the world, "producing meaning, forming subjects and regulating conduct within particular societies and institutions, at particular historical times" (MacLure, 2003, p. 175). Resources, such as curricula, textbooks and teacher texts, are the material manifestations of reproductive phenomenon such as discourse. Interpretation of resources may act to (re)produce the same systems of knowledge and practice embedded within them; however variable interpretations of meaning can, potentially, disrupt this reproduction (Sewell, 1992). Theorizing the constitution of nature in school science as a sociocultural product provides theoretical leverage to explain how agents in science education, such as professionals writing curriculum, developing textbooks, and teachers interpreting and enacting them, might be involved in changing these social constructions.

## Research Questions

In this research, I inquire about how nature is constituted by nine Ontario Grade 9 and 10 Academic Science teachers. The research question guiding this study is: *How is nature constituted by Ontario grade 9 and 10 academic science teachers through discourse and practice?*

Supplemental questions that this research aims to answer include:

- What epistemological relationships are present in the way nature is constituted by participants' practices and discourse?
- What ontological representations of nature are prioritised in participants' practices and discourse?
- What is the social organisation of Grade 9 and 10 Ontario school science, and how does this organisation influence teachers' practice related to how nature is constituted?

## Audience and Scholarly Contribution

The research findings, conclusions and implications in this thesis may be seen as largely critical of Grade 9 and 10 Academic schools science, and school science more generally, and therefore adheres to critical theory. Critical theory allows for the identification of power structures and to explain how power marginalizes or empowers (Habermas, 1971). I use a critical perspective to interpret how the constitution of nature in teaching practice represents sites of power that potentially privilege certain ways of teaching and speaking, while marginalising others. Criticism is done with the intention of understanding how certain school science practices produce certain constitutions of, and relationships with nature. This knowledge can then be used to broaden the discourse in NOS, increasing the scope of accepted teacher and student activity related to nature, with the intent to improve school science education.

The contribution of the research described in this thesis is primarily to scholarship in science education. More specifically, the research contributes to the already large body of scholarship on NOS, however, the unique addition my research makes is bringing to the fore nature, and how nature is discursively and practically constituted by science/school science activity. Infrequently, if at all, has the way nature is constituted by school science activity been evaluated explicitly. The research also should be of interest to those in fields of environmental education. School science is a primary location of environmental education (Steele, 2011), and therefore inculcates environment dispositions in students that may have variable influences on their interactions in the environment. This thesis also contributes, to a lesser extent, to fields of sociology of education, as there is a significant research focus presented on how institutional discourses works toward coordinating how nature is constituted by teacher practice.

## Reading the Study

The study of how nature is constituted in Ontario grade 9 and 10 Academic school science begins in chapter two, which presents a review of pertinent literature. This literature review summarises various ways humans understand ‘nature,’ relationships between humans and nature, and how these may have changed over time as human populations have become increasingly urbanised and engaged with technology. This chapter is expansive to communicate how deeply embedded questions of nature are within most contemporary discourses and disciplines. The second part of this chapter describes literature focusing on constitution of nature in school science, particularly Nature of Science (NOS), the domain of science education most pertinent to the findings of this thesis. A review of NOS literature is provided, specifically how nature is included in conceptualisations of NOS, suggestions for teaching NOS, the relationship between NOS beliefs and teacher practices, and a description of NOS practices relevant to studying nature. This chapter concludes by examining discourses in school science and their relationship to nature.

Chapter three discusses the methodology used in this study to answer the research questions. This includes how perspectives of institutional ethnography can be used to understand how participants’ teaching practices constitute nature. This chapter presents information on how participants were selected, and data was collected and analysed. Details are provided on the development and evolution of interview protocols, and the tools of data analysis. These include the methods of analysing interview transcripts and relevant texts through general inductive analysis and discourse analysis.

Chapter four presents a short biography on each participant relevant to teaching science and nature. This chapter also discusses the institutional context, providing details about the curriculum, assessment policy, and science teaching practice. I’ve provided discussion about dominant discourses related to teaching in Grade 9 and 10 Academic Science. This provides insight into the dominant conceptions of how participants are expected to do their job as science teachers. Dominant discourse related to teacher practice, such as lecturing, inquiry, and performing cookbook labs, is presented.

Chapter five is the first findings chapter. This chapter answers the research question: *What epistemological relationships are present in the way nature is constituted by participants' practices and discourse?* Results are presented through claims made by participants about their practice, and relevant teaching texts engage students in physical interaction with nature. This chapter identifies how teaching practices work to engage students in knowledge production related to how they should come to know nature. Analysis focuses on how these interactions constitute nature, what kind of knowledge is produced, and the institutional value of this knowledge.

Chapter six is the second findings chapter. This chapter answers the research question: *What ontological representations of nature are prioritised in participants' practices and discourse?* Results are presented through claims made by participants about their practice, and relevant teaching texts, which constitute specific ontological representations of nature. Analysis of data focuses on demonstrating how teaching practice can result in specific ways of understanding what nature is. Analysis focuses on ontological knowledge produced, and the utility of this knowledge to school science.

Chapter seven is the last findings chapter. This chapter answers the research question: *How does the social organisation of Grade 9 and 10 Ontario school science influence teachers practice related to how nature is constituted?* Results are presented through claims made by participants about the institutional apparatus that influences their practice. Analysis focuses on the institutional coordination of teacher practice through text found in curriculum and assessment policy. This chapter connects the findings in chapters five and six to institutional mechanisms of control to demonstrate how school itself coordinates how nature is constituted through teacher practice.

The final chapter, chapter eight, discusses the findings, presents conclusions, and identifies implication of the research. Discussion is focused on five central conclusions resulting from the research. Suggestions for Ontario school science reform, based on the results of this research, are discussed.

# Chapter 2 : Conceptions of Nature and School Science

How nature is constituted by humans results from socially constructed relationships we have with nature (Boddice, 2011). In thinking about what nature-human relationships mean, we might define these as links or connections between humans and nature, the interaction between humans and nature, the place of humanity in the nature of things, and the activity that occurs therein (Boddice, 2011). This simple definition, however, is stripped of its history that, when reviewed, demonstrates its foundation in nearly all Western systems of thought (Nimmo, 2011). This chapter provides an expansive, but not exhaustive, review of some of philosophical scholarship on nature, to orient readers to the deep embedded-ness of nature in language, disciplines and worldviews. Considerations of nature are not only of importance in science and school science; human conceptions of nature are influenced by diverse social institutions (Catton & Dunlap, 1980). It is important to recognise how aspects of social life outside of school may also have had bearing on the way science teachers participating in this study enact practices constituting nature.

The word human derives from the Latin, *Homo sapiens*, which itself is derived from Linnaeus' original classification for human (1735/1964), *Homo nosce te ipsum* – human, know thy-self. The Latin translation implies that humans are outside of the canonical anatomical classification schemes used for other forms of life, and instead exists solely in the human capacity to distinguish itself from non-human (Agamben, 2004). This distinction erects a dualism, whereby the human is viewed as unique and fundamentally different from non-self, which is all else in nature (Coburn, 1991). Historically, humans were seen as existing in relation to deities rather than to nature; it wasn't until late antiquity in which animals became the template against which humans were defined (Sax, 2011). In its early uses, the word human was used not to connote what we now call a species (*Homo sapiens*), but instead an experience of transience and vulnerability. During the Renaissance, as humans embraced new technologies and cultural products used to harness and utilise nature, the concept human came to encompass a sphere of existence opposed to nature as a whole (Nimmo, 2011). This succession occurred through the acquisition of new meanings without relinquishing the old, becoming increasingly rich, complicated and elusive.

Just as human has come to mean what it is not, nature has come to be defined by its relationship to humans. Nature is something other than human; nature is the *non-self* in a *self-non-self* dualism established throughout human self-discovery, or the *other* in an analogous *self-other* dualism (Cobern, 1991). To put this another way, nature becomes the object in a *subject-object* dualism defined by the human subject. Nature thus need not be described in any terms other than through the common element of it not being human. However, as a concept, nature has also undergone an accretion of meaning; animal was the original opposition, used to connote something like humans, but different in some significant way (Derrida, 2008). The word animal has come to mean something wild, savage and untameable, the opposite to human values of civilisation, rationality and control. The concept animal also holds meanings of longing and desire, for in animals we see a strength and freedom that humans do not possess, leading to oppositional meanings of human as being frail, incomplete and controlled (Plato, trans. 2008). According to Plato, the human drive for dominance is thus a defensive response of our perceived frailty and vulnerability in the face of nature. In early modernity, science provided a biological basis for the separation of humans from nature by defining a species as being distinct due to its inability to reproduce with non-members of a species. The most enduring feature used to distinguish humans from animals has been language; humans use complex language, other forms of nature do not. This distinction was made first by Aristotle, and was refined by Descartes[1] (trans. 2007). The remainder of this chapter will discuss the following topics: Humanity and nature; Nature and modernity; Nature in modern Western society; Nature in science, and; Nature in school science

[1] although this condition has been modified in recent times to the production of symbols, in recognition of animal communication

**Humanity and Nature**

While remaining sensitive to issues of historical determinism[2], we can interpret how certain events in human history may have influenced modern nature-human relationships. For example, Shepard (1992) claims that modern nature-human relationships - which he conceptualizes as a kind of "madness" - partly stem from the invention of agriculture 10,000 to 20,000 years ago, essentially causing the loss of developmental practices that once allowed humans to live in harmony with the natural environment. Shepard (1995) argues, "In the captivity and enslavement of plants and animals and the humanization of the landscape itself is the diminishment of the Other, against which people must define themselves, a diminishment revealing schizoid confusion in self-identity" (p. 37). This change in relationships between nature and humans is characterised by the use of technology to 'exploit' nature for human consumption; previous to this, claims Shepard, tools, which are a form of technology, simply allowed humans to sustain a mutually beneficial relationship with nature by taking from nature only what was needed for survival (Shepard, 1995).

Several related theories posit early Western European forms of Christianity and its interpretations throughout history (that have since come to dominate), as influential in the separation of humans and nature. Lynn White (1967), in his famous essay on the origins of the ecological crisis, claims the Christian doctrine of the creation sets humans apart from nature, advocates human control of nature, and implies that the natural world was created solely for our use. For example, passages such as this in Genesis: "Be fruitful and multiply, and fill the earth, and subdue it; and have dominion" (Genesis 1:28), supports White's thesis. Medieval Christian Stoic scholars, such as Saint Thomas Aquinas and Saint Augustine, further reified human dominance over animals, writing "human beings are superior to animals; and animals, like all other non-rational beings, exist to serve us in our weakness" (St. Augustine, trans 1993).

The influence of these Christian values in medieval times may have permitted social systems that required increasing utilisation of the land to provide for consumptive human needs (Attfield, 2012). "No more fundamental change in the idea of man's relationship to the soil can be

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[2] the belief that historical, and by extension present and future, events unfold according to predetermined sequences

imagined: Once man had been a part of nature; now he became her exploiter" (White, 1967, p. 56). According to White, the development of the heavy oxen-plough, which enabled more extensive farming systems, was the vehicle of this exploitation. A succession of technological innovation during the middle ages and beyond appear to have led to ever-increasing utilisation of the land and dominance over nature, with a corresponding widening separation between it and humans.

The human construction of nature through taxonomic ordering during the Enlightenment also appears to have influenced human separation from nature. According to Horkheimer and Adorno (1976), ordering the natural world allowed humans to increase separation from nature, form order into taxonomies, rank all life forms accordingly, and then study it, alleviating mans fear of the random, unpredictable, wild and unknown. Adorno claims how humans have since acted toward nature (and each other) has been dependent on how these taxonomies have been constructed. Foucault (1966/1994) problematizes order by showing that all orders can be reordered, as illustrated by his famous example of a fictional Chinese dictionary entry where animals are ordered in alternative ways (p. 182). The construction of order is shown to be problematic when taxonomies are contested. Instead of a 'real' order to nature, criticism of ordering identifies a political origin in its construction. Criticism makes visible the marginalising tendencies of taxonomies, and reveals the privilege granted to the minority that ordering enables.

Neil Evernden (1992) dates the modern difference between humanity and nature to the Italian Renaissance, when scientists expelled putative human qualities such as meaning and purpose from natural processes. Evernden claims this facilitated the exploitation of the environment, thus preparing the way for the Industrial Revolution, when rapid technological development drew humans closer to a more thorough connection to human-created objects and environments, and complete disconnection from nature. Electronic technology has come to replace animals as our anthropomorphic objects of attention, substituting a link to nature with a deepening link to human technology (Evernden, 1992). Some scholars (e.g., McKibben, 1989; Latour, 2004) have declared that humans are in an era in which complete disconnection from nature, at least philosophically (consciously/mentally) if not biologically, is possible, and progressing toward a reality. For example, McKibben (1989, p. 32) has predicted the "end of nature" through the global export of technology to remote corners of the globe.

The historical development of a human-centered or anthropo (human)-centric view described above has come to dominate Western systems of thought (Boddice, 2011; Nimmo, 2011). Anthropocentrism is a normative concept that embodies or expresses, whether implicitly or explicitly, a set of beliefs, or attitudes that privilege some aspect(s) of human experience, perspective or valuation (DeLapp, 2011). Our relationship with nature therefore occurs via how we perceive it, how we define it, and how we use it. The meanings and values attached to the words human and nature have come to define the relationship between these concepts.

Humans are anthropocentric creatures among nature; we are human, we see as a human, and it may therefore be impossible to view the world around us non-anthropocentrically. How can we know, as a human being, the perspectives of non-humans, who cannot communicate with us in the symbolic forms we currently use to make meaning? Yet, privileging (or being bound by) the human perspective does not necessitate a view of ourselves as fundamentally different than, superior to, and dominant over nature. Although these views have become synonymous with anthropocentrism, technically they may be more appropriately termed *anthropocentrist* orientations (Boddice, 2011). Anthropocentrist orientations represents the negative political orientations toward nature that are largely attributed to anthropocentrism, such as devaluing, deposing and marginalising nature, while elevating the value of the human. In this thesis, I suggest anthropocentrist orientations must be addressed in school science, and society in general.

## Nature and Modernity

Modernity can be viewed as, instead of a period of historical events (although it is also this), a “form of order, an ontological and epistemological formation that directs a related set of ways of seeing and knowing the human and the world” (Nimmo, 2011, p. 60). This related set of knowing has come to be called *humanism*. Modern discourses can be viewed to be united in their preoccupation with the place of humanity in the nature of things; even in their divergence, it is this common ground that underlies modern discourses (Latour, 1993). The modern view sees humans as the source of all meaning and value, the agents in all action, “the eye in the storm of existence itself” (Nimmo, 2011, p. 59). Humanism is not necessarily the same as anthropocentrism, however, as humanism connotes positive and celebratory aspects of what it is to be human, whereas anthropocentrism, in its common usage, foregrounds the negative aspects associated with privileging the human, such as neglecting the significance of non human others (or nature).

It has taken considerable intellectual and philosophical effort to maintain the distinction between humanity and non-human others, as the very nature of the subject (human) and object (non-human other/nature) must be in a dialectic; the object can only become an object when perceived as such by the subject, and the subject can only exist in a world of objects irreducible to subjectivity. Humanist discourse suppresses this dialectic, however, rendering it an asymmetrical dualism by making humans and non-humans irreconcilable ontological categories. This makes it possible to centralise and elevate the human, while the necessary other – nature – is suppressed and marginalised, relegated to context, or diminished to simply the ground upon which the dominant human stands. This dualism has manifested itself ontologically and epistemologically in the foundational disciplines of Western thought and knowledge (Nimmo, 2011). The split between nature and human is most apparent in the split between the natural sciences, which takes as its subject of study nature, with the humanities, which are concerned with all things human (Winch, 1990). We thus see analogies to the human-nature dualism in, for example, anthropology, where a culture-nature dualism defines the discipline, and in sociology, which has developed around a society-nature dualism (Nimmo, 2011).

## Nature in Contemporary Western Society

Embedded in contemporary Western discourses is the notion that humans have largely separated themselves from, and placed themselves in a dominant position over nature, and this determines how many people think about environmental issues (Slack, 2008). This thinking allows humans to perceive themselves as superior to the "Other" natural world and ultimately in control of it. "The tenacity of the binary is tenacious" (Slack, 2008, p. 480). The nature-human dualism creates a number of binaries influenced by cultural systems and practices, such as; language (Jung, 2001; Muhlhausler & Peace, 2006), science (Haraway, 1989, 2007), governance (Anderson, 1997; Huckle, 2008), and consumer habits (Baudrillard, 1998; Dauvergne, 2008). For example, in the English language, the very act of using the words *nature* and *human* objectifies these entities, and the conjunctions (for example, *and*, *or*) used to structure these objects in a grammatically correct sentence necessarily separates them. There are few ways to represent an interconnected relationship between humans and nature in the English language; those that do are not commonly used, and appear grammatically awkward and are therefore not taught (Muhlhausler & Peace, 2006).

Haraway (2007) further articulates the limitations of dualistic thinking by describing how humans and nature are in fact not separate but instead intricately "bound up in knots" (p. 5). Yet, the very discursive systems that humans engage in, such as those in science and school science, work to maintain the separation of nature and humans (Boddice, 2011). Notions of human and nature are constructed from the assumption that difference exists; difference then calls for a hierarchical arrangement of that difference, which then calls for control based on that hierarchy. Stibbe (2001) argues that dominant discourses and ordering systems have allowed humans to put themselves above animals, creating a common sense aura that normalizes animal subjugation.

Additionally, human power over the natural world has been linked to human control and subjugation of other humans. Sztybel (2006), for example, identifies thirty-nine similarities between how Nazis perceived and acted toward subjugated people during the Holocaust and how humans treat animals in modern-day industries. Cronan (1996) provides an example of this in the construction of "virgin" and "pristine" places in the United States, during which the government ejected Native American people and placed them on reservations.

Modern discourses of nature potentially position humans in specific economic and social relationships by normalizing anthropocentric hierarchies. For example, Escobar (1996) shows how, in many international development contexts, environmental pleas serve larger goals of accumulating capital rather than addressing the specific environmental needs of cultural groups. In the dualistic and anthropocentric discourse described, human relationships with nature depend first on what nature can do for humans, and then what some humans can do for others. This is the reason why numerous scholars call on humans to conceive of different relationships with each other when addressing "environmental" issues (Haraway, 2007; Williams, 1980).

Outside of human created discourse, the natural world is difficult to 'know'. Society can then imprint meaning onto nature, where systems and institutions provide the discursive space where people construct what is 'common sense' about human-nature relationships, a process that then allows a hegemonic understanding to develop. Additionally, language intervenes and mediates the world in ways that objectify and separate nature from the human. Finally, due to historical constructions of science as objective and as an institution based on facts and data, scientific discourse is often granted an unquestioned authority, and the enviable role of being able to speak for nature.

### Human views on nature

The majority or research on human orientation to nature have occurred in the environmental sciences and in a branch of sociology called environmental sociology. Riley Dunlap and William Catton Jr. (1980) gave perhaps the clearest expression of emerging environmental orientations in society by contrasting what they called the Human Exemptionalist Paradigm (HEP) with the New Ecological Paradigm (NEP). The HEP, they claimed, is based on the assumption that humans are so unique in their possession of culture as to be exempt from environmental forces and processes affecting other species. In contrast, the NEP stresses the complex interdependence of humans with other species and the material embedded-ness of human society within wider bio-physical processes and eco-system dynamics. Their research initiated a field of scholarship on environmental worldviews in which nature-human relationships are a foundational component.

Many authors claim that a Western worldview contributes to environmentally detrimental behaviours in citizens of Western countries (e.g., Bencze & Carter, 2011; Bowers, 1997, 2003; Crompton & Kasser, 2009; Orr, 2004). In his worldview theory, Kearny considers worldviews as “culturally organised macro-thoughts; those dynamically inter-related basic assumptions of a people that determine much of their behavior and decision making” (Kearny, 1984, p. 13). Sociologists claim a dominant worldview has been prevalent in Western culture for several centuries (Catton & Dunlap, 1984; Cobern, 1993; 2000). This dominant worldview, termed the Dominant Social Paradigm (DSP) (see Appendix A for a more detailed description) by Catton and Dunlap (1984), is based on the HEP described previously, and appears to contain a strong anthropocentric tradition that places humans as separate from, above, and having dominion over the rest of nature. Also characteristic of the DSP is a view of the world as a source of limitless opportunity for human progress, extracted through never ending solutions to the problems and puzzles nature presents to us (Catton & Dunlap, 1980; Pirages, 1978; White, 1967). Western worldviews appear to have spread to most modern nations and cultures that have had to endorse this worldview in order to attain a position in the global economy (Bencze & Carter, 2011). The beliefs of most individuals are therefore likely simultaneously affected by a multiplicity of factors and perspectives (Cobern, 1993; 1999) resulting in multi-dimensional worldviews that makes the singular characterisation of a single dominant one problematic at best.

Challenges to worldviews have occurred as humans reconsider our ability to use and re-use once considered limitless resources, making the beliefs of the DSP unjustifiable from an environmental point-of-view (Catton & Dunlap, 1980). Alternative worldviews, which consider the interdependence of humans and the environment, the changing natural environment, growing awareness of ecological problems, and the capacity limits of the environment, have become apparent in modern societies (Catton & Dunlap, 1980; Crompton & Kasser, 2009). The *New Ecological Paradigm* (NEP) (Catton & Dunlap, 1980) (see Appendix B for a more detailed description), which describes this social change, characterises humans as one among many species that are interdependently involved in the global ecosystem. The NEP has resulted in increased awareness of, and concern for, ‘other’ nature, due to human dependence on it; such perspectives on nature appear to be foundational too much of the environmental ‘movement’ (Bowers, 2003). In recent consideration of worldviews and ethics, scholars have identified anthropocentrism as a characteristic foundational assumption to both traditional Western worldviews and Western scientific worldviews (Bowers, 2003; Capra, 1991; Marten, 2001). Although the NEP and other worldviews demonstrating awareness and concern for nature are increasingly identified among citizens (e.g., Hoeg & Barrett, in press), Rob Boddice (2011) contends that anthropocentrism underpins even these social paradigms: the fact that they are social creations always already privileges the human perspective, and concern for nature is often founded on concern about environmental threats to human prosperity and survival.

**Environmental Ethics**

One issue seldom addressed in NOS discourse and pedagogy is ethics, in particular ethics extended towards nature (Östman, 1998). Ethical consideration of human interaction with nature is a topic squarely within the discipline of environmental ethics. Environmental ethics is a branch of environmental philosophy that seeks to extend the traditional barriers of ethics, human behavior toward other humans, to the non-human world (Shrader-Frechette, 1995). While numerous philosophers have written on ethics toward nature throughout history, environmental ethics only developed into a specific philosophical discipline in the 1970s. This emergence was no doubt due to the increasing awareness in the 1960s of the effects that technology, industry, economic expansion and population growth were having on the environment (Benson, 2001). Questions asked in environmental ethics include: Should humans continue to propagate our species, and life itself? What are human environmental obligations to future generations? And, relevant to this dissertation, should living organisms be used in school science for the sole purpose of the production of science knowledge? Since school science represents a significant, if not default (Steele, 2011), location for teaching about the environment, and nature, consideration of environmental ethics in school science is potentially influential in students understanding about not only *how*, but also *should*, humans interact with other parts of nature (Hart, 2005).

## Anthropocentric Environmental Ethics

One of the most fundamental questions that must be asked in environmental ethic is, *what* obligations do we have concerning the natural environment? If the answer is that we, as human beings, will perish if we do not constrain our actions towards nature, then that ethic is considered to be "anthropocentric." Within environmental ethics, however, anthropocentrism usually refers to an ethical framework that grants "moral standing" solely to human beings (DesJardins, 2001). Thus, an anthropocentric ethic claims that only human beings are morally considerable in their own right, meaning that all the direct moral obligations we possess, including those we have with regard to the environment, are owed to our fellow human beings.

Although many environmental philosophers want to distance themselves from the label of anthropocentrism, it nevertheless remains the case that a number of coherent anthropocentric environmental ethics have been elaborated (Blackstone, 1972; Passmore, 1974; O'Neill, 1997; and Gewirth, 2001). For example, pollution diminishes our health, resource depletion threatens our standards of living, climate change puts our homes at risk, the reduction of biodiversity results in the loss of potential medicines, and the eradication of wilderness means we lose a source of awe and beauty. Quite simply then, an anthropocentric ethic claims that we possess obligations to respect the environment for the sake of human well-being and prosperity. Despite their human-centeredness, anthropocentric environmental ethics have nevertheless played a part in the extension of moral standing (DesJardins, 2001). This extension has not been to the non-human natural world though, but instead to human beings who do not yet exist, a 'future-generation'.

## Utilitarianism and Animal Ethics

Peter Singer and Tom Regan are the most famous proponents of the view that we should extend moral standing to other species of animal, and thus are influential proponents of animal ethics. According to Singer, the criterion for moral standing is sentience: the capacity to feel pleasure and pain (Singer, 1974). Regan, on the other hand, claims moral standing should be acknowledged in all 'subjects-of-a-life': that is, those beings with beliefs, desires, perception, memory, emotions, a sense of future and the ability to initiate action (Regan, 1983/2004). So, while Regan and Singer give slightly different criteria for moral standing, both place a premium on a form of consciousness. The principle of equal consideration is seen in the *utilitarian* ethical framework, whereby the ultimate moral goal is to bring about the greatest possible satisfaction of interests. Two presuppositions of utilitarian ethics are: we must consider the interests of sentient beings equally, and; our obligations are founded on the aim of bringing about the greatest amount of interest-satisfaction that we can.

Tom Regan takes issue with Singer's utilitarian ethical framework, and uses the criterion of consciousness to build a "rights-based" theory. For Regan, all entities that are "subjects-of-a-life" possess "inherent value". This means that such entities have a value of their own, irrespective of their good for other beings or their contribution to some ultimate ethical norm. In effect then, Regan proposes that there are moral limits to what one can do to a subject-of-a-life. This position stands in contrast to Singer who feeds all interests into the utilitarian calculus and bases our moral obligations on what satisfies the greatest number.  Extending moral standing to animals, however, leads to the formulation of particular types of environmental obligations. Essentially, these ethics claim that when we consider how our actions impact on the environment, we should not just evaluate how these affect humans (present and/or future), but also how they affect the interests and rights of animals (Singer, 1993; Regan, 1983/2004).

Many environmental philosophers (e.g. Callicott, 1980, Sagoff, 1984) have claimed that animal liberation cannot be considered a legitimate environmental ethic because it is too narrowly individualistic, and the logic of animal ethics implies unjustifiable interference with natural processes. Sagoff (1984) points out that our concerns for the environment need to extend beyond merely worrying about individual living organisms. Nevertheless, clashes of interest between individual animals and other natural entities are inevitable, and animal ethicists invariably grant priority to individual conscious animals. Many environmental ethicists disagree, and are convinced that the boundaries of our ethical concern need to be further extended.

## Biocentric Environmental Ethics

Numerous philosophers have questioned the notion that only conscious beings have moral standing (e.g., Attfield, 1983). For many environmental philosophers, moral standing should be extended beyond conscious life to include individual living organisms, such as trees. The extension of consideration of right and value to all living organisms has been termed biocentrism (Taylor, 2008). For example, Schweitzer's influential "Reverence for Life" ethic (1923) claims that all living things have a "will to live", and that humans should not interfere with or extinguish this will. Paul W. Taylor's more recently claimed that all living things are "teleological centers of life" (Taylor, 1986); by this he means that living things have a good of their own that they strive towards, even if they lack awareness of this fact. In other words, because living organisms have a good of their own, they have inherent value; that is, value for their own sake, irrespective of their value to other beings. It is this value that grants individual living organisms moral status, and means that we must take the interests and needs of such entities into account when formulating our moral obligations.

Taylor advocates a position of general equality between the interests of living things, together with a series of principles in the event of clashes of interest. The first principle states that humans are allowed to act in self-defense to prevent harm being inflicted by other living organisms. Second, the basic interests of nonhuman living entities should take priority over the non-basic or trivial interests of humans. Third, when basic interests clash, humans are not required to sacrifice themselves for the sake of others (Taylor, 1986).

There are crucial challenges facing philosophers who attribute moral standing to individual living organisms. One challenge comes from the anthropocentric thinkers and animal liberationists. They deny that "being alive" is a sufficient condition for the possession of moral standing. A second challenge comes from philosophers who question the individualistic nature of these particular ethics. As mentioned above, these critics do not believe that an environmental ethic should place such a high premium on individuals. For many, this individualistic stance negates important ecological commitments to the interdependence of living things, and the harmony to be found in natural processes. Moreover, it is alleged that these individualistic ethics suffer from the same faults as anthropocentric and animal-centered ethics: they simply cannot account for our real and demanding obligations to holistic entities such as species and ecosystems.

## Toward Nature-centric Environmental Ethics

Aldo Leopold is undoubtedly the main influence on those who propose "holistic" ethics.Leopold's "land ethic" (Leopold, 1949/1989) demands that humans stop treating the land as a mere object or resource. For Leopold, land is not merely soil. Instead, land is a fountain of energy, flowing through a circuit of soils, plants and animals. In order to preserve the relations within the land, Leopold claims that we must grant moral standing to the land community itself, not just its individual members. This culminates in Leopold's famous ethical injunction: "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise" (Leopold, 1949/1989, p. 218-225).

But even if we accept that moral standing should be extended to holistic entities on this basis, we still need to consider how we are then to flesh out our moral obligations concerning the environment. In particular, it has been claimed that holistic ethics condone sacrificing individuals for the sake of the whole. And if human individuals are just another element within the larger and more important biotic community, is it not necessary under holistic ethics to kill some of these "human pests" for the sake of the larger whole? Such considerations have led Tom Regan to label the implications of holistic ethics as "environmental fascism" (Regan, 1983/2004, p. 362). In response, proponents of such ethics have claimed that acknowledging moral standing in holistic entities does not mean that one must deny the interests and rights of human beings. They claim that granting moral standing to “wholes” is not the same thing as taking it away from individuals.

## Radical ecological ethics

Many thinkers regard environmental concerns to have warranted an entirely new ideological perspective that has been termed, after its biological counterpart, “ecology”. While the ideas and beliefs within this “radical ecology” movement are diverse, they possess two common elements that separate them from the ethical extensionism outlined above. First, none see extending moral standing as sufficient to resolve the environmental crisis. They argue that a broader philosophical perspective is needed, requiring fundamental changes in both our attitude to and understanding of reality. For radical ecologists, ethical extensionism is inadequate because it remains too human-centered, using human beings as the paradigm examples of entities with moral standing and then extends outwards to those things considered sufficiently similar. In addition, radical ecologies also demand fundamental changes in society and its institutions. In other words, these ideologies have a distinctively political element, requiring us to confront the environmental crisis by changing the very way we live and function, both as a society and as individuals.

## Deep Ecology

According to Arne Naess (1973), deep ecologists advocate the development of a new eco-philosophy or “ecosophy“ to replace the destructive philosophy of modern industrial society. Deep ecology rejects anthropocentrism and takes a “total-field” perspective. In other words, deep ecologists are not aiming to formulate moral principles concerning the environment to supplement our existing ethical framework. Instead, they demand an entirely new worldview and philosophical perspective. While the various eco-philosophies that have developed within deep ecology are diverse, Naess (1986) compiled a list of eight principles or statements that are basic to deep ecology:

1. The well-being and flourishing of human and non-human life on Earth have value in themselves (synonyms: intrinsic value, inherent worth). These values are independent of the usefulness of the non-human world for human purposes.

2. Richness and diversity of life forms contribute to the realization of these values and are also values in themselves.

3. Humans have no right to reduce this richness and diversity except to satisfy vital needs.

4. The flourishing of human life and cultures is compatible with a substantially smaller population. The flourishing of non-human life requires a smaller human population.

5. Present human interference with the non-human world is excessive, and the situation is rapidly worsening.

6. Policies must therefore be changed. These policies affect basic economic, technological and ideological structures. The resulting state of affairs will be deeply different from the present.

7. The ideological change will be mainly that of appreciating life quality (dwelling in situations of inherent value) rather than adhering to an increasingly higher standard of living. There will be a profound awareness of the difference between bigness and greatness.

8. Those who subscribe to the foregoing points have an obligation directly or indirectly to try to implement the necessary changes. (Naess, 1986)

But while Naess regards those who subscribe to these statements as supporters of deep ecology, he does not believe it to follow that all such supporters will have the same worldview or "ecosophy". In other words deep ecologists do not offer one unified ultimate perspective, but possess various and divergent philosophical and religious allegiances.

Critics of deep ecology argue that it is too vague to address real environmental concerns (Shrader-Frechette, 1995). For example, in its refusal to reject so many worldviews and philosophical perspectives, many have claimed that it is difficult to uncover just what deep ecology advocates.

## Social Ecology

Social ecology shares with deep ecology the view that the foundations of the environmental crisis lie in the dominant ideology of modern western societies (Bookchin, 2001). For Bookchin, environmental problems are directly related to social problems. In particular, Bookchin (1982) claims that the hierarchies of power prevalent within modern societies have fostered a hierarchical relationship between humans and the natural world. Indeed, it is the ideology of the free market that has facilitated such hierarchies, reducing both human beings and the natural world to mere commodities. Bookchin argues that the liberation of both humans and nature are actually dependent on one another. In turn then, human societies and human relations with nature can be informed by the non-hierarchical relations found within the natural world. The interdependence and lack of hierarchy in nature, it is claimed, provides a blueprint for a non-hierarchical human society (Bookchin, 2001).

## Ecofeminism

Like social ecology, ecofeminism also points to a link between social domination and the domination of the natural world. And like both deep ecology and social ecology, ecofeminism calls for a radical overhaul of the prevailing philosophical perspective and ideology of western society. However, there are a number of different positions that feminist writers on the environment have taken.

Plumwood (2007) offers a critique of the rationalism inherent in traditional ethics and blames this rationalism for the oppression of both women and nature. The fundamental problem with rationalism, claims Plumwood, is its fostering of dualisms. For example, reason itself is usually presented in stark opposition to emotion. Traditional ethics, Plumwood argues, promote reason as capable of providing a stable foundation for moral argument, because of its impartiality and universalizability. Emotion, on the other hand, lacks these characteristics, and therefore makes for a questionable ethical framework. Plumwood claims that this dualism between reason and emotion grounds other dualisms in rationalist thought: in particular, mind/body, human/nature and man/woman. In each case, the former is held to be superior to the latter (Plumwood, 1991). So, for Plumwood, the inferiority of both women and nature has a common source: namely, rationalism. Once this is recognized, so the argument goes, it becomes clear that simple ethical extensionism as outlined above is insufficient to resolve the domination of women and nature. What is needed instead, according to Plumwood, is a challenge to rationalism itself, and thus a challenge to the dualisms it perpetuates. Other ecofeminists outline the connections between the domination of women and of nature, emphasizing those things that link women and the natural world. For example, women, it is claimed, stand in a much closer relationship to the natural world due to their capacity for child-bearing (Mies & Shiva, 1993). For some ecofeminists, this gives women a unique perspective on how to build harmonious relationships with the natural world. Indeed, many such thinkers advocate a spiritualist approach in which nature and the land are given a sacred value, harking back to ancient religions in which the Earth is considered female (Mies & Shiva, 1993). Ecofeminists make the same point as deep ecologists: to resolve the environmental problems we face, and the systems of domination in place, it is the consciousness and philosophical outlook of individuals that must change.

Many scholars in science education (e.g., Hart, 2003; Östman, 1998) suggest ethical questions must be asked of the practices typically used to teach students about nature. These practices place students in interactions and relationships with nature; these interactions often place nature in subservient positions to human intentions (Oakley, 2008). Such practices could therefore be said to socialise students into anthropocentric relationships with nature. Indeed, school science has been theorised as stemming from a primarily anthropocentric environmental ethic (Hodson, 2009). If school science is to be involved in socialising students to more sustainable relationships with nature, school science communities may need to consider how other environmental ethical perspectives might be enabled through school science practices.

## Nature in Science

Dominant discourse in school science is influenced by the knowledge, principles and values privileged in the discipline of Western science (Hodson, 2009; Tobin & Roth, 2007). The roots of Western science apparently stem from Greco-Judean culture and traditions, which, in the process of subjugation and colonization of other lands, attempted to export their beliefs system by eradicating as much as they could indigenous and religious practices and ways of knowing (Tobin & Roth, 2007). More recent influence has come from European enlightenment ideals, which viewed the human as being fundamentally different from and having dominion over nature. The anthropocentrism inherent in this creates a binary opposition which may be a foundation of scientific discourse. This binary opposition potentially patterns the scientists' perspective and practice which establish nature as objects of study; it follows that the truth and realism of nature can be determined through observation using the human senses. This perspective appears to be foundational to the values and beliefs in traditional, 'mythical' (Barthes, 1972) science epistemology. Thus, nature exists in typical science discourse as representations by objects that have been constructed through scientific observation (Östman, 1998). How science constitutes nature, then, is as an object, necessarily separated from the scientist, and from which, knowledge, and representations, such as models and mathematical algorithms, are constructed, to account for nature's complexity (Hodson, 2009). A deeper discussion of how science constructs nature will be provided in a subsequent section of this review.

Traditional science discourses are associated with objectivity and reductionism (Ravetz, 1979). Among these, Hodson (2009) has noted the influence of "Mertons Norms" (p. 85), which were proposed as constituting the most effective and efficient way of generating new scientific knowledge and serve to provide a set of moral imperatives to ensure proper conduct, keeping 'outsiders' from meddling in science. These norms include: universalism; communality; disinterestedness; organised skepticism (Merton, 1973) and; rationality and emotional neutrality (Barber, 1962). These norms again pre-suppose a distance and separation from sciences object of study, nature. A traditional and quintessential epistemological orientation of science is positivism (Aikenhead & Ogawa, 2007). Positivism views only sensory experience and the mathematical treatment of that experience as the only worthwhile source of knowledge (Coburn, 1989). This view is foundational to a universalised 'scientific method', a formulaic, procedural approach to doing science (Aikenhead & Ogawa, 2007). Positivism is deeply rooted in the traditions and epistemology of science, although many within science do acknowledge limitations of positivism (Hodson, 2009). Associated views of epistemology include empiricism, which values knowledge obtained in scientific experiments, and reductionism, which emphasises understanding complex systems by dividing them up into smaller parts that are more easily studied, then re-assembling the system to understand the whole. All of these aspects of science are believed to have significant influence on science teachers' beliefs and practices (Hodson, 2009).

Aikenhead and Ogawa (2007) provide one of the most sustained engagements with how traditions in 'Eurocentric' science work toward constituting nature, and contrast this with Indigenous and Neo-indigenous ways of knowing nature. Although they go into greater depth than what will be provided here, in summary, these authors claim, in Eurocentric science, with some exceptions, nature is constituted as: knowable; predictable; something described by universally applicable knowledge; something manipulable; understandable through mathematical algorithms, and; something in which universal characteristics can be logically and rationally obtained through observation using the senses (positivism), revealing a 'true' world (realism). They then suggest many of these assumptions are influential in practices of Western school science.

### Western scientific worldviews and nature

Western scientific worldviews (see Appendix A for a more detailed description) appear to have co-evolved with other Western worldviews from Greco-Judean culture and traditions and European enlightenment ideals, and typically view nature as subservient, and of utility, to, human beings (Tobin & Roth, 2007). Although the existence of a scientific worldview, let alone its characteristics, remains contested (Matthews, 2009), there is enough agreement on a 'scientific perspective' that the development of a scientific worldview has become a goal of important science reforms, such as the American Association for the Advancement of Science's (AAAS) Project 2061 (AAAS, 1990) (Appendix A), and is reflected in influential modern science education policy, such as the Next Generation Science Standards (NGSS) in the United States (Achieve, 2013). Scientific worldviews can be generally characterised by an analytical epistemological orientation that focuses on perceived salient objects and their particular attributes (Nisbett, 2003). While some scholars advocate for the importance of inculcating scientific worldviews (e.g., Gauch, 2009; Matthews, 2009), others make connections between Western scientific worldviews and the positivistic approaches used in school science (e.g., Harding, 1991; Hodson, 1998; Longino, 1994, 1995, 1997). These scientific approaches are potentially antithetical to more inclusive science perspectives because they inculcate a sense of separation from nature, making school science resistant to methods of inquiry that acknowledge our interconnection with nature, and therefore potentially ill-suited to develop the environmentally-beneficial relationships in students needed in environmental education (Chambers, 2008; Hart, 2005).

## Science representations of nature

Traditional science practices described in previous sections represent ways to construct the world/nature, by collecting knowledge using the human senses, engaging, and limited by, the human consciousness. Existing mental schemas related to understanding the world enable recognition of certain salient features while rejecting, or not being able to perceive, other features (Nisbett, 2003). This identification and sorting of particular observational and perceptive knowledge results in knowledge of the world/nature (Pozzner & Roth, 2003). This knowledge represents certain aspects of nature as a representation, such as a model (Mitchell, 2003). Representations of nature can take the form of objects, who's characteristics are described through scientific language (e g., a tree), or process models designed to describe the way nature that is too large, to small, and too complex to grasp, works (i.e., an atom) (Hodson, 2008). A problem with these representations is that they are often assumed to be reality; an instrumental model, which serves the purpose of providing a means to grasp what nature *may be,* becomes accepted as what nature *is* (Hodson, 2009)**.** In other words**,** scientific models of nature can come to represent the reality of the world/nature, constituting nature as how it is accounted for and represented in the scientific model (Cartwright, 1999). Science models and representations are typically valued according to their explanatory predictability (Aikenhead & Ogawa, 2007), rather than the holism with which they represent nature (Nicholson, 2013). Models and representations frequently become a 'black box" (Latour, 1987), a representation of nature known for its utility to human systems of knowledge and practice (e g., a tree has industrial, aesthetic values); this black box hides from view the complex network of interactions the natural entity is a part of, making invisible other possible ways of valuing that nature represented.

Understanding how science practices constitute nature

Science investigations of nature, theoretically, also reproduce specific relationships with, and habitual behaviours toward, nature. Very little research has inquired into how school science practices, those of the teacher and/or student, work towards producing particular relationships with, and constructions of, nature, making the contribution of the research described in this thesis particularly significant. The social outcomes of repeated interaction with nature in certain characteristic ways might be explained through perspectives from *social ecology*. Social ecology comprises the social and physical environments that constitute people's habitats. As ecological biologists study animals' behaviors in relation to their natural habitats (Stutchbury & Morton, 2001), socioecological psychologists study how natural and social habitats affect human mind and behavior and how human mind and behavior in turn affect natural and social habitats (see Figure 2.1). In the figure below, culture is defined as "explicit and implicit patterns of historically derived and selected ideas and their embodiment in institutions, practices, and artefacts" (Adams & Markus, 2004, p. 341)

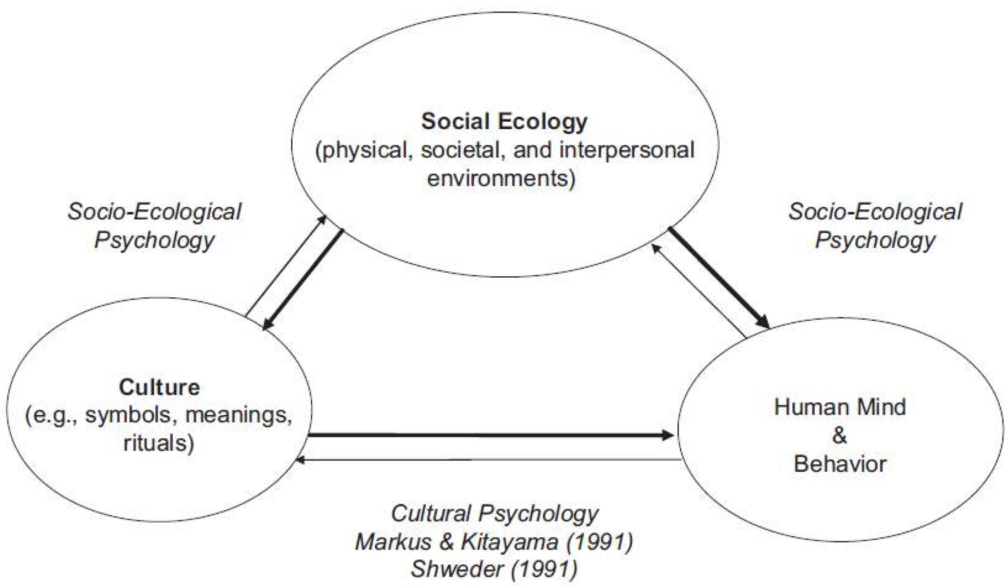


Figure 2.1. Culture, social ecology, and psychology.

Social ecology represents both physical and human environments that affect mind and behavior. What is relevant about social ecology to how science practices might constitute nature is in explaining how frequent physical and psychological practices of engaging with nature in science might habituate these practices, and develop psychological dispositions that sustain them (Oishi & Graham, 2010).

As an example of the type of research done in social ecology, Uskul, Kitayama, and Nisbett (2008) investigated how perceptual tendencies might differ among farmers, fishermen, and herders in a single region of Turkey. Earlier studies found that East Asians show holistic perceptual tendencies, whereas North Americans show analytic perceptual tendencies (see Nisbett, 2003, for a review). For instance, when participants are asked to pick the one object out of three (rooster, cow, grass) that is different from the others, most North Americans pick grass as the object that does not belong, because the rooster and cow are animals and grass is a plant. The key in this type of categorization is the characteristics of each object rather than the relationships among them. East Asians, in contrast, typically pick rooster as the object that does not belong, because the cow eats grass but the rooster does not. The key in this categorization is the relationship among the objects rather than the characteristics of each element. Because East Asians and North Americans are different in many respects (e.g., language, religion, history), it was difficult to determine why these cultural differences emerged. By focusing on a single region in Turkey, Uskul et al. (2008) were able to control for many confounding factors typical of cross-cultural research. Because the daily economic activities of farmers and fishermen are more dependent on others than are the economic activities of herders, these researchers predicted that farmers and fishermen would show more holistic perceptual tendencies (e.g., tendencies to categorize on the basis of relationships rather than characteristics of elements) than would herders. In several different perceptual tasks, they generally found support for their prediction.

A few studies demonstrate how the ecology of science laboratory influences human behavior and psychology. For example, an early study by Bybee (1984) investigated how certain science laboratory procedures created patterns of behavior among scientists. He concluded that scientists regularly performing laboratory procedures tend to interact with objects in their everyday life in analytical fashion. More recent studies have connected science investigative practices to treatment of animals. Holmberg (2008) conducted social ecological research on how course work and habitual laboratory practice influenced participants' feelings about killing laboratory rodents. She found that, although participants did exhibit some remorse for killing the rodents, habitual experimental practices and procedures created emotional distance and separation that made killing animals, in general, easier. While social ecology is a re-emerging field of psychology, it shows great promise in uniting social and everyday contextual features of human environments with psychological phenomenon, such as beliefs, and dispositions, that might aid in understanding the relationship between practice/behavior and psychology.

## Re-including nature in science

Disruptions to the traditional discourses of science occurred as postmodern scholars started to question the truth of scientific objectivity, and cultural and socio-political aspects of science. Michel Foucault (1970) has suggested that objective knowledge is made powerful through discourse in Western society, giving it political currency, which opposes traditional views that science is value-free. Jerome Ravetz (1979) rejected the so-called 'objective knowledge' of traditional science, pointing out that the scientific community 'decides' what qualifies as knowledge and it is therefore a social construct. Postmodern criticism of science reached critical mass in the 'science wars' of the 1990's, during which academics of the social sciences and science debated about epistemology, objectivity and realism.

Thomas Kuhn, one of the first scholars within the disciplines of science to identify disparity between traditional conceptions of science practice, which he termed "normal science" (p. 5), and its more pragmatic realities, observed "No part of the aim of normal science is to call forth new sorts of phenomena; indeed those that will not fit the box are often not seen at all" (p. 24). This view invalidates claims that humans perceive nature objectively. Karl Popper, who made great strides in establishing the philosophy of science as a legitimate discipline, advanced a theory of knowledge construction based on the falsifiability of scientific theory. His common-sense realism and adherence to objectivity and rationalism contrasted with the views of Kuhn, and later his own disciple Feyerabend (1975), both of whom prioritised the sociocultural influences of knowledge production in science.

What many scholars question is whether it is true to say that science is the study of 'nature', or whether it is, in fact, the study of the symbols and interpretation of those symbols humans have created that represent nature as we perceive it (e.g., Mitchel, 2003; Gilbert & Sakar, 2000). Therefore, truth claims made by science can be criticised as simply human interpretations of nature. Many branches of science such as particle physics, and certain fields in astronomy

(Hodson, 2009) do not adhere to the epistemological and ontological perspectives of more traditional science disciplines that generally appear to constitute nature as an entity separate and distinct from humans (Gibert & Sakar, 2000). New philosophical perspectives have arisen, particularly in life and environmental sciences, such as *organicism* (Nicholson, 2013), which values the understanding of nature in holistic ways, rather than through reductive epistemologies associated with traditional science practices. Organicism is a response to *vitalism*, a defunct hypothesis in science that humans are fundamentally different than other types of nature (Nicholson, 2013). The process of re-including nature continues to be constrained by a human consciousness boundary in science. For example, although *vitalism* has been falsified through improved understanding of atomic structure, which demonstrates humans are composed of the same fundamental types of matter as the rest of nature, the ontological divide between humans and nature still appears to be foundational to epistemological methods of most sciences (Gilbert & Sakar, 2000). Even with the acceptance of human cultural influence in the processes of science, this is seen primarily in the margins of the discipline, and consideration that nature is a sociocultural constitution is generally not acknowledged in mainstream science (Hodson, 2009).

## Nature and Education

A significant amount of literature has been written on learning about nature, primarily from the field of environmental education. A small sample of literature pertinent to this thesis is reviewed here. Hart (2003) suggests the environment should be an important component of students' education – even more important than traditional school subjects such as science. This is, in part, he explains, because the way students are socialised into relationship with nature in school (and society) has more significant bearing on human social practices related to sustainability than learning specific skills and knowledge in traditional school subjects. Bowers (1997) documents the complicity of the educational establishment in supporting modern society's engagement with technology, and rapidly increasing economic/consumer-based globalization. He argues that education, from the primary grades to universities, must be totally reformed to support new, ecologically sustainable paths for society. Orr (2004), on the other hand, argues that instead of trying to stop 'progress', the environmental movement, through school education, must endorse teaching 'the nature of design'. He describes this as an ecological design revolution that can change how we provide food, shelter, energy, materials, and livelihood, and how we deal with waste. Stevenson (2007), however, draws several contradictions in the purpose and practice between school and education for sustainability. Some of these contradictions are centered on problems associated with learning about nature indoors, in discrete units of time, and in discrete subjects. These features, he suggests, are contraindicative to what may be needed in environmental education, which are holistic, interdisciplinary experiences occurring over undefined periods of time, ideally, outdoors.

Nature in school science

Steele's (2011) study on the implementation of environmental education in Ontario secondary science is one of the most relevant studies to this dissertation. Steele identified deep epistemological rifts between science and environmental education based on how each values nature. A sizable amount of literature explores relationships between science and environmental education, because, it has long been a general assumption of educators that science dovetails nicely with environmental education (Steele, 2011). However, the divergent natures of traditional science education and an evolving environmental education suggest that these school subjects are in many respects incompatible and that merging them presents significant difficulties for both. Hart (2003) points out the incongruity between science as knowledge transmission and environmental education as active deliberation, debate and independent learning. Stevenson ( 2007) suggests that interdisciplinary pedagogy creates difficulties for teachers in terms of teaching strategies and assessment in that single-discipline pedagogies are much simpler to enact (and thus more prevalent). Environmental education adds ethical/moral, political, social and cultural components to curriculum (Hart, 2003) thereby challenging teachers' views that science should be 'value-free' (Dillon, 2002). Pedretti, Bencze, Hewitt, Romkey and Jivraj (2008) noted that traditional science education is often a review of disciplinary knowledge and that teachers are reluctant to broach the social and environmental issues (SE) of STSE fearing that it "devalues the curriculum, alienates traditional science students and jeopardizes their own status as gatekeepers of scientific knowledge" (p.943). Hart (2003) contends that it is the E (environment) in STSE science curriculum that presents educators with the most pedagogical difficulty. There is another, somewhat tangential argument that can be made in regards to the STSE model, wherein science and technology as human centered (anthropocentric) endeavours are situated in direct opposition to environment (Steele, 2011). Our language is riddled with metaphors of human agency in confrontation with nature and environment, and is an indication of our deeply lodged values (Hodson, 2003). Steele (2011) claims the assumption that studies in science and technology will smoothly ally with environmental education is naïve. Despite concerns and obvious disjunctures, there has been continued effort to ally science and environmental education, as evident in textbooks designed for new science teachers, which devote a large amount of space attempting to integrate these disciplines (e.g., Pedretti & Bellomo, 2015)

Although these studies are compelling, and have some bearing on the research of this thesis, they do not inquire into relationships between science and nature, directly. Environmental education is a discipline in which study of nature is only a part, along with educational principles, pedagogies, philosophies and practices. Disjunctures between science and environmental education occur along many lines, and much of the previous research reports dissonance between pedagogical values that are not clearly connected to how these constitute nature differently. Although defining sciences' relationship with nature is debatable, for purposes of school science there is sufficient consensus for a standard account to be discernible (Tobin & Roth, 2007). Cobern and Loving (2001) have produced one of the most widely known accounts of what science is, stating, "Science is a naturalistic, material explanatory system used to account for *natural phenomenon* that ideally must be objectively and empirically testable" (p. 60-61). To paraphrase, science can be said to be the *study of nature*. Perhaps ironically, nature appears in school science discourse and teacher practice in 'unnatural forms' (Fensham, 1988), replaced by scientific words, phrases and concepts, and embedded in science methods through ontological and epistemological assumptions that act to oppress nature (Östman, 1998). This oppression appears to exist in science education research as well, as the constitution of nature in school science has not been a frequent focus of research. What is presented here are summaries of the few studies that do investigate how nature is constituted in school science, and review of Nature of Science (NOS), a curricular area in which examination about how science constitutes nature appears to be the most feasible and relevant.

Nature of Science (NOS)

Sociological perspectives, and criticisms, of the practices and process of science, particularly from sociocultural standpoints, are relatively well-known in science (e.g., Bencze, 2008; Bencze & Carter, 2011: Pedretti et al., 2006). These perspectives are relevant to NOS curricular domains in science education (Pedretti & Bellomo, 2015). NOS is an attempt by scholars in science education to describe the practice of science through topics such as; how scientific research and inquiry is conducted; what is included as scientific knowledge; scientific epistemology; and the culture of science (Hodson, 2009). From these relatively well accepted descriptions, NOS would appear to be a reasonable location for inquiry about how nature is constituted by science.

Nature is present in some components of NOS education. For example, Cobern and Loving (2001) outline beliefs and assumptions that should be foundational to NOS in school:

- Science is about *natural phenomena*
- The explanations that science offers are *naturalistic* and material
- Science explanations are empirically testable (in principle) against *natural phenomena* or against other scientific explanations of *natural phenomena* (the test for theoretical consistency)
- Science is an explanatory system – it is more than a descriptive ad hoc accounting of *natural phenomena*
- Science presupposes the possibility of knowledge about *nature*
- Science presupposes there is order in *nature*
- Science presupposes causation in *nature*

(Emphasis added) (Cobern & Loving, 2001, p.60-61)

These elements, however, do not make clear what exactly nature is, and instead constitute nature as what science and scientists ‘work with’. Despite several clear statements about what science is, there exists variability in science teachers’ (and students’) perceptions and beliefs about NOS.

NOS Views and Beliefs

One of the first studies of the features of NOS taught in school was done by Smolicz and Nunan (1975), who identified 4 “ideological pivots” in school science curricula: i) *anthropocentrism*; ii) *quantification*, in which scientists are seen as not just observers but as measurers and quantifiers; iii) *positivistic faith*, in which scientists believe in the inevitable linear progress of science towards truth about the world, and; iv) *analytical ideal*, the assumption that phenomenon and events are best studied and explained via analysis, an entirely mechanistic view of the world. Investigations have demonstrated the existence of these same ideologies, valuing objectivity or “naïve positivism”, is still widespread in school science in Ontario (Alsop, 2009; Nadeau & Desautels, 1984). Loving (1997) claims that all too often:

> a) Science is taught totally ignoring what it took to get the explanations we are learning – often with lectures, reading text, and memorising for a test. In other words, it is taught free of history, free of philosophy, and in its final form. b) Science is taught as having one method that all scientists follow, step-by-step. c) Science is taught as if explanations are the truth – with little equivocation. d) Laboratory experiences are designed as recipes with one right answer. Finally, e) scientists are portrayed as somehow free from human foibles, humor, or any interest other than their work

While much has changed in science education since Smolicz and Nunan (1975) identified 4 ideological pivots, largely from the addition of NOS and Science, Technology, Society and Environment (STSE) to curricula, many school science curricula and resources continue to manifest these ideals (Clough, 2006; Loving, 1997). To understand why school science continues to conserve traditional ideals, a significant amount of research has attempted to evaluate teachers’ NOS views, or beliefs, and connect these to teaching practice. These views are usually ascertained by the use of survey and/or questionnaire instruments. Reviews by Lederman (2007) and Abd-El-Khalick and Lederman (2000), describe instruments that take into account recent NOS considerations by scholars in philosophy and sociology of science. Notable among these instruments are the *Conceptions of Scientific Theories Test* (Cotham & Smith, 1981), *Nature of Science Profile* (Nott & Wellington, 1993), *Views on Science-Technology-Society* (Aikenhead et al., 1989), and *Views of Nature of Science Questionnaire* (VNOS) (Lederman et al., 2002). More interesting than the existence of these surveys, however, are the NOS views that these instruments have identified. For example, using the VNOS, Tsai (2002) found that teachers' NOS beliefs could be categorised as "traditional', 'process' or 'constructivist', and the majority of teachers (15 out of 21) had traditional beliefs, although this study did not extend to observation of teacher practice. Hashweh`s (1996) study of 35 science teachers did extend consideration to classroom practice, revealing that teachers who held a constructivist orientation toward science knowledge are more likely to take account of students prior understanding, have a richer repertoire of teaching and learning strategies, and adopt more successful strategies for effective conceptual change than teachers with positivistic orientations. Similarly, Kang and Wallace (2005) and Kang (2007) found that teachers with 'more realistic' NOS views were more likely to develop science lessons that portrayed science as tentative knowledge and to adopt constructivist pedagogies.

Despite the attention NOS views have elicited in science education research, some studies suggest that teachers' NOS views have negligible effect on curricular choices and classroom practice. For example, Lederman`s (1999) study of five biology teachers demonstrated that, instead of NOS views, teachers' concerns about classroom management, and instructional goals related to content acquisition, and student engagement and motivation were more influential. Abd-El-Khalick et al (1998) observed the classroom activities of 14 teachers with desirable NOS views, and clearly stated intentions to emphasis NOS in their teaching activities, but found little evidence these teachers put their NOS views into practice. Following a 16-month action research intervention with four elementary school teachers, Waters-Adams (2006) concluded that there was little direct link between teacher`s espoused views of NOS and their classroom practice. Instead, they suggest, teachers` decision making about classroom practices is the result of a complex mix of tacit views about science, views and beliefs built up through personal experience teaching about science, and various beliefs about the aims of education, the way children learn, and how curriculum should be structured.

Hodson comments that, despite the complexity of school science phenomenon that influences teacher practice, NOS understandings are at least as relevant as other factors involved in how teachers teach about science (Hodson, 2009). Unfortunately, research continues to suggest that, with some notable exceptions, teachers NOS views still fall short of what researchers consider to be adequate, acceptable, or desirable. Generally, the perceived weaknesses concern the ignorance of the theory-laden nature of observation and experimentation, belief in a universal, formulaic scientific method of science inquiry, uncertainty about the status of science knowledge, a tendency to overlook socio-cultural aspects of the practice of science, and the role of creativity and imagination in science (Abd-El-Khalick et al., 1998; Nott & Wellington, 1998; Lederman et. al., 2001; Southerland et al., 2003).

## Teaching NOS

Differences between teacher beliefs, espoused beliefs, rhetoric, and what actually occurs during teaching, or teacher practice, are not uncommon (Hodson, 2009). What these divergent results suggest, however, is that NOS beliefs do not necessarily translate into teacher practices, either explicitly or implicitly. Dissonance between NOS beliefs and practices has caused many educators to question how NOS should be taught to students, and to teachers. Since nature is not frequently explicitly addressed in science, school science, or NOS discourse (Östman, 1998), understanding implicit messages about nature in discourse becomes necessary to understand how nature may be constituted. Alternatively, NOS taught with explicit reference to nature may be required to constitute it in a way science teachers, or science education communities, deem appropriate. Some debate has occurred about whether NOS needs to be explicitly taught; for example, disagreement has occurred over whether learning the tenets of NOS, and doing activities associated with these is sufficient; or whether NOS can be learned implicitly, through unguided practice of scientific methods (Hodson, 2009). Abd-El-Khalick and Lederman (2000) assembled a detailed review of 17 activities designed to enhance teachers conceptions of NOS – eight describing implicit approaches, nine as explicit approaches. These approaches differed in the "extent to which the learner was provided the conceptual tools, such as key aspects of NOS, that would enable them to think about and reflect on the activities in which they are engaged" (Abd-El-Khalick and Lederman, 2000, p. 690). Explicit approaches assumed that NOS was to be learned as content, just like any other science content, and rejected the idea that NOS understanding will just develop in students as a consequence of engaging in other activities. In other words, NOS should not be seen as an incidental by-product of an activity; rather it should be seen as a specific goal. Abd-El-Khalick and Lederman (2000) concluded that "an explicit approach was generally more 'effective' in fostering 'appropriate' conceptions of NOS among prospective and practicing teachers" (p. 692). Other research confirms this. For example, Akerson et al. (2000) report a substantial improvement on elementary teachers NOS views when they were required to reflect on NOS orally and in writing, following a series of case studies, debates, and other activities. In order to test the robustness of the conclusions regarding explicit and reflective NOS instruction, Abd-El-Khalick (2005) provided 56 preservice secondary school science teachers with purpose-made course units, designed to teach NOS explicitly, and provide opportunities for student reflection on the NOS learning. Compared with student-teachers learning more traditional content in a parallel class, the target group developed deeper and more coherent understandings of NOS.

Other studies suggest implicit learning of NOS may also be influential in students' and teachers' views of science. Cummins (1989) connected NOS orientations to a "hidden curriculum" (Jackson, 1968). The hidden curriculum is the metaphor used in educational literature which refers to hidden outcomes of school. These outcomes result from practices that contain semiotic messages about what is and is not valued that sometimes are in conflict with explicit priorities (Jackson, 1968). Cummins and Others (1989) identify student alignment with positivism as an outcome of the hidden curriculum. This results from the epistemological assumptions about the truth-value of science knowledge present in school science curricula, and textbooks. They also see how positivism is valued in the hidden curriculum in the way that students are asked to perform experiments. The formulaic procedures given to students doing labs ensure that procedures result in empirical evidence, which is understood as knowledge. Cummins and Others claim that this reduces students' natural innate tendencies to make more holistic claims and draw conclusions based on non-empirical evidence, which is unacceptable knowledge in science. Khishfe & Lederman (2006) found that nine students learned all aspects of NOS equally as well, regardless of whether it was taught implicitly, within the context of a unit, or explicitly through content designed to teach NOS. Heap (2006) notes generic, 'content-free' activities, such as 'tricky-tracks' devised by Lederman and Abd-El-Khalick (1998) were particularly effective in stimulating shifts in in-service elementary teachers' NOS views, supporting the view of many scholars (e.g., Bencze & Elshof, 2004; Clough, 2006) that both context embedded (implicit) and context-free (explicit) approaches are necessary.

As Hodson argues, NOS knowledge does not lay "out there", waiting to be learned by students; it has to be taught (Hodson, 2009, p. 66). However, this teaching is not always through the use of explicit language or activity, and nature, in particular, is often taught to students through implied meanings in NOS discourse and practices (Östman, 1996; 1998: Roberts, 1998). These implied meanings, if not reflected on, addressed, and displaced, can result in conceptions (or misconceptions) built up over many years of school (Hodson, 1996). Misconceptions can be addressed by displacing and replacing them by new ideas that are intelligible, plausible, and fruitful (Posner et. al., 1982). However, many scholars (e.g., Alsop, 2005; Sinatra, 2005) have pointed out the way this rationalist view fails to recognize the complexity, uncertainty, and fragility of learning. Particularly relevant to this dissertation is recognition that conceptual change may rely on teaching knowledge or concepts that must replace old ones; however, as pointed out previously, NOS does not appear to contain discourse that disrupts exclusion and marginalisation of nature. Instead, the discourse present in the way NOS describes nature appears to sustain anthropocentric constitutions of it (Fensham, 1988). The system of knowledge that teachers have to draw on to teach NOS explicitly to students, therefore, already contains (mis)-conceptions of nature that, I argue, are problematic, making this knowledge ineffective to disrupt misconceptions about nature in school science.

## NOS Practices in School Science

Much of the previous discussion on NOS beliefs and views pertains to the psychological aspects of learning and knowing, with an assumption that this mental realm will have some influence or determination on the practices of teachers (Hodson, 2009). The research findings demonstrate that teachers develop context-dependant practices as they experience teaching, and the knowledge and beliefs contained in the consciousness may or may not directly affect their teaching actions (Abd-El-Khalick & Lederman, 2000; Brickhouse, 1990; Lederman, 1999; Waters-Adams, 2006). For example, Tobin and McRobbie (1997) found the teacher's goals for student learning, teaching contexts, and teacher beliefs about students, the nature of science, and the curriculum were all highly influential in guiding teacher practice. Since measured beliefs, values and views may be inaccurate predictors of NOS teaching, research attention must be also directed more specifically at teaching practices related to NOS.

Epistemological values thought to be common in science (often mistakenly) are embedded in practices common to school science (Hodson, 2008). Cobern (1989), for instance, shows how an epistemology derived from positivism works as a sorting mechanism for correct and incorrect concepts; knowledge and concepts gained through non-positivistic ways are dispelled and discarded, thereby reproducing positivistic orientations. Currently, an epistemological boundary that appears to exist in science excludes most forms of indigenous knowledge, just as it excludes art, religion and many other domains of knowledge (Bowers, 1997). This likely makes non-positivistic constitutions of nature difficult to enact in school science. Positivism is observable even in forms of communication and teaching approaches present in science classrooms. Lundqvist, Almqvist and Östman (2009) found that communication between teachers and students often act to orient students toward positivism. For example, students' frequent desires to "jump to conclusions" and "make assumptions" are in conflict with rational and logical observation. Teachers re-orient students toward differentiating between observations and inference, so this become natural and automatic. This orientation often takes on the form of "naïve positivism" (Lundqvist et al., 2009, p. 862), propagating the idea of pure objectivity, which is silent on the fact that science engages the human subject, and therefore true objectivity is not possible. Finally, Zemplen (2009) adds to the mounting evidence for the presence of NOS practices that reproduce positivism. Zemplen points out that the sociological aspects of NOS, such as different views on what constitutes science, different ways science is practiced by different groups in the world, and the increasing impetus in Western science to include the pluralistic scientific views of experts, are generally being ignored in NOS lessons in school. Instead, privileged epistemological aspects of NOS, centered on empiricism and reductionism, dominate NOS teaching and learning. These create a homogenised science which may contradict the sociological realities of how science is practiced outside of school.

Among the many NOS practices that might be enacted in school, science experimentation/inquiry has perhaps unique importance because these activities are seen as representing what scientists do, and are therefore important for identifying epistemological beliefs underlying teaching actions (Kang & Wallace, 2004). For more than a century, laboratory activities have been used in science teaching (DeBoer, 2001). In promoting experimental activities over the years, there have been a series of rationales for their use, as well as taxonomies of types (Hodson, 1993). In Tobin's (1986) study, lab activities were typically not conceptually integrated with the science course as a whole. His study suggests that when teachers have naive epistemological beliefs in which they consider knowledge as a transmittable entity, they view lab activities as an addition to the main lesson, failing to see lab activities as opportunities for students to make meanings through scientific inquiry.

Engaging students in empirical activity can potentially promote students' understanding of scientific concepts, problem-solving abilities and attitudes to science (Arzi, 2003). Carefully crafted laboratory activities, therefore, with appropriate physical facilities and positive psychosocial aspects, may stimulate intellectual activities, increase social contacts, promote learning and students' development, and limit negative behaviour among students (Nidzam, Ahmad, Osman & Halim, 2013 ). To improve student achievement in cognitive and affective directions, many studies have been conducted to determine the effectiveness of teaching and learning science using laboratory activities (e.g., Fraser & Lee 2009; Henderson et al. 2000; Hofstein & Lunetta 2004). However, a critical review on the function of the laboratory in science teaching and learning indicated that the research failed to show relationship between experiences in the laboratory and student learning (Hofstein & Lunetta, 2004). According to Pyatt and Sims (2007), in many practical activities, students are not given the opportunity to explore and create their own understanding of the phenomenon being studied. This is because most science laboratory activities are largely expository and teacher-centred activities conducted in accordance with the steps that have been prepared under the supervision of teachers. Using Social ecological perspectives, Ahmad, Osman and Halim (2013) investigated how school science laboratory practices, including how the physical materials and equipment were used, influenced students and teachers sense of satisfaction. They found that when science equipment was used to measure nature, teachers gained greater satisfaction than in laboratory practices in which students were exploring nature in less structured ways, such as through simple observations or 'improper' use of equipment. To minimize the wastage of time and materials and the possibility of injury or damage, students are not usually given freedom to depart from established procedures. Furthermore, Wellington (1998) states that several weaknesses of practical work in laboratories are:

1. the noise can cause students to be confused;
2. practical work might go wrong, thereby giving a mixed message to students;
3. some students do not like practical work;

4. group work can be less effective; and
5. it can be time-consuming.

Oakley (2009; 2012), in a study investigating 153 Ontario science teachers, problematizes dissection in school science. Her findings indicate that the majority of teachers continue to strongly favour traditional dissection and see it as vital to biology education. Oakley argues that teachers need to engage more deeply with the ethical questions that underlie dissection and consider how its learning outcomes can be achieved through more humane science education practices

Advocating for and criticising practices of science in NOS, such as science experiments and dissection, however, appear to be limited by the discourse within which they are produced. In other words, since nature is typically marginalised in science discourse (Östman, 1998), many individuals in the fields of science and science education may not have the conceptual and linguistic tools to perceive how nature is constituted by science practices, such as those used conducting science experiments. Criticisms of science practices appear to be limited by discourse already associated with, and present in, science, such as limitations imposed on science knowledge gained through representational, reductive, or positivistic perspectives (Hodson, 2009). These criticisms are suggested as fruitful and important aspects of NOS with which students and teacher might interrogate and come to understand (Lederman et. al, 2002). While such criticisms are valid, they are based on knowledge and practice that already exists in science discourse, which infrequently problematizes the way science practices constitute nature.

**Nature in School Science Discourse**

Paul Hart (2003) suggests that school experiences shape students' personal relationships with the social and natural world, framing their sense of responsibility to each other and nature. Much of this framing occurs through the discourses they encounter in school (Chambers, 2008). Pomeroy (1993) categorized school science discourses as either traditional or non-traditional. The traditional view is largely positivistic and empiricist, subscribing to such notions as: scientific knowledge is objective and a true reflection of reality; scientific observations are free from the observer's pre-conceptions; knowledge exists independent of the knower; and observation and experiments are the only infallible sources of scientific knowledge. The non-traditional view is largely constructivist - including social constructivist - and includes beliefs such as: scientific knowledge is partly subjective and reality is a construction of the knower; scientific observations as not free from human preconceptions; and that in addition to experiments and observations, human creativity and imagination play roles in the production of scientific knowledge (Pomeroy, 1993). Both of these discourses, however, might be conceived of as anthropocentric, as nature is viewed as an object to be utilised for scientific study in the first type, and nature is viewed as a purely human construction in the second. However, the non-traditional discourse holds promise for more inclusive constitutions of nature, in that it disrupts notions that nature exists only as it is described by science. This acknowledgment opens possibilities for different conceptualisations of nature in science.

Discourse that more specifically constitutes nature has also been examined, although infrequently. Östman (1994), for example, argues that science education constructs a particular view of the human-nature relationship and of the world around us, and that "it is therefore not possible to isolate or to separate the teaching of science concepts from socialization in to some kind of environmental consciousness" (p. 142). If Östman is correct, that places a particularly heavy burden on science teachers—that being, a consequence of their teaching is the development of a kind of "environmental consciousness". Östman, in collaboration with Roberts, developed the notion of companion meanings, notably in terms of science discourse and text (Östman, 1998; Östman & Roberts, 1994; Roberts, 1995, 1998). Companion meanings include not only the deliberate or policy driven meanings, but also "the not so- deliberate (but still very real …) 'extra' meanings that accompany scientific meaning, in curriculum and textbook as well as in teaching" (Roberts, 1998, p. 11). Companion meanings are embedded in discourses through *what* is said or not said and *how* it is said or not said. Drawing upon the dialogical meaning inherent in discourse, Östman (1994; 1996; 1998) describes the concepts of a "nature language" and "subject focus," two category systems useful for revealing companion meanings communicated in science texts. Nature language employs discursive practices and root metaphor(s) (or a blend of different root metaphors) to govern the use of language *about* nature, conceptualizing reality and constructing a particular view of nature. Östman delineates four categories of nature language: *classical*, *biomechanistic*, *ecomechanistic*, and, added by Östman in 1998, *organicist*. Classical and organicist represent opposite extremes, with biomechanistic and ecomechanistic blends of the two. The concept of subject focus is concerned with the discourse around the *relationship* between human beings and nature. How teachers (or texts) describe and/or use nature in science classrooms communicates a certain view of this human-nature relationship, ascribing a value to nature and our consequent moral responsibility (Östman, 1994; 1996; 1998). Drawing from the work of Fensham (1988), Östman delineates two primary categories of subject focus: *Induction into Science* and *Learning from Science*. The *Induction into Science* subject focus views nature simply as an educational tool for teaching students science concepts; no moral obligations are associated with this particular stance. Within *Learning from Science*, science is a means for describing and explaining nature and natural phenomena, essentially the reverse of the *Induction into Science* subject focus. Östman further distinguishes four subject foci within *Learning from Science*: *Exploitation of Nature*, *Human Being as Threat*, *Survival of Homo sapiens,* and *Preservation of Nature*. Each subject focus constructs a particular concept of nature, together with a vision of the relationship between human beings and nature.

Chambers (2008) used Östman's framework to analyze for nature language and subject focus in Alberta environmental/science educational resources for elementary school children, co-developed by the Alberta government and corporate entities in Alberta. She found that school developed texts contained, predominantly, human relationships with nature based on *Exploitation of Nature*, in which*:* "human beings have used or can use nature to promote their material welfare…[It] also implies that nature is a resource for exploitation by human beings and that we have no moral responsibility in that respect" (Östman, 1994, p.145). Government produced texts contained predominantly the subject focus of *Survival of Homo sapiens.* This subject focus does not express human control as strongly as exploitation of nature, and an implicit moral responsibility towards nature, shifts the human-nature relationship towards *Survival of Homo sapiens*. Within this subject focus, it is hoped that students will develop an attitude of responsibility for nature because "human beings are dependent on nature" (Östman, 1994, p. 146). This subject focus, it could be argued, is anthropocentric, however, since nature is valued according to its life giving properties to humans, and not because it has intrinsic value in its own right.

Sharma and Buxton (2015) attempted to understand how the language of science textbooks works to represent the world for students in distinct ways that have serious implications for their ecological literacy. Using a methodological framework based on critical discourse analysis and systemic functional linguistics, they focused on clarifying the textual representations of the relationships between natural and social systems as portrayed in a seventh-grade science textbook from the United States. Results indicate that this science textbook offers outdated representations of natural systems' relationships with social systems and the role of human agency in these relationships. For example, the textbook textually creates a representation of a "pristine" natural world in which human presence is marginal and mostly limited to scientific investigations of natural systems, and elevates resource consumption by "people" as the sole cause of environmental problems. These authors claim the science textbook examined oversimplifies the complexities of natural–social interactions and elides more influential and larger sociocultural and politico-economic factors behind environmental stress and degradation.

Hoeg (2013) conducted a discourse analysis of three Ontario Grade 10 Academic Science textbooks, using a framework of nature discourse derived from Dryzek (1997), and binaries of anthropocentrism and biocentrism (Taylor, 2010). Hoeg found that anthropocentric discourse related to: Mechanistic processes of nature; Nature as a resource; Fragile nature; Humans separate from nature; Hierarchy; Ambivalence; Management; Nature dependency, and; Threat/fear of nature constituted 76% of the discourse related to nature in the text. Biocentric themes included: Complexity of nature; Nature has intrinsic value; Nested systems; Human dependency; Cooperation; Caretakers, and; Interdependence; these were found in the remaining 24% of nature discourse in the text. The author suggests that these results are evidence of human-nature binary oppositional social relations in school science, with anthropocentrism being the more influential structure.

## School Science Community Discourse

As Hodson (2009) notes in discussing how NOS practices are enacted, there are community and other institutional factors that are influential in teacher practice aside from their training as science teachers. These factors included discourse related to science teacher expectations and cultures, traditions of science pedagogical approaches, and science student expectations.

Attention is drawn to the reproductive nature of science specific community discourse by Roth (2002), who implicates these as being detrimental to current science reform efforts, although he is very general in identifying what these structures are. Sammel (2008) makes similar claims in his response to Ajay Sharma's "Portrait of a science teacher as Bricoleur: A case study from India". Sammel makes the argument that, although science teachers may be discursively produced, "inherent structural components of science education ensure teachers reproduce epistemological, racial, socioeconomic and pedagogical inequities" (Sammel, 2008), and that these must be better understood in order for science reform to be effective. Like Roth, Sammel is not specific in the identification of these structures, however.

A pair of studies report on new science teachers difficulties as they teach for the first time. Watson (2006) found that new teachers encountered difficulties in lesson delivery, such as lacking skill in didactic discussions with students and organising lessons in the "logical", step-by-step way that students were accustomed to. Watson explained this as being a result of pedagogical discourse that existed in the community of science teachers which exerted pressure on new teachers to teach in a way they were not comfortable doing. In a similar study by Saka, Southerland and Brooks (2009), they identified community expectations and 'rules' in discourse that prevented science teachers from being able to implement the more reform-minded practice they were trained for in their teacher education programs.

More specific pedagogical expectations and assumptions embedded in science teaching discourse have also been identified in research. For example, valuing mastery of scientific knowledge in school science was identified as existing in discourse in science education as early as 1979 (Lin, 1979). Tobias and Raphael (1997) identify knowledge tests as a discursive priority of science education (although common in other disciplines as well) which reproduces the (over) valuation of discrete factual knowledge. These authors traced widespread use of this type of test to the high value placed on scientific-based knowledge even in other school subjects. Although the discourse places value on test-based modes of assessment, it is easy to see connection to scientific positivism, which privileges the type of knowledge Tobias and Raphael claim is the basis of tests. Cavanaugh (2007) identifies science labs as a discursive structure unique to science education. The strong support for science labs by teachers and scientists (Cavanaugh, 2007) emphasises how these are discursively constituted as valuable in school science, yet the author's suggestion for more structured, formulaic procedures ostensibly indicates lack of awareness of the deeper epistemological assumptions contained in this discourse. Tippett (2010) reports on another common source of discourse in science education – the textbook. Refutation text, typical of modern science textbooks, is viewed as a more effective way than traditional expository text to learn concepts and to induce conceptual change. However, refutation text counters misconceptions based on holism by argumentation and questioning concepts in a reductive manor. This type of text values a particular worldview (scientific/Western), epistemology (positivism) and culture (Western). Although the use of textbooks may be prioritised in science teacher discourse, it is also a vehicle for other discourses of science (e.g., Bazzul, 2012), as demonstrated in the previous section.

Shanahan and Neiswandt (2011) produced a report based on research that implicates science community discourse as an agent of identity. In their study, Grade 10 science students were surveyed to determine their perceptions of the role of the science student. They found that: intelligence (knowing scientific facts and knowledge); scientific thinking (e.g., logical, rational, and positivistic); skill in science (expectation to carry out prescribed scientific procedures); and, well-behaved (expectation to sit and listen for long periods, and safely follow laboratory procedures) were statistically significant discursive structures defining the student roles specific to school science in Ontario.

## Economic Discourses in School Science and Nature

School science is also under the influence of broader social discourses contained in society. Economic discourses, for example, appear to be intertwined and co-dependent to a large degree, with science and school science (Bencze, 2010). Economic discourse may also be underpinned by assumptions about the dominance of humans in relation to nature (Dryzek, 1997); indeed, it may be an anthropocentric orientation toward nature that, if not permitting capitalist modes of production, have enabled them to become dominant (Nimmo, 2011). Modern economics appears to be based on values and principles associated with *neoliberalism*. Although a contested notion, neoliberalism is normally associated with laissez-faire economic policies, and criticism of legislative market reform (McMurtry, 1999). The term *liberal* in neo-liberal apparently refers to the older economic ideology of liberalism, which called for minimalizing government interference in the propagation and growth of private enterprise (Boas & Grans-Morse, 2009).

What is new in neoliberalism is the corporate coordination of governmental mechanisms to optimise conditions for entrepreneurialism and capitalism. In its more common usage, neoliberalism refers to the social and economic values underlying reform policies such as eliminating price controls, deregulating capital markets, lowering trade barriers, and reducing state influence on the economy especially by privatization and fiscal austerity (Boas & Grans-Morse, 2009). Neo-liberals tend to see the world in term of market metaphors. Referring to nations as companies is typically neoliberal, rather than liberal. Neo-liberals tend to believe that humans exist for the market, and not the other way around: certainly in the sense that it is good to participate in the market, and that those who do not participate have failed in some way (Reidner, 2015). In personal ethics, the general neoliberal vision is that every human being is an entrepreneur managing their own life, and should act as such. Individuals who choose their friends, hobbies, sports, and partners, to maximize their status with future employers, are ethically neoliberal (Reidner, 2015). This attitude - not unusual among ambitious students - is unknown in any pre-existing moral philosophy, and is absent from early liberalism. Such social actions are not necessarily monetarised, but they represent an extension of the market principle into non-economic area of life - again typical for neoliberalism. A neoliberal relaxation of government regulations for business and trade has resulted in new, extra-national entities, such as the World Trade Organisation (WTO) and the Organization for Economic Co-operation and Development (OECD), whose related branch in education, the Program for International Student Assessment (PISA) has influenced national education systems (Apple, 2001). The consequences of neoliberalism for education are widespread, but include increased inequity of education through the privatization of schools, as well as, likely, the inculcation of values in students associated with liberalism, such as competition, consumption and individualism, while underemphasizing and naturalizing the role of corporations, economic ‘common sense’ and private interest in science (Bencze & Carter, 2011; Hoeg, 2015). Closely linked to neo-liberalism in modern global economics, neo-conservatism refers to a general orientation to preserve traditional social interactions and stratification so that those already in power are ensured their continued power status and that the accumulation of wealth will continue to favor the traditional elite (Gabbard, 2000). In schools, this may result in the conservation of traditional knowledge and practices that advantage the elite, groups that have historically held power and wealth in society (Carter & Dediwalge, 2009).

Apple describes connections between neoliberalism and education (2001), and science education (2004), as existing in knowledge viewed as a product, or commodity, students must acquire to determine their value to neoliberal systems of production. The ingestion of a steady diet of conclusions (products) in science can cause students to develop tendencies of conformity that prevent them from drawing their own conclusions, and critiquing knowledge and those who control it (Woods, 1998). DeLissovoy & McLaren (2003) demonstrate how trends in educational accountability reify the consciousness and creativity of students into simple scores and indices according to a logic of commodification. According to Means (2013), the neoliberal systems that account for qualities such as innovation and creativity, ironically, restrict and oppress these qualities. The ‘value’ of the commodity is determined by assessment practices, which, although varying around the world, work to determine a quantitative account of students ‘readiness’ (Black & William, 2005). Carlson (2005) describes how neoliberal policies, and the corporatisation of schools, such as the policing of students, and quantitative assessment practices, work to oppress many students. Similarly, Grimaldi (2012) uses evidence from a case study on an inclusive education policy enacted to combat social exclusion and dropout in a disadvantaged inner-city area in the south of Italy to demonstrate how neoliberalism, as the new global orthodoxy in the field of education, subjugates and marginalizes policies and practices meant to enable social justice and equity. On the other hand, Lingard & Mills (2007) suggest that teacher pedagogy is potentially efficacious in reducing inequities and fostering social justice in school, though it cannot make all of the difference, and is necessarily influenced by curriculum, the purposes of schooling and assessment. Comber and Nixon (2009), in an institutional ethnographic study, found neoliberal discourse related to performance, managerialism, and accountability came to define how teachers viewed their roles and job expectations. Dorey (2013) reports on a new generation of accountability and mangerialism, in the form of assessments in the USA that will be based on the common national curricula. This is of concern, he claims, because such wide-spread assessment reduces the ability of education communities to tailor assessment to individual and local needs. In Ontario, provincial common assessment, the Education Quality and Accountability Office (EQAO) examination, provides evidence of educational outputs that are used to evaluate schools and, indirectly, teachers (Chudnovsky, 2010). Scott (2013) describes how neoliberal education mechanisms, such as merit pay incentives, charter schools, vocational curriculum, and high-stakes testing regimes do not fulfill their purported objectives, and instead are enormously detrimental to students, education workers, marginalized groups, social equality and ultimately the collective good.

A specifically and highly defined system of expectations, such as standardised curriculum for students, or performance expectations for teachers, can be seen as a system of performativity (Ball, 2000; 2008). Performativity, describes Ball, is the degree to which an individual aligns their behavior (teacher practice, learning) to pre-existing standards of ‘performance’, so that performance can be measured by those in authority. This acts as a mechanism of control (Foucault, 1980), to optimise the outputs of education (and other institutional) systems.

The ultimate purpose of this system of control is to ensure the output of education aligns with the needs and desires of the private sector (Ball, 2008). Pierce (2013) goes into great detail to describe how contemporary Science Technology Engineering and Mathematics (STEM) education functions to produce students with skills, knowledge and subjectivities useful to science work defined by corporations. The discipline of science education, claims Pierce, is being increasingly, sharply aligned with utilitarian purposes of education beneficial to neoliberal corporate entities, rather than individuals, communities, or nature.

Carter and Dediwalge (2009) demonstrate how a new Australian curriculum innovation, Sustainability by the Bay (SLB), emphasises neoliberal discourse by inculcating in students values and practices of competitive *consumers* rather than producers of knowledge. In the same study, neoconservative discourse is identified in SLB in the way it prioritises Western canonical scientific knowledge. These discourses in science education appear to limit students’ access to needed cultural capital (Bourdieu, 1990) that might enable them to have more agency in their use of science. A culture of privatization and competition were observed in science lessons at an elite private school by Brandt et al. (2010), reflecting the neoliberal values that infused the culture of the school as a whole. Neo-conservative influences were observed in the delivery of traditional school science approaches and knowledge, which were an advantage to the elite students attending the school. Ken Tobin (2011) describes the influence of neo-liberalism on the standards, competition, and accountability systems that mediate enacted curricula in schools and science classrooms, and criticised the resulting effects, such as teacher accountability and competition between individuals, schools, school districts and countries. Wesleys (2011) writes of the pervasive spread of neoliberal ideology of accountability and sanctions in public high schools in New York City that impose didactic, teacher-directed science lessons which are viewed as inappropriate to the diversity present in the classroom. Bazzul (2012), in a paper drawing attention to the need for critical consideration of how students are constituted in school science, noted the influence of neo-liberal discourse in grade 11 Ontario Biology textbooks.

As Larry Bencze (2010) has stated, neoliberal influences in science education have the potential to lead to confused, de-skilled, homogenised and isolated science students. Human dominance over nature appears to be a foundation of these modern discourses that are linked to neoliberal capitalism (Bowers, 1997; Dryzek, 1997; Nimmo, 2011). None of these studies, however, examine nature in the context of neoliberal schooling. This thesis, therefore, appears to be the first research to connect neoliberalism to constitutions of nature in school science.

## Nature in School Science Discourses that Marginalise the Other

Foucault has stated that what is not said in discourse is marginalised by its non-inclusion (1984). Anthropocentric orientations generally prioritise and value that which is seen to contribute to human civilisation (as determined by those in power) (Nimmo, 2011). Thus, individual differences that are not valued, such as certain forms of sexuality, gender and race, are 'othered', and marginalised or silenced, and seen as wild or uncivilised 'nature' (Harding, 1991). Scientific knowledge can therefore be said to marginalise, non-male, non-Caucasian, non-heterosexual perspectives, because these represent categories of knowledge based on socio-cultural constructions, not the realist view of biology/nature that traditional science discourse is based on. Dominant traditional discourses of white male-only science have been dispelled by academic work identifying the contribution of women scientists (e.g., Allchin, 2004; Haraway, 1989; McGee & Warms, 2004; Schliebinger, 1999) however, and feminist science scholars have called for greater inclusion of women, feminine discourse, and of more inclusive perspectives in general. Yet the dominant discourse in school science appears to still be rooted in the masculine perspective. For example, the three ideological pivots identified by Smolicz and Nunan (1975) as impregnating science – anthropocentrism, quantitative methodology and analysis – could be regarded as masculine and still dominant in Western science education (Hodson, 2009). The historic marginalisation of feminine perspectives have received abundant attention in science education literature and several excellent reviews establishing this marginalisation are readily available (e.g., Brotman & Moore, 2008; Pinder, 2008).

Mayberry (1998) reports that masculine discourses are reproduced through student collaborations in school science classrooms. According to this author, certain arrangements between students marginalise girls, because, when partnered with boys, dominant male learning discourses overpower those of girls, reproducing the traditional gendered type of science that has been criticised in feminist research (Mayberry, 1998). Tobkin, Seiler and Walls (1999) and Sammel (2009) identify discourse that reproduces 'Whiteness' in science education. Both of these pieces of research investigate structural racism in science education by exploring the positions of power and privilege that accompany Western, anthropocentric ways of knowing the world. These authors argue that privileged assumptions about knowing and understanding the world may not be shared by all individuals, and not be representative of "other" groups, marginalising some students. The authors specifically identify structures related to objectification and privilege as being complicit in the reproduction of whiteness in science.

## Marginalisation of Other Science Knowledge of Nature

A traditional discourse privileged in Western school science curricula acts as a gatekeeper, valuing certain knowledge and disregarding other types of knowledge (Ninnes, 2003). In this context, science can be said to marginalise Aboriginal, indigenous and traditional environmental knowledge because they are gained through non-traditional scientific practices, which may not be based on realist orientations that position nature as an object to be studied, and are therefore seen as incompatible with Western science and not included in curricula (Hodson, 2009).

This exclusionary practice can be criticised because it does not reflect a common heritage, but one "drawn from the framework of those who have dominated society and educational discourse (i.e., mostly White, male and middle class)" (Stanley & Brickhouse, 1994, p. 388). Kawagley et al. (1998) argue that this "narrow view of science not only diminishes the legitimacy of knowledge derived through generations of naturalistic observation and insight, it simultaneously devalues those cultures which traditionally rely heavily on naturalistic observation and insight" (p. 134).

Several scholars have identified ways traditional naturalistic environmental knowledge could be included in school science (e.g., Aikenhead & Ogawa, 2007; George, 1999; Sutherland & Denick, 2002; Sutherland, 2005). This needs to be conducted carefully, however, to avoid being re-conceptualised through Western perspectives, or simply used as a comparison in school science to demonstrate the validity and superiority of scientific methods (Southerland, 2000). Exclusionary criteria such as that proposed by Cobern and Loving (2001) ostensibly act to resist other forms of knowledge making it into science classrooms, where they could be beneficial in multicultural classrooms and progressive science programs involving environmental education or science activism (Glason et al., 2010; Stauffacher et al., 2006).

This review has demonstrated how nature, through its constitution in relation to humans, is presuppositional to a wide variety of modern discourses in society, science and school science. The occurrence of nature as a function of discourse is fundamental to human systems of language and thought, making its localisation and identifying modes of its constitution challenging. Additionally, the layers of discourse and institutional language, each of which containing assumptions about nature, need to be identified, exposed and penetrated in order to gain access to how nature is constituted by teacher practice. In other words, through evaluating the discourse and practices of teachers teaching science, one can begin to piece together how nature is constituted by some of the patterned ways science is taught.

# Chapter 3 : Methodology

My inquiry into how nature is constituted by Grade 9 and 10 Academic science teachers, starts by looking at the daily activities of participants, yet understands this activity as being organised and coordinated in certain ways through mechanism of the institution of school and/or school science. The research looks for reproductive phenomenon related to the constitution of nature, and attempts to understand this reproduction as empowered and privileged cultural practice(s) characteristic of school science. The research represents a type of *ethnography*, and adheres to many (but not all) of the principles of *institutional ethnography*. This chapter will discuss; foundational concepts and theories (structure; agency; discourse) related to the methodology; ethnographic research and traditions; institutional ethnography; the specific methods used in the empirical study, and; issues of ethics and validity.

## Foundations of Methodology

One way to think about contemporary (and historical) dualistic relationships with nature is that these are largely determined by 'structures' in culture, institutions and language (Boddice, 2011). Throughout its early history, research in social sciences has fixed its analytical gaze primarily on a society considered to be a product of the human intellect and consciousness (Nimmo, 2011). Yet, within these disciplinary boundaries, two distinct schools of thought emerged that initially created an ontological binary similar to the nature-human binary. One school, which led to the establishment of sociology as a discipline, was described in early scholarship by Durkheim (1895/1982), in which he depicted a society *structured* by "social facts" (p. 59), objective realities (collective rules and consciousness) that controlled the activities and behaviours of individuals. The term structure empowers that which it designates; in its nominative sense, it implies structure in its transitive verbal sense. Sewell (1992) claims "whatever aspect of social life we designate as structure is posited as 'structuring' some other aspect of social existence-whether it is class that structures politics, gender that structures employment opportunities, rhetorical conventions that structure texts or utterances, or other modes of production that structure social formations" (p. 2).

Structuralist interpretations of human conduct have been criticised by growing numbers of sociologists and anthropologists who acknowledge the influence of human agency in social interactions (e.g., Sawchuk, 2003; Smith, 1999). Max Weber, in reaction to the structural determinism of Durkheim, established in *Economy and Society* (1921/1968) a sociological school based on the individual, giving individual agency (conscious decision, choice, and identity) primacy in human activity. Weber viewed structures as interpretable by human actors; as such, he offered the original formulation of the relationship between meaning and social structure (Sawchuk & Stetsenko, 2008). Despite introducing the idea of agency, Weber still viewed structure as something outside of society rather than a product of humans' daily activity. Human agency, according to William Sewell (1992), means "to be capable of exerting some degree of control over the social relations in which one is enmeshed, which in turn implies the ability to transform those social relations to some degree" (p. 20). A capacity for agency includes desiring, having certain beliefs, forming intentions, and acting creatively and is inherent in all humans (Goffman, 1967). Sewell argues, however, that humans are born with only a highly generalized capacity for agency that is formed by a specific range of cultural schemas and resources available in a person's particular social milieu. The specific forms that agency will take consequently vary enormously and are culturally and historically determined (Sewell, 1992).

Together, these two perspectives represent opposite theoretical orientations in the classical structure/agency dilemma of sociology and anthropology (Sewell, 1992), represented in the following figure:

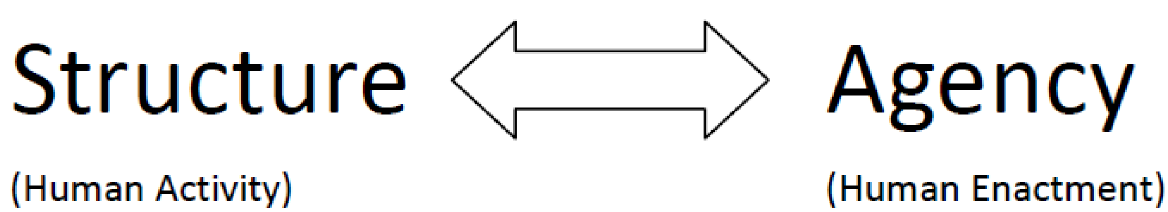


Figure 3.1. Structure and Agency

The reconciliation of structure and agency has provided the bulk of theoretical work in sociology since its inception (Delanty, 1999). Structure and agency appear to be mutually incompatible: structure in its traditional anthropological and common usage assumes a far too rigid causal determinism in social life, impervious to human agency. This makes dealing with change awkward; the metaphor implies stability, and without theoretical mechanisms explaining how structured patterns change over time, it follows that structure potentially limits or even eradicates human agency. Structure can be a useful way to explain dominant teacher practices related to nature. Often, there appear to be reproductive social phenomenon in science teaching communities that ensure certain practices are reproduced, that resist individual agency (Hodson, 2009)

## Reconciliations of Structure and Agency

Contemporary sociologists have endeavored to demonstrate how structure and agency are complementary to and dependant on each other (Delanty, 1999). Among recent theories of structure, Dorothy Smith offers a perspective that attempts to reconcile structure and agency. Smith uses the term "ruling relations" (Smith, 1999, p. 8) to describe those extra-local reproductive phenomena in social systems analogous to structure. In contrast to more traditional structure-agency approaches, the local and extra-local are seen as occurring together and being the same thing, produced by what people do. In other words, whatever extra-local social phenomenon that acts to similarly organize people's actions in society (structure) is necessarily produced by those very actions. Smith sees these relations as arising from the actual activity of people's lives; yet the daily activity producing these structures are themselves regulated by materials found in everyday existence, primarily in the form of texts. *Textualisation* is the term Smith (1999) uses to describe the relationship between the communicated word found in text and people's interpretation of the meaning of that text. According to Smith, the text contains rules of social relations that have the ability to activate certain preordained social actions among subjects; yet texts are variously interpretable, and people each bring their own unique subjectivities to the reading of texts, which can alter patterns of social action arising from readings. What is common among contemporary considerations of structure and agency (e.g. Giddens, 1981; Sewell, 1992; Smith, 1999) is their description of structure as something that is produced and reproduced through social behaviour, rather than something that is "outside" of society; the enactment of structures by individuals operating in social systems provides the theoretical leverage required, in the form of individual interpretation, to suggest how structural change can take place. The concept of ruling relations, and their dissemination through texts, is a powerful conceptual framework to understand how teacher practice constitutes nature. The possibility that a dominant 'ruling' ideology permeates school science, and that much practices is aligned to this ideology by texts teachers read, such as curriculum, policy documents, the written lessons and activities they use to teach, and textbooks, became influential in guiding my research, and using institutional ethnographic perspectives in my methodology.

## From Structure and Agency to Discourse

Discourse is seen as another social relation involved in the constitution of nature in society (Dryzek, 2007). Notions of discourse stem from post-structural thought, which question modernist and structuralist views of truth and knowledge; that a singular truth exists, which can be known by the Cartesian or Humanist subject, "the thinking, self-aware, truth seeking individual, who is able to master both their own internal passions, and the physical world around him, through the exercise of reason" (MacLure, 2003, p. 174). Instead, discourse theory views truth as discourse dependant, regulated and produced and perpetuated by discourse itself. Thus, knowledge is only validated, or made true, by the rules and assumptions of a particular discourse. In its critique of rationality and absolute truth, discourse is seen as a construct preferred over structure and agency by, for example, post structural scholars, who are critical of structural determination of society (Mills, 2004).

The conception of discourse in this dissertation resembles that of Foucault, first appearing in *Archaeology of Knowledge* (1972) and developed further in his lecture on "the order of discourse" (1981). Foucault's European-philosophical conceptualisation of discourse is frequently associated with human action or practice, as seen in his frequently quoted statement that discourses are "practices that systematically form the objects of which they speak" (1972, p. 49). Discourse might be broadly described as sets of practices (or knowledge) that construct reality and provide a shared way of understanding the world. They can be thought of as "practices for producing meaning, forming subjects and regulating conduct within particular societies and institutions, at particular historical times" (MacLure, 2003, p. 175). These practices and/or knowledge constitute both the possibilities and the limitations of what can be said, done or known by defining truth and knowledge in particular shared social relations (McCloskey, 2008). Thus, discourse can be seen as a way of 'framing the world' (Gerin-Lajoie, 2012, p. 205). In Foucault's conception, discourses are inextricably linked to *institutions* (the law, education, the family, etc.) and to the *disciplines (*such as psychology, medicine, science, or pedagogy) that coordinate and organise the practice of those within these social systems (Mills, 2004). It is the connection to institutions, such as school, from which my interest in the use of discourse for this research stems.

Social constructs based on the individual, such as identity, agency and subjectivity are all viewed as an effect of discourse because discourse not only determines what is possible to say, know and do, but also "what kind of person one is entitled/obliged to 'be'" (MacClure, 2003, p. 175). In Foucault's (1979) terms, the individual is "fabricated" (p. 217) into the social order. Tied to the notions of truth and subjectivity in Foucauldian discourse is power. In the Foucauldian sense, power is not held by individuals, but circulates in and through institutional discourse, inculcating "into the very grain" of people who are made subjects through their involvement in discourse (Foucault, 1980, p. 39). In other words, people can and do acquire power; this happens not through conscious effort to grasp and wield power, but through their practice of and participation in particular discourses.

Discourse as I have described it has some striking similarities to traditional conceptualisations of structure in that there is a definite constraining and reproductive aspect. Both structure and discourse appear to coordinate the activity of people, organising knowledge, practice and thought. These activities potentially inculcate a certain subjectivity, which can be viewed as analogous to 'mental schema' described by Sewell (1992). Both structure and discourse are described as being embedded in and communicated through human symbols, usually language, in material form (resources). One apparent difference is that structure metaphorically invokes a reductive view of these socially coordinating processes, while discourse appears more holistic and fluid; yet, Sewell (1992) describes structures as polysemic, multi-dimensional, and occurring on multiple levels, which does signify a degree of holism. Like traditional theories of structure, a perceived determinism in Foucauldian discourse makes the contribution of individual aspects of subjectivity uncertain, and, as Sarah Mills states (2004), "questions of agency are less clear and, as a consequence, questions of how much control one has over what happens as a result of one's own actions are very much to the fore" (p. 27). Discourse theory has difficulty in locating, describing and accounting for the individual subject who resists power (Mills, 2004). I draw this comparison between discourse and the broad conceptualization of structure I developed earlier to support my belief that constitutions of nature constructed through discourse, can also be viewed as structure-like phenomenon that are resistant to change. Giddens (2006) argues, as with structure, discourse is not completely deterministic, but is instead only constraining. If this were not so, whether using structure or discourse as a theory of social interaction, difference and variability, let alone change, would be unlikely; people in similar social and institutional environments would be more or less the same, and we would not see the variability in individuality, agency and/or subjectivity that does exist.

School science is a social realm influenced by various but interconnected discourses, such as general school institutional discourses, science discourse, and broader social discourses. In my attempt to understand how nature is constituted in school science by science teachers, each of these discourses may be influential and may be considered. My inquiry will start with how activities of the teacher constitute nature, and trace these actions back to the institutional and social discourses that come to bear on the teacher's practices.

**Ethnographic Research in Education**

Considering the constitution of nature as a science education 'cultural practice' rationalises ethnographic inquiry, to understand how this constitution takes place. Ethnography, in its most fundamental usage, means the systematic study of people and their cultures (Gall, Gall & Borg, 2007). Ethnography grew out of disenchantment with positivism in the 1960's and 1970's, causing many educational researchers to turn to more naturalistic and qualitative methods of studying social systems (May, 2002). Ethnography involves the intense study of the features of a given social system or culture and the patterns in those features (Giddens, 2006). This approach was initially developed by anthropologists, who made considerable effort to penetrate and integrate with foreign indigenous cultures in an attempt to study them (Gall et al., 2007). Nobu Shimahara (1988) identified three major foci of ethnographic research: discovering cultural patterns in human behaviour, conveying the emic perspectives of cultural members, and studying the real-life settings in which culture is manifested. Ethnographers seek to find *commonalities* in the beliefs, customs, and lifestyles that characterise groups of individuals living in proximity and identifying as a group, tribe or society. They are less interested in the *idiosyncrasies* of individual human beings, instead viewing each individual as a “document” (Shimahara, 1988, p. 80) that provides information about the larger cultural system.

The concept of culture has been problematized in modern times due to an insistence on the absence of hierarchy among cultures, and recognition that peoples of the world are grouped into many cultures, each with unique and positive qualities represented in patterns of traditions, symbols, rituals and artefacts (Wax, 1993). Gerin-Lajoie describes culture “as a ‘way of life’ influenced by history (including personal histories), where social practices are embedded in power relations” (personal communication, June 7, 2016). Murray Wax characterises culture as an overlapping multiplicity of qualities he describes as “a thing of shreds and patches” (p. 101); this view is in opposition to early anthropological conceptions of “plural, distinct, historically homogenous cultures that are both scientifically misleading and educationally irrelevant” (p. 103). These variable descriptions demonstrate that understandings of culture have changed over time, and lack unity (Lofland et al., 2006). Nonetheless, ethnographers still believe that what makes human beings unique as a species is the influence of culture in their lives and that an important difference between groups of people is their culture. Culture allows a particular group or society to live together and thrive through a system of shared meanings and values. How this ‘way of life’ is communicated and reproduced is frequently connected to structures and/or discourse (Gordon, Holland & Lahelma, 2002).

Ethnographic study often requires “direct observation, it requires being immersed in the field situation” (Spindler, 1982, p.154) with the researcher as a major instrument of research. A range of data types are collected — mostly qualitative, but also quantitative. There are many diverse types of ethnography, however, as a methodology, they are all concerned with understanding social relations between people in cultural settings. Approaches in classroom research that derive from linguistics and ethnomethodology are often linked to social interaction studies. Following Garfinkel (1967), 'ethnomethodology attempts to understand "folk" (ethno) methods (methodology) for organizing the world. Ethnography is conducted through a variety of research methods, however, the most characteristic in education are participant observation, interviews, videotaping, and collection and analysis of ‘cultural resources’ (such as: policy texts; teacher documents; student work) (Gall, Gall & Borg, 2007). In educational ethnographic research, researchers are further implicated in their field, since they have usually themselves experienced schooling as a participant. Issues of authenticity and authority are particularly poignant in ethnographic research (Gordon, Holland & Lahelma, 2002).

A key issue for educational ethnographers is the question of whether learning is better viewed primarily as a process of *cultural acquisition* or of *cultural transmission* (Gall et al., 2007). Research on cultural acquisition focuses on how individuals seek to acquire, or to avoid acquiring, the concepts, values, skills and behaviors that are reflected in the common culture. For example, Goldston and Nichols (2009) identified individual subjectivities of black science teachers, which they found to be in conflict with those of the dominant discourse of school science, including; valuing oral traditions; sensitivity to inequities of science education; and, awareness of community space and sharing. Studies of cultural acquisition appear to focus analysis toward individual agency rather than social structure. Cultural transmission, on the other hand, is interested in how the larger social structures intervene in individuals' lives in order to inculcate, or in some cases, repress, learning of particular concepts, values, skills, identities or behaviours. Shanahan and Neiswant (2011) found, for example, that social structures in school science communicated to students very specific ideas about the 'type' of student that belonged in science including those that are: intelligent (knowing scientific facts and knowledge); scientific thinkers (logical, rational, and positivistic); skilled in science (expectation to carry out prescribed scientific procedures); and, well-behaved (expectation to sit and listen for long periods, and safely follow laboratory procedures). George Spindler and Loiuse Spindler (1992) observed that the more individual focus of cultural acquisition makes it all too easy to adhere to a "blame the victim" (p.61) interpretation of individual's learning problems, and the preoccupation with the individual diffuses ethnography's unique perspective on how societies use their cultural resources to organise the conditions and purposes of learning. On the other hand, if one believes that individuals shape their own destiny, or have agency, this belief is difficult to reconcile with the regularities observed in social life, which sociology and anthropology traditionally interpret as structure.

Ethnography is not without moral and ethical issues; its history of inquiring into people and societies of others to describe how they live and are different from us is deeply embedded in imperialism (Smith, 2002). In sociology today ethnography is frequently used to describe the experiences and lives of those who are marginalized in some way in society. Ethnographers, in attempting to describe a people's ways of living, have to understand the people, and must become to some degree close to and be trusted by them. Ethnographic work is explicitly a product of two intersecting dialogues, one with those who are members of the settings to be described and the other with the discourse the research is to be read in (Smith, 2002). Issues of power lie in this intersection. One issue is that in reporting on the lived experiences of participants to outsiders, who then interpret however they want what is read, the reported experiences and relationships are often betrayed. Traditionally, the ethnographer takes what people have to say and reassemble it in an academic setting and language very different from which it was obtained, and with interests and purposes that do not originate with the participants. Striking an ethical balance between these conflicting interests is one of the central issues of ethnography. Increasingly, ethical balance is achieved by; authors making their own subjectivities and interpretations visible in reports; presenting in as direct manor as possible the voices of those being written about in studies, and; writing provocative auto ethnography, which focus on one’s own personal – and particularly emotional – experiences (Lofland et al., 2006). Conceptualising the discipline of science teaching as a form a ‘culture’, as I do in this dissertation, rationalises my use of ethnography in this research.

**Institutional Ethnography**

The research described here is broadly based on many (but not all) of the principles of institutional ethnography. I provide here a relatively detailed description of institutional ethnography in order to identify the methodological perspectives important to my research. Institutional ethnography is a specific type of ethnographic research that has much in common with other types of ethnography in that it also attempts to find patterns of social behavior that that might be said to be characteristic of specific groups (Griffith, 2006). As its name suggests, institutional ethnography situates inquiry among institutions, but this is meant in the broadest sense of the word. Institutions can be described as objectifying forms of organising and concerting people's activities that are distinctive in that they construct forms of consciousness that tend to override individuals’ perspectives (Smith, 2005). Foundational to these forms of consciousness are texts. Dorothy Smith, who is widely attributed as being the founder of institutional ethnography, claims “the architecture of institutions is through and through textual, whether in print or computerized, and institutional ethnography increasingly incorporates attention to texts and textuality" (2000, p. 22). In a sense one of institutional ethnography's aims is to discover how the institution is being produced through the particular nature and activity done by people at work. This begins with the issues and problems of people's lives and develops inquiry from the standpoint of their experience in everyday living (Smith, 1999). Inquiry is not confined only to description of the local organization of people's experiences (although these are essential); instead, the focus is on discovering how contemporary living is organized by and coordinated with what people, likely unknown to them, are doing elsewhere and at different times. The institutional ethnographer relies on the language people use to speak of what they know, their experience, and how they get things done. The language or the speech genre (Bahktin, 1986) of the institutional setting carries institutional organization.

Smith has been labeled a feminist scholar (Sawchuk & Stetsenko, 2008), and these influences are obvious in institutional ethnography. Feminism, as a political movement, appears to have originated in the 1960's to draw attention to, and change, social systems that disadvantage women. Feminist theory is one of the major contemporary sociological theories, which analyzes the status of women and men in society with the purpose of using that knowledge to better women's lives (Gall et al., 2007). Feminist theorists also question the differences between women, including how race, class, ethnicity, sexuality, nationality, and age intersect with gender (Harding, 1991). Contemporary feminist perspectives have expanded to inquire into the lives of all of those subject to dominant social relations, for the purpose of liberation from oppression (Smith, 2005). As an example of feminist scholarship, in her seminal research with Allison Griffith on single mothers (1990), a feminist perspective is found in their interpretation of the way single mothers were judged according to masculine rules of relations that dismissed the work of the single mother and positioned these families as being deficient, and as the cause of an assortment of social and education problems for the children. Feminist perspectives are interested in interrogating and changing the social organisation of society that has historically been designed by and to the advantage of men (Harding, 1991; Smith, 1987). Much of this social organisation is hidden from view due to the normalisation of masculine social structures and discourse; the feminist perspective makes these ruling relations visible, tangible, and unacceptable. Masculine perspectives have been associated with characteristics such as objectivity, rationalism, analysis, and anthropocentrism, characteristics that are also identifiable and dominant in traditional school science (Harding, 1991). Feminist perspectives, on the other hand, tend toward holism and inclusivity, making these perspectives attractive for school science education with goals to provide more holistic learning experiences (Longino, 1994). Although Dorothy Smith, long ago (1987), called her work a sociology "for women" (p.1), more recently, she and other researchers who use this approach (e.g., Campbell & Manicom, 1995) have broadened the potential scope of institutional ethnography, claiming that this form of analysis offers something for all those whose lives are subject to ruling relations. The interrogation of dominant masculine structures such as anthropocentrism, in efforts to produce more inclusive forms of knowledge, make feminist perspectives relevant to the research methodology of this thesis.

Like other types of ethnography, institutional ethnographers use participant observations, interviews, and the collection of cultural artefacts, specifically texts, as forms of data. Textual analysis, to ascertain the institutional social relations coordinating the specific 'work' of interest, is of particular significance in institutional ethnography. Increasingly, institutional ethnographers analyze discourse to gain access to the institutional ruling relations that organise the everyday lives of the people of interest in research (Comber & Nixon, 2009). Institutional ethnography departs from other ethnographic approaches by prioritising peoples' expertise in the conduct of their everyday lives - their "work", as Smith (1999, p. 13) has termed it - rather than its description through the objective frameworks of the ethnographer. Another distinction is its political nature. "Institutional ethnography allows one to disclose (to the people studied) how matters come about as they do in their experience and to provide methods of making their working experience accountable to themselves…rather than to the ruling apparatus of which institutions are a part" (Smith, 1987, p. 178). Thus, institutional ethnography has an authentic and emancipatory orientation that sets it apart from issues of validity and power that afflict many other types of ethnography. Institutional ethnography shares many of these features with critical ethnography, to the point where it becomes difficult to distinguish one from the other. Institutional ethnography, however, is associated with a more specific philosophical foundation (Feminism), than critical ethnography, and tackles specific types of social problematics – those associated with work in institutions, which critical ethnography may or may not take as a research focus. According to Smith (1999) the radical and differentiating feature of institutional ethnography is that of identifying the organization of the trans- or extra-local ruling relations[3] in the actual sites where people live or work, where they can be observed as local and temporally situated activities.

## Empirical Study

This study explores how nature is constituted by nine Ontario Grade 9 and 10 Academic Science teachers. The research methodology contains many of the components and perspectives of institutional ethnography described in the previous section; for example, my research sought to understand how participants everyday practice was coordinated by institutional ruling relations, and what bearing this had on how nature is constituted. Like in institutional ethnography, I initiated research with little pre-articulated protocol about how the research should proceed. Indeed, Smith (2005) insisted that this sort of ethnography is a method that evolves, and that researchers would work out how to proceed as they go along. Where my study diverges from a full institutional ethnography is the depth to which I trace the institutional coordination of teacher practice. Due to ethical considerations, I had access only to the nine "institutional informants" (Smith, 1999, p. 7) who participated in my study. In a full institutional ethnography, interviewing other informants, such as curriculum coordinators, principals, and school board members, often becomes necessary to understand the institutional social relations coordinating work. Along with these various informants come different sets of relevant institutional texts. Since I had limited access in my study, my data consisted only of what teachers said, and texts directly related to their practice.

This study attempts to answer the following broad research question: *How is nature constituted by Ontario grade 9 and 10 academic science teachers through discourse and practice?* Supplemental questions that this research aims to answer are:

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[3] These might the varieties of text-mediated discourse, the disciplines, the school

- What epistemological relationships are present in the way nature is constituted by participants' practices and discourse?
- What ontological representations of nature are prioritised in participants' practices and discourse?
- What is the social organisation of Grade 9 and 10 Ontario school science, and how does this organisation influence teachers' practice related to how nature is constituted?

Practice is conceived broadly here, and can include teaching activities, pedagogical approaches, and the enactment of specific learning experiences. In this study, practices encompass all of the work teachers do. Much of the evidence collected of participants' practice comes from their *claims* about their practice. Although there may be an ontological gap between claims about practice and what is actually done, the ontological object of interest, the social relations that organise the work of those in the institution, can be seen to be contained in the discourse of participant interviews and institutional documents (Comber & Nixon, 2009). Thus, participants' claims of their practice, even with errors of correspondence between claimed and actual practice, contain discourse enabling identification of social relations pertinent to the institutional phenomenon of interest (Kane et al., 2002), in this case, the constitution of nature by science teachers. Additionally, there is abundant research connecting the veracity of teachers' claims about practice with observed teaching activity in classrooms (e.g., Brown, 2002; Cervone, 1997; Ercikan & Roth, 2014; Marbach-Ad & McGinness, 2008). These issues of validity are discussed at greater length later in this chapter.

**Participants**

Nine full time science teachers participated in this research. Participants were selected using a 'snowball' sampling method (Gall et al., 2007), in which I accessed networks of Grade 9 and 10 science teachers first through individuals I know, who then conveyed the research participation request to suitable candidates they know; these candidates then further transmitted the recruitment request, expanding the network of potential participants.

Grade 9 and 10 Academic Science teachers were chosen for this study. Grade 9 and 10 science is the final two years of mandatory school science in Ontario, and the Academic program is designed to provide students with a deep "understanding of concepts in biology, chemistry, earth and space science, and physics" (MoE, 2008, p. 24). Given the courses similar aims and intended target student, to increase the number of potential participants, candidates teaching either grade were asked to participate in the study. In practice, grade 9 and 10 Academic Science is suggested for those students planning to focus on science in university, leading to science related careers. An alternate to the Academic courses are Applied Science courses, meant for students who will not pursue a university level science degree. Applied courses are less academically rigorous than the Academic level course, and are designed to teach more practical uses of science for everyday living. Teachers of Grade 9 and 10 Academic Science were chosen because they provided access to: (a) courses aimed at a career in science and therefore offer access to teaching practices that will influence possible future science professionals, including future science teachers (b) teachers of science at the highest level possible before becoming streamed into Biology, Chemistry and Physics in the higher grades. At this level, teachers are expected to inculcate the perspectives foundational to the discipline as a whole, rather than the more specific epistemological orientations of the Grade 11 and 12 science subjects (Hodson, 2009).

**Interviews**

Two, 2-hour interviews were a primary data collection activity of the study. Interviews focused on participants' background, institutional factors that influenced their teaching, and their teaching practice, both generally, and in relation to nature. Interviews are a type of narrative research, a broad category which typically attempts to use personal experiences communicated through language as a source of subjective, individualistic data (Reissman, 1993). Narratives initially held the promise of providing solutions to the problems of positivism by the use of methods that uncover experiences, voices and perceptions that are lost through the objectification of social interactions through more positivistic methods (Silverman, 2000). Yet, narrative inquiry is challenged by poststructuralist thought, particularly that found in the work of Foucault and his followers. In his extensive writing on the history of madness, punishment, sexuality, and other topics, Foucault (1984) suggested viewing the subject not as the originator of language, but rather as “a variable and complex function of discourse” (p. 118), even questioning the viability of the concept of the subject itself. Here, Foucault brings in the notion of how discourse (or text) shapes individual subjectivity, including the everyday activity and practice done in people’s actual lives. Texts appear in peoples talk because they are an integral part of what people do and know (Campbell & Gregor, 2002). But if the subject is understood to be merely a function of larger discursive systems, including texts, then the method of narrative inquiry runs the risk of constructing a tale that reproduces conventional and dominant language, and creating, despite its oppositional intent, yet another form of hegemonic discourse. It is this reproduction of dominant language and discourse, however, which makes the interview of particular interest and use to institutional ethnography, as inquiry is intended towards institutional language and discourse that contains the institutional social relations that signify a larger coordinating discursive system. At the same time, my research begins with and takes for granted the possibility that people experience, see, and conceive things differently (Smith, 2005). Each individual begins from a null point of consciousness (Schutz 1962), based in her or his body that no one shares. Social relations and organization generate difference; approaching things differently is what makes the concerting of people's activities open-ended and productive. Interviews provide the interaction required to access both science teachers’ individual experiences and perceptions, and those that might signal extra-local social relations.

The interviews were designed to establish a standpoint located in participants’ everyday lives as teachers in schools, by asking about their everyday practices teaching science. The interviews also gave me a standpoint from which I was able to explore these social relations – as a former science teacher, with some understanding of science teaching practice, with an interest in how nature is constituted by these practices, and the role of the institution in this constitution. Since an institutional order doesn't offer an obvious focus, locating these standpoints is critical, as they “organize the direction of the sociological gaze and provide a framework of relevance” (Smith, 2002, p. 20).

One issue I had to overcome in interviews was the tendency of teachers to speak from the generalized and generalizing discourse of professional school education, which can lack descriptive content and may be largely useless to access the actual activities of teachers in which will be embedded the social relations I am interested in. However, as Comber and Nixon (2009) point out, the genre of this professional discourse itself, and the identification of that which it marginalises, can reveal wider managerial and bureaucratic discourses that often are dominant over pedagogical discourse in the conduct of classroom practice. While I am interested in all discourses that may be connected to nature, interviews needed to be in a format that also evoked communication at a more descriptive level, providing detail about enacted activity related to how nature is constituted (Smith 1990).

These difficulties resulted in challenges developing the interview protocol. The authors of many published institutional ethnographic studies have pointed out the dynamic and evolving nature of interviews in these studies; Lisa McKoy (2006), for example, claims that it is difficult to develop a suitable interview protocol until the researcher starts the actual process of inquiry, and is able to observe or hear about the daily experiences and perspectives of the participants. Interviewees are typically chosen as the research progresses, as the researcher learns more about the topic, and can identify what needs to be known and who would know about it (Campbell & Gregor, 2002).

To guide the development of the interview, I conducted a preliminary phase of research where I had informal dialogue with three Grade 9 and 10 science teachers to gain understanding about what the types of data I might collect, the resources they might use in the classroom, and their ideas about how the research might be conducted, as well as pre-trial a set of interview questions. This preliminary phase was necessary to ascertain the feasibility of identifying the presumably deeply embedded social relations constituting nature I am interested in, and identify some of the linguistic and discursive barriers (institutional language) that I would have to address during interviews. This preliminary investigation indicated the interview protocol might focus on:

- describing how they teach;
- identifying some activities/practices they value;
- describing nature;
- describing nature of science;
- describing what influences their teaching.

Semi-structured interviews were developed, taking into account the perspectives gained in the preliminary inquiry. Semi-structured interviews typically can be thought of as a guide, consisting of a list of open-ended questions that direct conversation without forcing the interviewee to select pre-established responses (Lofland et al., 2006). The goal is to elicit from the interviewee rich, detailed materials that can be used for data analysis. Participants were told that a minimum of two, one-and-a-half-hour interviews would be required. The first set of interviews (for complete interview protocol, see Appendix D) generally involved:

a) Questioning the participants about personal experiences in science and nature, and their perceptions on the relationship between the two.

b) Questioning participants about classroom materials (including teacher/student activity texts) that influence what the teacher does in the classroom.

c) Questioning participants on the ‘institutional’ (i.e. the curriculum), and cultural factors (beliefs and values) that influence how they teach.

d) Asking how they teach about/for/in nature.

Each interview lasted approximately 2 hours, and was conducted at a location suggested by the participant, outside of their school. Interviews were recorded for later transcription. There was a progression from interview to interview, even when the same topics or questions were asked each time, as dimensions of the institution that I had not predicted or was unaware of at the beginning of the study became obvious through dialogue with participants. The open-structure and progression of the interview questions enabled this dialogue to occur, which may have be unlikely to happen using a more formalized and structured set of questions typical in some other forms of qualitative research (though by no means all). Traditionally structured interviews suppress the effect of dialogue, aiming at the outset to produce a monologic (Bakhtin, 1981) in which the respondent's part is subdued to the terms of the pre-set questions and pre-coded responses. Dialogue can be concealed either by the suppression of dialogue before analysis or by deploying theory too early (Bakhtin, 1981). Instead I attempted to create dialogue which, while recognizing my own interests in the research, relied on the participants to ‘teach’ me what I must learn from him or her to understand the social relations in which they are involved (Gadamer, 1994). As Alison Griffith (2006) states, “Institutional ethnographers are actively seeking to be changed, to discover not only what they did not know but also, as the research progresses, how to think differently about what they are learning” (p. 136). Through the progression of dialogue with participants, the first interview provided necessary background, contextual, and institutional data needed to start to answer my research questions. It also allowed me to identify what I needed to focus on during second interviews-specific *texts* that described activities the participants enacted- in order to access how nature is constituted by teacher practice and discourse.

Second interview and collection of texts

The second set of interviews (see Appendix E for complete interview protocol) focused on emergent themes from the first interview, co-evaluation with participants of three specific activities they selected, and institutional documents related to these activities. Since the constitution of nature may be largely implicit, questions had to be developed that would provide dialogue revealing these implicit meanings. It was determined that inclusion of questions focusing on how the activity represented Nature of Science (NOS) would be important to elicit this information, since this is the curricular area related to practices of science, which establishes the scientists' relationship with nature (Cobern, 1991). In addition, questions asking about how teaching activity relates to known discursive relationships with nature (for example, questions containing words such as dominance, control, manipulation) were also deemed to be important. A general semi-structured protocol was devised, which was used to co-evaluate each document with the participant, based on the following broad areas:

- Divergent questions, focusing on: how the activity fits within the general practices of school science; the participants intention for the activity; what they do/how they use the activity, and; what, if anything, would they do to improve it if there were no limitations.

- Convergent questions, relating the activity to: science; nature of science; nature, and; the institution of school.

- The use of key words, such as: control; manipulate; dominance; were used to prompt participants to relate the lesson to these ideas.

Institutional ethnographic researchers frequently focus, or converge, interview questions on institutionally relevant phenomenon identified in initial or prior interviews (Griffin, 2006).

Questions during the second interview therefore converged on institution phenomenon related to the constitution of nature communicated by participants during first interviews. The convergent direction of some of the question in the second interview, however, likely also stemmed from personal biases and beliefs about nature and school science. For example, as I expressed in the introduction, I was aware of, and struggled against, some of the dominant social norms related to nature in school science, which resisted my own attempts to provide a different form of science education. In other words, I had some beliefs about school science practices and nature, such as that these practices often engage students in controlling and dominating nature. These personal beliefs and experiences insert bias into research methodology (Charmaz, 2006). Such bias is an accepted part of qualitative research methods, however, and provides the researcher with a 'platform' from which to interpret data (Charmaz, 2006). Each interview lasted approximately 2 hours, and was conducted at a location suggested by the participant, outside of their school. Interviews were recorded for later transcription.

## Document Selection

The mystery of institutions is how they generalize people's activities across many local settings. According to Smith (2005), generalization is text-mediated, frequently through institutionally related *documents* containing standardized and replicable texts that are read, written and spoken to coordinate the local settings of people's work with work done by others, bringing external regulation into their daily activity. The text-reader conversation is active, but, unlike conversation between two individuals, the document remains the same; this feature provides institutional documents the ability to organise activity similarly in different locations. A given document may not be read by every person in the same way, but for each text the reader interprets and internalises the text, becomes changed by it and in a sense becomes its agent (Smith, 1999).

The collection and analysis of documents is an additional way in ethnographic and other qualitative research, besides interviews and participant observation, to gain access to and understand the research setting (Mirriam, 2009). Documents, also termed artifacts by some researchers (LeCompte & Preissle, 1993) differ from participant observation and interviews by the fact that they have existence before the research starts. This provides particular advantage to the researcher in that, because they exist independent of a research agenda, they are nonreactive, that is, unaffected by the research process. They are a product of the context in which they were produced and therefore grounded in the actualities of the everyday life of the participant. Teacher produced documents have the potential to demonstrate how institutional codes of activity have been taken up and interpreted by teachers (Comber & Nixon, 2009).

The teacher produced documents used in this study may be considered ‘artifacts’, because they are the teachers’ tools and instruments of everyday living (Hodder, 2003). For the second interview, I therefore requested participants bring with them three documents from their personal teaching materials. These documents are particularly important to understand how nature is constituted by teachers, since they are directly used by participants to plan and organise their daily teaching activity. These activities are represented in documents/texts that the students use to do the activity. The three documents participants were asked to select and bring to the second interview were:

i) A document containing the activity the teacher feels is the most representative of the way they want students to engage in science (the best thing they do in their program all year)

ii) A document containing an activity that is ‘typical’ of how they engage students in science inquiry

iii) A document containing an activity in which the goal was to learn about nature.

These three documents were chosen for several reasons. During the first interview, participants frequently spoke about a single activity or project, one they were clearly proud of, and this dominated much of the discussion. Participants also spoke of more frequently occurring types of science investigations that appeared to represent a more typical way of doing science than the activity they apparently thought was their best. Finally, since it became clear during the first interview that learning about nature was *not* the explicit intention of most lessons, it was determined that a lesson in which the goal *is* to learn about nature would be important to understand how nature is explicitly constituted. The choice of these three types of lessons is also rationalised through an institutional ethnographic perspective, graphically represented in non-canonical activity theory (Sawchuk & Stetsenko, 2008). As seen in Figure 3.1, three realms of activity are relevant to institutional ethnography: activity/structure appears to represent *ruling relations* in institutional ethnography; enactment/activity suggests *everyday activity*, and; meaning, although less developed in institutional ethnography, would appear to be represented in *standpoint*.

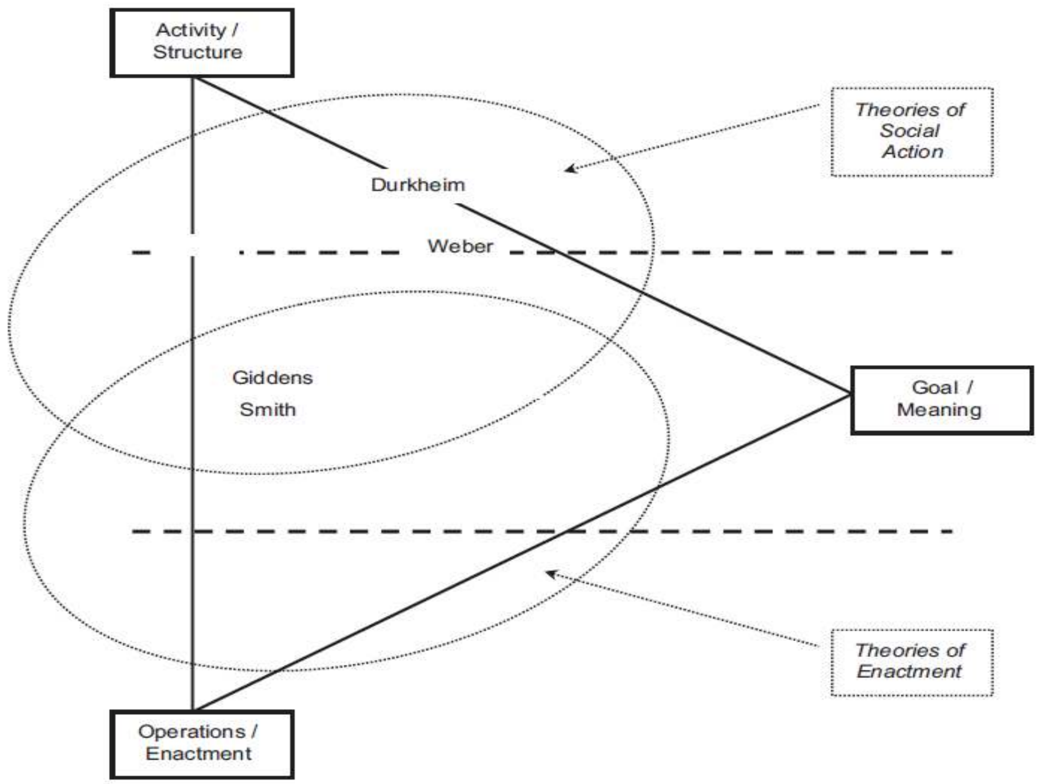


Figure 3.2. Non-canonical activity theory (adapted from Sawchuk & Stetsenko, 2008)

The best lessons/activity done all year, therefore, can be seen to represent meaning/purpose aspects of teacher enactment (goal/meaning in the diagram). This was an activity that was, perhaps, equally influenced by structures and local considerations. The activity that represents the ‘typical science activity’ appears to well represent the structures, or dominant discourse, present in school science education (activity/structure in the diagram). The activity selected by participants in which the intention was to teach about nature, represents the “local” (operations/enactment in the diagram) aspects of school science because it is based on the particular topic that is specific to this research, and therefore local conditions are of foremost significance in its enactment. The other two lesson choices were open ended in their subject focus, thus local considerations specific to teaching nature were not as relevant to their enactment. In addition, teaching about nature likely should be a locally relevant endeavour (Hart, 2005). These classifications are used only for the purpose of justification of the selection of these activities; likely, each lesson was influenced to varying degrees by each of the three aspects of activity represented in Figure 3.1.

I also analysed documents related to the practices and activities participants spoke about, and selected for the second interview. These documents primarily consisted of parts of the Ontario Grade 9 and 10 Academic Science curriculum and Assessment Policy (MoE, 2008) , and Growing Success (MoE, 2010), because these were identified during interviews as influential to teacher practice in the constitution of nature. These documents provided deeper understanding of the institutional influences on the specific activities they spoke about, and selected for the second interview.

**Data Analysis**

Smith (2006) advocates for analytical focus occurring at the level of social relations, which she conceives of as “what people are doing and experiencing in a given local site that are at the same time hooked into sequences of action implicating and coordinating multiple local sites where others are active” (p. 52). Analysis of data in my study proceeded by tracing the social relations participants were drawn into through their work. The point of analysis was to find data that demonstrates how participants were aligning their activities with similar practices of science teachers elsewhere, in order to illuminate the social relations that shape the constitution of nature. There was a definite analytic focus on that aspect of what participants said/do that is common or the same as what other participants in other locations are doing or saying. I was interested in those actions communicated by grade 9 and 10 academic science teachers that are connected to how nature is constituted, but also reference either explicitly or implicitly a larger institutional organisational framework.

Analysis of texts

The interview and textual data from documents collected about the constitution of nature was intertwined with many other issues, discourses, people and places (Campbell & Gregor, 2002). Analysis began in the development of interview questions that were responsive to what participants were saying. Analysis did not use pre-existing sets of categories and concepts as frameworks to organise and thematize transcripts or text. Typical of institutional ethnography, the focus was distinctly on those statements of doing or work that could be related to institutional texts or discourse. Analysis was directed by the people participating in the study; what they view as important and affective in texts, or those implicitly or explicitly referenced by them during interviews or observations became the focus of analysis. The point of analysis was not to describe an objective *potential* discourse found in texts; rather it was to understand how participants' activity produced the discourse found in texts through their daily actions. The analysis was meant to be usable to readers and participants so that they can better understand the social relations constituting nature present in their work place.

One type of analysis done most closely aligns with a general inductive approach (Thomas, 2006). A general inductive approach is evident in much qualitative research (Bryman & Burgess, 1994), often without an explicit label being given to the strategy. A general inductive approach is more oriented to explicating the local characteristics of the social relations the participants are engaged in, rather than attempting to provide an abstracted theory (grounded theory) or a generalised, objective set of rules and assumptions about these (Smith, 2006).

The procedures used in this research are common to the development of codes and themes in several other types of qualitative analysis, such as constant comparison analysis, and were carried out in the following steps:

1. The analysis was carried out through multiple readings and interpretations of the raw data, the inductive component. Although the findings were unavoidably influenced by pre-existing beliefs and biases, the aim was that findings arise directly from the analysis of the raw data, using participants' own words and conceptions of their work, not from a priori expectations or models. The objective of tracing ruling relations of the institution, however, provided a focus, or domain of relevance, for conducting the analysis.

2. The primary mode of analysis was the development of codes and categories from the raw data into a model or framework. Analysis of the interview and textual data was done by reading the transcripts and document texts, and identifying segments of text with common meanings, that could be *coded* to develop categories. A code is a construct that refers to a certain type of phenomenon mentioned in the database (Gall et al., 2007). An example of this coding is present below, using the following quote made by Joanne:

> I would say science at the best of times is sort of a descriptor (segment 1), it provides sort of a systematic account (segment 2) of what's happening so something as convoluted as the Krebs cycle (segment 3), so getting all the details down (segment 4), so it's descriptive (segment 5) it also can be manipulative (segment 6) (Interview 1)

The following codes were developed from this quote:

Science is a descriptor – Segment 1,5

Science accounts for nature – Segment 2

Nature is complex – Segment 3,4

Science manipulates – Segment 6

Codes were then grouped with other, similar codes to form categories. This process was aided by using NVivo qualitative research software (NVivo, 2010). The findings resulted from multiple interpretations made from the raw data. Inevitably, the findings were shaped by particular assumptions, previous experiences and beliefs. For the findings to be usable, decisions were made about what is more important and less important in the data. For example, there was abundant data on participants' backgrounds, beliefs about various issues pertaining to teaching science, and various types of institutional phenomenon. Some of this data was used in the next chapter on the context of the study, but much of it was omitted from this thesis because it was interpreted as not relevant to the research question, or the institutional ruling relations that coordinated science teacher practice that constitutes nature. The analysis resulted in themes corresponding to the social relations that participants describe which organise how nature is constituted in school science.

Critical discourse analysis of significant texts

A Critical Discourse Analysis (CDA) of significant texts was an addition methodological approach that offered triangulation of data to support the findings of the research. Triangulation can be defined as an "attempt to map out, or explain more fully, the richness and complexity of human behavior by studying it from more than one standpoint” (Cohen & Manion, 2000, p. 254). According to Denzin (2006), combining general inductive analysis with CDA, as done in this research, would represent a *Theory triangulation,* because it involves using more than one theoretical scheme to interpret texts relevant to the study (interview transcripts and various classroom and institutional texts). Combining multiple theoretical perspectives in data analysis can overcome weaknesses or intrinsic biases, and the problems that come from single-theory studies. Specifically, by adding CDA as an interpretive lens during analysis, I was able to perceive discursive patterns and themes in text that, while supporting themes identified during general inductive analysis, were different, providing a richer understanding of the social phenomenon of science teacher practice. The use of both interviews and document analysis in this study also provides *methodological triangulation* (Denzin, 2006). These different methods result in different kinds of data, both of which can provide insight into the phenomenon of interest, the constitution of nature through teacher practice.

Discourse analysis is increasingly utilised in institutional ethnographic studies because, as Dorothy Smith (2005). Foucault (1981) and others suggest, it is in the discourse communicated by individuals in institutions, and institutional texts, that provides access to the mechanisms of control (Foucault, 1981), or ruling relations (Smith, 2005), that institutional ethnographers are interested in. According to Peacock, (2013), institutional ethnography is both a social ontology and social scientific procedure that seeks to empirically investigate *discourse* as social relations that are organized by the activities of people. Critical discourse analysis has often be used by institutional ethnographers as a means to examine certain texts, not so much for their form as their function, because they are understood to be embedded within a field established through sequences of institutional action. As an example, Comber and Nixon (2009), in an institutional ethnographic study utilising critical discourse analysis, found neoliberal discourse related to performance, managerialism, and accountability came to define how teachers viewed their roles and job expectations.

Discourse in this study was ‘taken’ from the participants’ standpoint (Grade 9 and 10 Academic Science teachers); typically in institutional ethnography, the subject is viewed as embodied and located in activity which the discourse coordinates with, in this study, other science teachers at other schools. Thus, discourse was found in the practices of participants in the actualities of their everyday lives as they experience them. Their ‘practices’ are coordinated through discourse as how what they do is made accountable to themselves and others (Garfinkel 1967). I use discourse as a way to understand objectified organization of social relations that exist in people's activities, but which come to coordinate and ‘rule’ what they do, overpowering, to some degree, many aspects of individual agency, identity and subjectivity (Smith, 2005). This problematization of, rather than taking for granted, the practices (work) that produce institutions is the specific relevance of discourse to my ethnographic study.

To access discourse, analysis was done on statements made by teachers and the text of the activities they selected for the second interview. Text analysis methods such as CDA are seen as being complimentary to, and therefore used, in ethnography (Comber & Nixon, 2009). Textbooks, curricula, and other textual resources of teachers can be thought of as containing discourse or discursive formations that can be identified, analysed and criticised (Chiappetta & Fillman, 2007). CDA is concerned with studying and analyzing written texts and spoken words to reveal the discursive sources of power, dominance, inequality, and bias and how these sources are initiated, maintained, reproduced, and transformed within specific social, economic, political, and historical contexts (van Dijk, 1988). CDA tries to illuminate ways in which the dominant social constructions in a society, such as knowledge about nature-human relationships in science, construct versions of reality that perpetrate these same constructions. By unmasking such practices, CDA scholars aim to support the victims of such domination and encourage them to resist and transform their lives (Foucault, 1972). In these terms, the victims might be thought to be nature itself, or oppressed science teachers and students with different views of nature-human relationships (Yoon, 2005).

CDA tries to unite, and determine the relationship between, three levels of analysis: (a) the actual text; (b) the discursive practices (that is the process involved in creating, writing, speaking, reading, and hearing); and (c) the larger social context that bears upon the text and the discursive practices (Fairclough, 2000). These texts then are read by students and teachers, whom often construct identities and subjectivities constituted by the discourse embedded in the text (Gee, 1990). Gerin-Lajoie (2012) clarifies that discursive practices involve *ways of being in the world* that signify specific and recognizable social identities. Thus, students may learn to some degree how to be science students and/or scientists through what they read in the textbook; teachers may learn to some degree how to be science teachers.

Discourse is interpreted differently by people because they have different backgrounds, knowledge, and power positions—therefore, the 'right' interpretation does not exist whereas a more or less plausible or adequate interpretation is likely (Fairclough, 2003; Wodak & Ludwig, 1999). van Dijk (2000) acknowledges that CDA does not have a unitary theoretical framework or methodology because it is best viewed as a shared perspective encompassing a range of approaches. Huckin (1997) recommends that text first be approached in an uncritical manner, and then examined again using a more critical perspective .Several CDA techniques have been developed to facilitate this level of analysis.

Discourse analysis on a macro-level (Huckin, 1997) was done on texts during the initial, inductive analysis to aid in the formation of codes and categories. Finer levels of discourse analysis were then performed on select texts within categories and themes, to better define these constructs (Huckin, 1997). The table below is a summary of the techniques I used to determine the first 2 levels of analysis defined by Fairclough (2000) – the relationship between the actual text and the discursive practices of the text. Techniques are derived from CDA methods described by Gee (2011) and Fairclough (1993).

Table 3.1. Critical Discourse Analysis techniques (Fairclough, 2003; Gee, 2011).

| Technique/Strategy | How Technique Works |
|---|---|
| Unspoken/Naïve Assumptions | This strategy attempts to articulate what the text is saying without actually saying it. Such text includes statements about what is real (ontological), statements of knowledge establishing what exists, propositional assumptions (what's going to happen), and value laden assumptions (for example statements explicating how science can know |

| | |
|---|---|
| | nature implies it is an object we can know and are dominant over-anthropocentrism) . Other considerations are arguments for some things assumed and for others, not assumed? |
| `Making Strange` | In this strategy, we attempt to view each statement only through the meaning conveyed by the words themselves, rather than through the historical and sociocultural frames that give the statement other meanings. This helps to identify assumptions and what is taken for granted. |
| Nominalization | Instead of representing particular phenomena as historically situated processes open to change, they are spoken about like nouns leaving out actors. |
| Intersecting Genres/ Genres of Governance | This strategy identifies various institutional or speech genres not normally associate with science. Genres using language soliciting students to use, consume or buy are examples of an intersecting genre. |
| Mediation & Genre Chains | Mediation involves tracing how the meaning is moved from one text (or social practice) to another. Analyzing the chains of texts involved in getting a piece of text into, for example, a science textbook. |
| Genre Mixing and Interdiscursivity | Looking at the presence of mixed genres such as the mixture of school bureaucracy and scientific discovery. This hybridity also has an impact on social practices, for example the school expectations and limitations on how scientific inquiry might proceed in the science class. |
| Intertextuality | Looking at the presence of other texts within the science texts along with the assumptions that are made around the inclusion of these texts; the assumptions that connect one text to another. |
| Universals and Particulars | Essentially, how universals are constructed in terms of representations. What is seen is inevitable and universal thereby constituting the political space. |

| | |
|---|---|
| Constative and performative | Does the utterance describe something in the world, or is it performative, attempting to do something in the world successfully or unsuccessfully. |
| Dialogicality | Involves paying attention to the various voices contained within a text. Does the text allow for many voices? Does it allow for disagreement? How does the text portray difference? Is the language absolute? (Eco, 1989; Holquist 1981) |
| Internal Relations within the Text | Involves the semantic relation between clauses, words, sentences, grammatical relations (subordination of one thing to another), and the lexical relations between terms (the occurrence of one word with another, ex. Achievement and money) |
| Deictics | How is the statement or utterance tied to a specific context through the definite articles; what specifics meanings must be filled for the statement to makes sense. |
| `Why this way?` | How would a statement's meaning or connotation change if the statement were re-written grammatically, such as changing human and nature relationships to; human relationships with nature; or, human-nature relationships; or, nature-human relationships. How does the way it is written now contribute to a particular effect/meaning? |
| Activities/Relations Building | Ask what practices are being enacted or re-enforced. What kinds of relations in terms of other institutions or groups, are these activities associated? |
| Material Distribution | How do statements describe and justify specific distributions of goods (social and material) |
| Systems of Knowledge | How do the statements privilege one system of signs and knowledge over another? What kinds of knowing/speaking are privileged? |

Once this fine level of analysis was complete, the third level of analysis recommended by Fairclough (2000), pertaining to the larger social context that bears upon the text and the discursive practices, was aided by the discourse types, developed by Östman, in collaboration with Roberts (Östman, 1998; Östman & Roberts, 1994; Roberts, 1995, 1998). Drawing upon the dialogical meaning inherent in discourses, Östman (1994; 1996; 1998) describes the concepts of a "nature language" (Figure 3.2) and "subject focus" (Figure 3.3), two category systems useful for revealing companion meanings communicated in science texts. Nature language employs discursive practices and root metaphor(s) (or a blend of different root metaphors) to govern the use of language *about* nature, conceptualizing reality and constructing a particular view of nature.

| | Classical | Biomechanistic | Ecomechanistic | Organicist |
|---|---|---|---|---|
| | ← | | | → |
| | **Continuum from Classical (mechanistic) to Organicist (holistic)** | | | |
| Root metaphor(s) | Mechanistic, deterministic, atomistic<br><br>Objectified approach (nature is an object/thing separate from humans and human values) | Life functional ideas used (nature functions to support life), but classical notions and language predominant | Ecologically oriented form of classical language<br><br>Holistic views are articulated alongside atomistic and mechanistic, but organicist language dominant | Interconnected, holistic language<br><br>Ecological/systems perspective (nature is understood relationally, i.e., parts understood in relation to the whole; phenomena understood in relation to other phenomena) |
| Discourse rules | Root metaphor: machine | Metaphorical blend: view that nature functions as a machine *and* its purpose is to create and maintain life | Metaphorical blend: nature is a self-regulating whole that can be explained by mechanistic/ atomistic reasoning | Root metaphor: integration/whole |

Figure 3.3. Östman's (1994, 1996, 1998) categories for nature language.

The concept of subject focus is concerned with the discourse around the *relationship* between human beings and nature. How teachers (or texts) describe and/or use nature in science classrooms communicates a certain view of this human-nature relationship, ascribing a value to nature and our consequent moral responsibility (Östman, 1994; 1996; 1998). Drawing from the

work of Fensham (1988), Östman delineates two primary categories of subject focus: *Induction into Science* and *Learning from Science*. The *Induction into Science* subject focus views nature simply as an educational tool for teaching

| | |
|---|---|
| **Exploitation of Nature** | Human beings have used or can use nature to promote their material welfare; nature is a resource for exploitation by human beings and we have no moral responsibility in that respect. |
| **Human Being as Threat** | Human beings are threatening themselves and other living organisms; language used does not ascribe value to nature; communicates the idea that human beings have no moral responsibility or obligation when dealing with nature. |
| **Survival of *Homo sapiens*** | Humans should take a responsible attitude towards nature insofar as the survival or well-being of other human beings could be at stake; anthropocentric or human-centred ethical argument. |
| **Preservation of Nature** | Humans should take a responsible, duty-based attitude towards nature; nature has intrinsic value which we do not have the right to violate; biocentric or nature-centred ethical argument. |

Figure 3.4. Östman's (1994, 1996, 1998) categories for human-nature relationships or subject foci.

## Ethical Concerns

Participants had full access to the transcripts made of their interview, and had the opportunity to make any corrections or clarifications they deemed appropriate, and they had input into the development of themes and constructs, in that many were derived from their own words and experiences. A summary of ongoing analysis of the data was made available to participants, from which they made suggestions about emerging themes and clarified the definition of themes. Notwithstanding any prior consent, the participants were given the right to veto the use of the data at any point before, during or after the study and withdraw from the study at any time. This research placed participants in a situation of very minimal risk. Participants had the option to participate in both interviews. All raw data was stored in a location known only to myself, and pseudonyms are used for all names and locations.

My position to the participants was one of a known investigator, and I tried to establish an “insider” role to minimize the power imbalances inherent in the interviewer/interviewee relationship (Lofland et al., 2006). Being a former teacher, I was able to nurture the role of being a colleague, creating a more comfortable environment for the participants, making it more likely that they would allow me access to their thoughts, and practice. It should be noted, however, that the attempt to “balance” power differentials in the relationship of interviewer/interviewee is in itself a demonstration of control and power, highlighting the fact that any attempt to neutralize power differentials establishes the interviewer as the individual with power (Lofland et al., 2006).

Occasionally during interviews, participants were emotional when describing teaching or life experiences, and this might have placed them in a situation of vulnerability. For example, Janet described experiences as child in school in which she decided to care for a family of ducks that had lost its habitat on the school grounds. Janet was quite emotional describing this experience, and the revelation of her emotions may have introduced an aspect of vulnerability to the interview. However, I was aware of participants’ vulnerability in these situations, and was careful not to abuse the power this provided me.

## Validity

The current study appears to be the only research inquiring into the constitution of nature by teacher practices; indeed, studies of how nature is constituted in school, of any type, are infrequent. The little research that exists generally has found that discourse which values the human above nature, and uses language that constitutes nature in reductive and mechanistic terms, is common in school science (for example, Östman, 1992, 94, 96). Although these reports have some relevance to the current study, they were conducted nearly two decades ago, at a time prior to environmental education reforms in Ontario, which, one may assume, could have changed school science discourse in this province. A few recent studies have investigated discourse in science textbooks (e g., Bazzul, 2012; Hoeg, 2013; Sharma & Buxton, 2015); however these are studies of theoretical or potential discourse, as they do not attempt to understand how this discourse might be put into practice by teachers and students. There therefore appears to be no published research to which the results of the current study are directly comparable.

My own bias may have had an effect on my interpretation of the results. As a former science teacher who had reflected on how nature was taught in school science, I had preconceptions that may have influenced my interpretation of the data. For example, my fondest memories are of being in nature as a child, and I would state that I value all parts of nature highly. I believe everything is nature, including humans, and all of nature has intrinsic value. Early experiences in science, such as the bee experiment I described in the introduction, caused me to be critical of relationships with nature science often imposed on me. As a teacher, I came to understand school science as having certain, perhaps dominant social norms related to how students were supposed to engage with nature. I observed an apparent ‘culture’ of school science that appeared to align teaching, including my own, toward certain established norms. These practices, I realised, often engaged students in activity in which they were controlling and dominating nature. Additionally, reading I had done for my Masters thesis (on environmental perceptions of preservice teachers) and for this dissertation research, consistently pointed to strong anthropocentric traditions in school, and school science. This correlated with my own observations, perceptions, and experiences as a former science teacher, science graduate student and science researcher. However, I taught in school systems outside of Canada, and most of the literature I read also was not directly relevant to Ontario school science. Additionally, the commitments of the Ontario Ministry of Education to science curricula that includes NOS, STSE, and environmental perspectives, I hoped, would result in teacher practices that worked to disrupt anthropocentrism. Stated simply, I attempted to enter this research with an open mind.

I have outlined my experience and certain beliefs about science education and nature to provide a form of ‘external’ validity, or transferability to my research. In qualitative research, statement of potential biases or pre-existing beliefs acts as a way for readers of the research to interpret results, 'connect' with the research, allowing the application of findings to other settings (Charmaz, 2006). In other words, reader who understand and/or share some of my experiences and beliefs about science, science education, and nature, may be better able to observe and evaluate phenomenon I described in this dissertation to their own teaching practices and classroom science activity.

The results of this study are partially validated by triangulation of methods (Gall et al., 2007). Using both general inductive analysis, and critical discourse analysis allowed me to apply different theoretical perspectives to interpret the data, which resulted in greater support for themes than a single perspective would, as well as additional ways to understand the social setting (Denzin, 2006). Although interviews provide only teacher claims about what they did, these claims are validated by the activities they selected, upon which the second interview was conducted. These practices are material examples of the activity, and text, used in the activities participants choose. The nature of discourse itself also addresses issues of validity in participant claims – as Foucault suggested, the participant in an interview is not the originator of language, but rather as "a variable and complex function of discourse" (1984, p.118). In other words, although the participant may make conscious claims about their activity, these claims themselves contain discourse they may be unaware of, which provide evidence of the systems of knowledge and practice foundational to their teaching activity. Indeed, it is this reproduction of dominant language and discourse that makes the interview of particular interest and use to my study, as inquiry is intended towards institutional language and discourse that contains the institutional social relations that signify a larger coordinating discursive system.

Finally, there is still the possibility teachers claims about their practice in interviews do not align closely with what they actually do in their classroom. Again, the lessons they selected provide considerable links to practice; these lessons represent and are represented in Grade 9 and 10 Academic Science cultures, regardless of whether the teacher actually taught them, or taught them differently than described. The texts themselves are those that the student uses in doing the activity, therefore the student has direct interaction with the discourse contained in the text of these activities. Additionally, connections have been made between teachers' claims about their practice, and actual observed practice. If teachers' claims represent theoretical or potential practice, rather than actual practice, they can be considered to be beliefs (Kane, Sandretto &

Heath, 2002). Although beliefs cannot truly be observed one can infer two types, *espoused beliefs* and *beliefs-in-use*. Espoused beliefs are those beliefs which people describe when asked and beliefs-in-use are those beliefs that become apparent through observation of a person's actions (Barrett & Nieswandt, 2010; Kane et al., 2002). This study examines beliefs-in-use, as the participants are practicing teachers, and are, apparently teaching according to their claims. There is a strong correlation between beliefs-in-use described during interviews and actual practice (Brown, 2002; Cervone, 1997; Ercikan & Roth, 2014; Marbach-Ad & McGinness, 2008).

# Chapter 4: Participants and context of study

This chapter presents a short biography of participants, relevant information about the school settings in which they work, and details of the documents they selected for co-evaluation during the second interview. In this chapter, I also begin some analysis of participant statements, to orient the reader to methods used and the findings, which are presented in greater depth, in subsequent chapters. Nine Ontario Grade 9/10 Academic Science teachers participated in this study. Demographic information about the participants is found in Table 4.1.

Table 4.1 – Demographic information about participants

| **Name (pseudonyms)** | **Gender** | **# of years teaching** | **Educational Background** | **Current school details** | **Grades/Subjects taught** |
|---|---|---|---|---|---|
| Alice | Female | 14 | M.Sc. in Biology/Physiology<br><br>M.Ed. | Secondary school, gifted students, mid-high SES, high parental involvement | Grade 9 & 10 Academic and Applied science<br><br>Grade 12 University Biology |
| Ellen | Female | 11 | M.Sc. in Zoology<br><br>B.Ed. | K-12, gifted students, high achieving, mid-high SES, high parental involvement | Grades 9-10 academic and applied science<br><br>Grade 12 college and university biology |
| Heather | Female | 9 | B.Sc. with honors in Biology/Zoology<br><br>B.Ed. | K-12 public school, mid-low SES, low parental involvement, high immigrant population | Grades 9-10 academic and applied science<br><br>Grade 12 college and university biology |
| Janet | Female | 12 | -BSc. With honours in environmental studies | K-12, public school, mid-high SES, low immigrant population, high | Grade 9, 10 academic and applied science<br><br>Grade 12 University |

| | | | | | |
|---|---|---|---|---|---|
| | | | | parental involvement | Chemistry and Physics<br><br>Grade 12 college Chemistry and Physics<br><br>Grade 12 University Biology |
| Joanne | Female | 18 | BSc , Chemistry and Biochemistry,<br><br>M.Sc.<br><br>B.Ed.<br><br>Doctoral student in education | High ELL, the second poorest neighborhood in Canada.<br><br>French immersion location for the school board.<br><br>Over 50 different nationalities | Grade 9, 10 academic and applied science<br><br>Grade 9, 10, 11 math academic and applied,<br><br>Locally developed, Grade 11 chemistry and physics<br><br>Grade 12 University Chemistry and Physics<br><br>Grade 12 college Chemistry and Physics<br><br>Grade 12 University Biology |
| Frances | Female | 28 years | B. Ed, French,<br><br>Phys. Ed., Biology | Model is the "Northern Initiative" in which students from Grades 7-12 are in the school. | Grades 9-10 Academic Science.<br><br>Grades 9-10 Applied Science -Grade 11 Biology College and University levels.<br><br>French Immersion Gr.<br><br>9-10 Advanced Science and Gr. 11 Biology.<br><br>Grades 8 and 12 Phys. Ed.<br><br>Gr 7 Core French, Immersion French, French Immersion Social Studies, Math |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | and Science |
| Steve | Male | 8 | M.Sc. Physics<br><br>B.Ed. | Science focused high school; high achieving students; mid-high SES; high parental involvement | Grades 9-10 Academic Science.<br><br>Grades 9-10 Applied Science<br><br>Grade 12 college Chemistry and Physics<br><br>Grade 12 University Chemistry and Physics |
| Teresa | Female | 17 | B.Sc. Earth science and biology<br><br>B.Ed.<br><br>M.A (OISE) - Curriculum, Teaching and Learning. | Bring IT school, paperless, focus on 21 century learning and technology | Grades 9-12,<br><br>Intermediate science, biology, environmental science, earth and space science. |
| Zoltan | Male | 9 | B.Sc. Spec. Biology & Major Environmental Science<br><br>B.Ed. | low SES; high ELL; high immigrant demographic | Grade 9 Math, Science, Geography<br><br>Grade 10 Science, Math, Careers<br><br>Grade 11 Biology, Environmental. Science<br><br>Grade 12 World Issues, Resource Management, Economics |

All of the participants were experienced science teachers, with an average of 14 years teaching experience between them. Each participant except Ellen works in a public school in Southern Ontario, in or near to the General Toronto Area. Ellen’s school is a private school, but it follows the Ontario provincial curriculum and assessment policies, and is evaluated and accredited by the Toronto District School Board. Several participants have leadership roles in their school; for example, Joanne is head of the high school science department at her school, Janet is the grade 10 science team leader, and Steve is the head of Junior/Intermediate science and Senior Chemistry. In addition to teaching, some participants also have or had professional development leadership experiences, or have taught new science teachers in teacher education programs. Joanne, for example, teaches Senior Chemistry for preservice teachers at a university in Southern Ontario, and Alice taught Junior/Intermediate Science for preservice teachers at another university in Southern Ontario. Teresa was the science coordinator in her school board in 2013-14, a role in which she trained in-service science teachers about how to do inquiry in school science.

During interviews participants spoke in some depth about their past experiences in nature, and in science. Experiences in nature (Hart, 2005; Orr, 2004) and in science (Hodson, 2009; Lederman et al., 2002) are thought to influence individual beliefs and practices related to these topics. I will therefore provide some information about relevant experiences in science and nature in the proceeding section.

**Frances**

Frances is the only participant that did not have a strong science background. Frances's first degree was in physical education, and she claims: "I came into science through the back door. I don't even have a science degree! I got this job because of good timing. I mean all the other applicants had one, but they didn't have anyone else who spoke French at that time." (Interview 1). Frances did have an interest in Biology in high school, but did not do well in Physics or Chemistry, because, she explained, she dislikes Math. Frances taught at the Ontario Science Center for 2 years, and enjoyed that experience, because there was "much less pressure than if I was teaching. You don't have the marking you don't have the other stuff." (Interview 1).

Frances described herself as a city person and that she is "allergic to most of nature" (Interview 1). Frances claims she did not experience nature frequently in her childhood experiences, explaining:

> When I was in university, I took this camping course; we needed it for the Physical Education class, so we needed to learn outdoor activities. I did everything I could to get out of that course, even though it was a blast. So, when I go in nature, I don't mind it, buts it's not like, 'oh yeah, let's go camping'. My idea of roughing it is not having a Jacuzzi. (Interview 1)

Although Frances did not have significant training in science, she enjoys teaching science, and has gained expertise in science teaching over a 28 year career. She did, however, describe teaching practices that were generally more 'traditional' than other participants, particularly with regards to engaging students in methods of science. Most of the practices she described frequently involved lecturing, class discussion, and worksheet-type activities.

**Joanne**

Joanne has a strong background in science, having obtained a Masters degree in Chemistry. Joanne described some science research she was involved in during her degree, explaining:

> There was a project I was really interested in that I ended up pursuing. I ended up discovering this novel, new, biochemical. We were looking for something else, found this, and it met the requirements for my Masters' research. (Interview 1)

Joanne also described some oppressive experiences in university science having to do with gender, explaining several professors in her faculty had histories of sexual harassment, and she felt undervalued as a woman in chemistry.

Joanne explained her family background has had a large influence on her relationship with nature. As a family that emigrated from Italy, she claimed her parents had anxiety about their children exploring outside of their immediate residence, and required them to stay within the house yard. Although she grew up around the Niagara Escarpment, a geological feature with high biodiversity adjacent to Lake Ontario, and having nature all around her, her family believed that only the poor lived 'close to nature', and that wealth was equated to distance from nature. As a result, Joanne did not have many experiences in nature growing up. In a comment that perhaps summarizes her feelings about nature, she said:

> I would not say I'm super comfortable in nature. I could build a lean-too and survive overnight, but that would not be good times for me. Whereas other people I know are very comfortable doing that, other people I know are very much into that. (Interview 1)

Joanne described herself as a story-teller, using stories related to science and nature, and emphasizing the importance of connecting to students' interests through storytelling. Science methods she described in her practice were primarily formulaic laboratory activities.

**Zoltan**

Zoltan did not have the science research background some of the other participants have, however his degree in Environmental Science led him to work for environmental groups on the Niagara Escarpment, such as the Ministry of the Environment, and the Metro Conservation Authority. He explained that when the Haris government came into power, many workers in his field lost their jobs, and so he went to Asia to 'backpack' for a year.

Nature is, claims Zoltan, an important part of his life. Although he grew up in the inner city of Toronto, he moved to Mississauga as a teenager, where he "played in nature a bit more". (Interview 1). He also said "after high school I started camping, and canoeing. I would go out with a few friends, a canoe and just had a lot of fun." (Interview 1). Zoltan is now an avid outdoorsman, describing experiences canoeing on the Algonquin, almost losing his life climbing Mount Kinabola in Malaysia, and camping in the northern parts of Ontario. Some of the dangerous experiences he described perhaps influence philosophical beliefs he has about nature, which he explains in the following statement: "When you say nature I think, yeah you have to respect nature. Nature bites, it will bite you." (Interview 1). Zoltan, like Joanne, described his teaching practice as Socratic, but eclectic. He described many teaching experiences based on class discussion, in which he talks about Nature in ways to make it relevant to students. The science methods contained in the activities he selected, and described in interviews, appear to be primarily formulaic-type laboratory experiences in which students are using prescribed practices of science to investigate nature. Zoltan was one of only two participants who selected an outdoor activity as one of the three model activities they co-evaluated with me during the second interview.

**Teresa**

Teresa has significant experience in science, having majored in Biology during her bachelor degree. Working with the Teaching Assistant, who was a marine conservationist, in a university anatomy course prompted her interest in environmental science. During the summer of the final year of her Bachelor of Science degree, Teresa worked in Taiwan, making scientific observations on dolphins. She has a keen interest in conducting science outdoors, in nature, because, she stated:

> If I can't see the processes happening, I don't like it, I don't get it, whereas being outside, I can see erosion happening, it's sort of on a macro-scale as opposed to a micro-scale, so that's what attracted me to it. (Interview 1)

Teresa's interest in becoming a better science teacher caused her to pursue and Masters of Education degree, in which she conducted research about student learning in Science, Technology, Society, and Environments (STSE) education. Her research focused on teaching about issues and concerns related to science that prioritized humans, however, rather than issues and concerns in which nature was prioritized.

Teresa's experiences in nature were similar in many ways to those espoused by other participants. Growing up in a relatively urbanized area of Southern Ontario, she was not immersed in nature, and like Joanne, claimed cultural beliefs were part of the reason for this, stating:

> Growing up, my family, we didn't go out on hikes, we didn't go out to visit nature. I mean, I guess, Eastern European background; we didn't really go out and do that kind of stuff. We camped, but it was all car camping, so we didn't really go out and explore the woods or any of that. (Interview 1)

Teresa is deeply committed to science education related to STSE and inquiry, and described many teaching practices representative of these curricular areas of science education. However, these learning activities, like her Masters research, appeared to emphasize and prioritize human social issues, rather than more biocentric concerns that might prioritize nature.

**Alice**

Alice knew she wanted to pursue a career in science during her high school years, claiming science attracted and interested her. As a result, Alice obtained a Bachelor and Masters Degree in science. Her Masters research involved studying the cardiovascular function of mammals, which she describes in this statement:

> When I did my Masters at the university, my focus was on cardiovascular respiration during pregnancy, and our model organism was the sheep, so I had an animal model for my masters, so I worked with my animal subjects, and had to care for them, and things like that, but also, on the flip side, I performed surgeries on them to catheterize them, and so on, so it's kind of a strange relationship that I had with my subjects. I don't know what else to call them, my animal models. (Interview 1)

Although this statement is used here to demonstrate potentially influential experiences to future perspectives on teaching about nature in science, the language Alice uses here is also relevant. Science language in this statement objectifies nature, such as, for example, identifying the sheep as the 'subject', or a 'model'. Such language represents discourse, and analysis of this discourse can demonstrate how nature is constituted by science and in school science. Analysis such as this, pertaining to language participants used describing lessons, and in teaching documents, is presented in the proceeding results chapters.

Alice also spoke of experiences she had with nature growing up, explaining that she grew up on a mushroom farm in Southern Ontario, and so she was surrounded by nature. However, accompanying this environment was, she claimed, a utilitarian view of nature, in which she, and her family, saw nature through an economic lens, stating:

> I grew up on a mushroom farm, so we were outside a lot, and my dad was of course dealing with typical farmer issues, understanding how things grow, and how to grow the crop so that we could produce a lot of mushrooms, that was the topic of our conversation, how good the crop was, but related to selling it, the business end of things. (Interview 1)

Alice claims that, although she was outside, using nature to make money perhaps influenced "a different perspective on nature" and that, "even though we were outside, I didn't know anything about nature per say" (Interview 1). Alice described teaching activities that were heavily focused on engaging students in inquiry, however these were indoor classroom or laboratory investigations in which students were using typical methods of science investigation, involving measuring physical and chemical characteristics of phenomenon, to identify mathematical relationships that can be used to represent this phenomenon (Aikenhead & Ogawa, 2007).

**Ellen**

Ellen was another participant who had a significant background in science before becoming a teacher. Ellen worked as a scientist for 12 years before obtaining her Bachelor of Education, working in various contract positions, such as in the "Ministry of Natural Resources researching how they are going to facilitate moving species due to climate change" (Interview 1). More than the other participants, Ellen appeared to have fewer ethical or moral dilemmas with potentially controversial practices and products of science. Although she was critical of how science is used in corporate enterprises, her opinion was that "the problem is not science, its people" (Interview 1), a belief she expressed several times. This suggests she may have some idealized views of science, perhaps seeing it as a system of knowledge and beliefs that can be separated from humans who use it. Such idealization of science is often connected to beliefs that culture, values, ethics and morals are not part of science (Cobern & Loving, 1991); these beliefs may be relevant to the (mis) use science.

Ellen spoke of many experiences interacting and playing in nature as a child, describing playing in the dirt, and spending time in her families' garden. When describing what interested her about nature, she claimed,

> I've always sorted and organised things. You might not be able to tell from my desk here, but I love doing taxonomy, I love identifying plants, identifying insects, I loved organising things, part of my love of nature is understanding the organisation of it. (Interview 1)

This comment demonstrates in Ellen, perhaps more than other participants, a curiosity that appears to stem from seeing nature as an interesting object, perhaps something valuable to study and figure out. Ellen claimed she was always interested to see what would happen to nature if she altered it in some way, stating, "I was always interested in the animals, oh I want to see the bugs...pulling the legs off a grasshopper and throwing it into a spiders web." (Interview 1). These apparently oppressive practices toward nature seem to have relevance to her approach to teaching science as well. Ellen was committed to engaging students in science practices in which they used nature, both inanimate and living, to learn science knowledge and practices.

**Heather**

Heather appeared to have greater commitment to nature, the environment, and teaching students to respect and appreciate the environment, than other participants. Heather was particularly attracted to Biology, because she enjoyed the outdoor experiences and field trips her teacher designed for them. Heather had a significant amount of practical experience and training in science in her undergraduate degree, completing a Bachelor of Science with honors in Biology. During her teaching degree, she completed a research project that involved a field study at a beach. She described this study as involving:

> A transect survey of a beach, which was part of a new conservatory area, and they had to know where things were distributed so they could put in anti-clamming registration, to make this area more protected, so, it was kind of neat that that data could go to something meaningful. (Interview 1)

Heather describes herself as very curious, particularly about the environment, and nature. In describing her curiosity, she said "I'm constantly just asking why, and what factor would effect this, whether it's a change in a predator prey relationship, I'm very curious about that and I kind of just want to know how are things connected in the ecosystem" (Interview 1). She claims her love of nature comes from experiences she had as a child at her grandparent's cottage, and at summer camp in Algonquin Park, an experience in which "it was all girls, we just enjoyed being outside, and loved the nature part of it as well. For me spending time outside in the summer was a big thing, and I just loved being in nature." (Interview 1). Heather's interest in nature caused her to seek jobs related to nature; for example, she was a nature interpreter at the Wayan Marsh in the Ottawa region during her undergraduate degree. She also has used her interest in nature commercially, explaining, “I'm an independent travel consultant, so I just sent 120 kids to Costa Rica for a week, and I also run and environmentally friendly fundraising company”(Interview 1).

Teaching practices Heather described typically emphasized the environment, environmental issues, and how science can be used to understand these issues. She was one of the two participants that choose an outdoor activity as one of the three selected for co-evaluation during the second interview. One of these activities was also the only one in which the apparent, explicit goal of the experience was to develop value for and appreciation of nature. There were, however, some interesting choices made by Heather that seemed in conflict with her overall commitment to outdoor and environmental education. For example, she chose, as the best activity she does all year, a frog dissection. Although this will be evaluated in greater detail in the results chapters, this activity appears to contain strong, implicit and explicit, anthropocentric constitutions of nature.

**Janet**

Janet, like most of the other participants, obtained a degree in science, majoring in Biology, before becoming a science teacher. She engaged in some science research during the honours year of her degree, studying plant tissue culturing to test stress tolerance in potato plants. Janet said she was drawn to this research because “I always loved plants, I helped my mother take care of our plants as a kid, and I always wondered how to best help them grow” (Interview 1). Plants were interesting to Janet because she appreciated the mystery they represented, that they were

> a complex, living organism, yet very difficult to know because they don’t really move much, don’t demonstrate obvious complex behavior….I always felt there was more to plants than what I could see, and I wanted to find out what it is. (Interview 1)

Janet said that although she loved her honours research, she was unhappy with the isolation she felt as a researcher, and wanted more social interaction in her career, causing her to choose teaching.

Growing up in rural area of Ontario, nature was a large part of Janet's childhood. "My earliest memories are of being outside, grass, trees, sunshine, and happiness" (Interview 1), she explained. Janet expressed great appreciation for and respect for nature, stating:

> I think we've lost something, as we live more in cities, and leave the country, a connection with nature, familiarity; it was part of my everyday life when I was a kid. I valued, and value that, but I don't talk to many people that feel the same way. I'm not sure if that's something we need, but I feel I need it, and I want my kids (students) to experience that too. (Interview 1)

Janet's described her classroom as an active place, where students are engaged in hands-on learning in science, doing science experiments, and inquiries. The lessons she selected had much in common with other participants, in that they engaged students in methods of science investigation and lab work, with nature as the object of investigation, with the intent to learn prioritized science knowledge and skills.

**Steve**

Steve said he always did well in science because he "has an analytical, logical mind" (Interview 1). Receiving high marks in science throughout school, he said it was natural to major in science in university. "I always did really well in physics and chemistry, because I enjoy the microscopic, atomic, the idea that things we see have a lot more complexity to them, and understanding that, I always found that really engaging" (Interview 1). Steve choose teaching, instead of science, because, he claimed, university science labs "were boring, they seemed so scripted, everyone was doing exactly the same thing, the recipe, and it was alike a big competition, to see who could finish first and get the right answer. That repelled me a bit" (Interview 1). Steve became a science teacher because he wanted to remain in science, but was interested to see if he could develop science investigations different than the formulaic experiences he had in school science.

Living in the city, nature was, claimed Steve, not a large part of his life growing up. "I didn't spend a lot of time outdoors, I was more interested in indoor activities, sports, reading, things like that" (Interview 1). Steve says his appreciation of nature has increased as an adult; for example, he enjoys going camping and exploring nature with his wife and children. He claimed "I think it's important, getting exposure to nature; I want my kids to have some of that, I think kids in the world today don't get enough of that" (Interview 1). As a result, Steve tries to bring nature into his science class "through discussion, by talking about nature when they are doing various activities, bringing attention to environmental issues, and studying these in lessons and projects" (Interview 1).

Steve's approach to teaching science is to "engage students in authentic science…not cookbook labs so much, although I do those sometimes, but their own investigations, wherever possible, in a way that's relevant to them" (Interview 1). This is somewhat reflected in the lessons he choose for co-evaluation during the second interview, in which students had some choice in what they investigated in at least one activity (Germ Ecology Study).

**Grade 9 and 10 Academic School Science**

As provincially mandated school subjects, there are specific expectations for students and teachers associated with Grade 9 and 10 Academic Science. Many of these expectations are communicated in policy, such as the curriculum. Other expectations are communicated in science teacher professional development sessions, and newsletters. These expectations communicate to teachers aspects of what they are responsible for, such as: professional conduct; how and what they should be teaching, and; how and what they should be assessing. Together, these expectations are communicated in 'dominant discourse', the discourse created by those in power, which becomes the accepted way of looking at (or speaking about) a subject (MacLure, 2003). In institutions, such as schools, dominant discourse is frequently communicated through official policy text and spoken word (Smith, 2005). The dominant discourse conveyed by participants in this study describes what is expected in the *work* of an Ontario Grade 9 and 10 Academic science teacher. The significant dominant discourse that was communicated in this study is presented in the following sections.

Curriculum

Language about the curriculum tends to be part of the dominant discourse in schools (Gerin-Lajoie, 2012). The curriculum was the most common topic of conversation when participants spoke about the institutional factors influencing their day to day enactment of school science. The curriculum used for Grade 9 and 10 Academic Science is specific to these two grades, and was revised in 2008 by the Ontario Ministry of Education (MoE). The curriculum is a policy document that outlines the provincial science education vision, goals and expectations. Expectations are derived from three overarching goals, which are summarized as:

1. to relate science to technology, society, and the environment
2. to develop the skills, strategies, and habits of mind required for scientific inquiry
3. to understand the basic concepts of science (MoE, 2008, p. 2)

In addition to these goals, the document articulates the importance of the Nature of Science (NOS) to student learning. NOS is a content area concerned with how science is practiced, including cultural, sociological, and affective aspects of practices and products of science (Pedretti & Bellomo, 2015). This important component of science education contains content relevant to how nature is constituted through practices of science. Other considerations in the Grade 9 and 10 science curriculum include: Environmental Education; inclusion and access for all learners, and; English Language Learners (ELL's). Science content is aligned vertically along the following 4 strands: Biology, Chemistry, Earth and Space Science, and Physics. Within each strand broad conceptual and skill based *overall expectations* are defined; *specific expectations* that provide more finitely described knowledge and skill expectations are derived from the overall expectations for each strand. In addition to this main curriculum document, science teaching in Ontario is expected to reflect the 2009 curriculum initiative, *Acting Today, Shaping Tomorrow: A Policy Framework for Environmental Education in Ontario Schools* (MoE, 2009), which describes how environmental education might be integrated across disciplines and throughout grade levels in Ontario schools. Although not specific to school science, the goals, skills and concepts outlined in the document clearly identify science as important to the environmental education outcomes it communicates. The Ontario Ministry of Education supports interpretation of the curriculum by teachers, and its design appears to provide considerable choice to teachers in regards to what is taught and evaluated. For example, when describing the learning expectations, the policy states:

> Teachers will use their *professional judgment* to determine which specific expectations should be used to evaluate achievement of the overall expectations, and which ones will be covered in instruction and assessment (e.g., through direct observation) but not necessarily evaluated. (Emphasis added) (MoE, 2008, p. 23)

The language of this statement, particularly the phrase "use their professional judgment" appears to provide agency to science departments and teachers to prioritize certain expectations over others. Such flexibility in curriculum choice was reflected by participants, who described units they prioritized, which invariably reduced the amount of time they had for others. Joanne, for example, stated:

> A few years ago, I was at a STAO (Science Teachers Association of Ontario) conference, and the Ministry of Education said we could/should treat some of the curriculum with benign negligence, so I tend to focus on the chemistry because that is what they will need next year. Astronomy usually gets left out a bit, or covered really fast. (Interview 1)

Joanne also teaches high school chemistry, and majored in chemistry in her undergraduate science degree. Her comment suggests she views the curriculum as a document with enough flexibility to allow for what appear to be her priorities and preferences. Comments such as these, suggest the curriculum is not as deterministic to teaching practice as participants frequently claimed.

When considering the curriculum as a social relation that both enables and limits teacher practice related to constitution of nature, how the curriculum suggests nature should be taught is of primary interest. For example, the discourse in the EE goal "students should understand their fundamental connections to each other, to the world around them, and to all living things" (MoE, 2008, p. 12), contains discursive meanings related to humans and nature that may set limitations on what is possible to think and do (Foucault, 1984). Relevant institutional text, and its meaning, will be discussed more in Chapter 7.

## ‘Delivering’ the Curriculum

The intention of this research was to identify and understand how teaching *practice* constitutes nature, so it was not surprising much of the discussion involved practices associated with ‘delivering’ the curriculum. The phrase deliver the curriculum was used frequently by participants: for example, Heather said “when it comes right down to it, my job is to deliver the curriculum” (Interview 1). Clarifying questions indicated what participants’ generally mean by delivering the curriculum is “ensuring that students are learning what is in the curriculum” (Steve, Interview 1). This section will provide some of the dominant ways participants spoke about ensuring students were learning what is in the curriculum.

### Lecturing

All of the participants claimed to teach the curriculum through lecture. Lecture, according to how participants described it, is a relatively teacher-centered approach, in which the teacher is presenting knowledge students need to know orally, often with visual aids, such as PowerPoint presentation. Lecture was seen as the most efficient way to ‘cover’ learning expectations in the curriculum quickly. Alice, for example, said:

> I’d have to say, when I need to cover a lot of material, lecture is still one of the things I do, to do that. There is just too much to cover in the curriculum, and sometimes lecture is the most efficient way to get through it all. (Interview 1)

Participants generally described their role as providers of knowledge. This can be observed in Elizabeth’s comment, for example, “the science teacher has to know their stuff, and know the content, so would say that knowledge is the priority for a science teacher, knowing the knowledge (Elizabeth, Interview 1). The use of “’the’ content” and “’the’ knowledge” discursively constitutes science knowledge as a particular product that is agreed upon, stable, and a true representation of reality.

Lecturing was described as having advantages over other practices, such as more open-ended student activity such as inquiry. Frances’ statement about teaching knowledge through lecturing conveys her view on its advantages:

> In education now they want discovery, and they want open ended, the problem is, unless they have the basic knowledge they can't go anywhere, because they might spend their time discovering, going down a path that is totally wrong, we know it's wrong, so let's go back. So let's make sure they know the right stuff, through lecture, and then they can go beyond. (Interview 1)

The unguided discovery learning described by Frances may very well be inefficient in teaching students specific science concepts deemed important by science teachers and/or the curriculum (Mathews, 2002). Most of the participants, despite admitting to lecturing, did acknowledge its limitations. Ellen, for example, stated:

> I try to avoid lecture, as much as possible, I prefer to do instruction, practice, hands on, demo, discussion, certainly lab activities, stations. We just started the electricity unit, and, kids experience is really varied. That's really useful because when you have a class discussion, you hear a lot of different stories and experiences from the kids, and it's more of a shared discussion, rather than me just going on and lecturing. (Interview 1)

Class discussion was often suggested by participants as an alternative and preferred practice to lecturing about nature. Many participants described teaching science during class discussion as a practice of telling stories. Joanne was a great advocate of storytelling, explaining how she taught about Coulombs Law by telling a story about Michael Faraday in the next statement:

> I talk about Michael Faraday, and the reason why I talk about him is he's a real interesting figure in the history of science, he grew up dirt poor, worked his way up, and he sort of got in the Royal Academy of Science through the back door, and I tell them that science back then was limited to who could take it, and I know my students, especially where I teach now, relate to that because they are the underdogs, they are the ones who don't have all the opportunities, and I talk about resilience and persistence, so suddenly Faraday, and coulombs' law becomes slightly more interesting because of the back story (Interview 1)

Teaching through stories is a traditional instructional approach, utilised by many cultures throughout the world to learn about nature (Kawagley et. al., 1998). These stories often act to convey cultural stories or meta-narratives, communicating values and traditions of cultures and societies, in this case, overcoming odds, persistence toward a goal, hard work, resulting in success. The intention of the story Joanne tells here about Faraday, however, appears to be intended to engage students' interest, so that specific, prescribed science knowledge, in this case, Coulombs' Law, will be more effectively learned. In other words, telling-stories appears to be a pedagogical strategy to make lecture more engaging to students, but the primary intention is still to convey the required, prescribed knowledge outlined in the curriculum.

Nature of Science

A dominant discourse describing what scientists do, and therefore what students should do in science class, was frequently observed during interviews, and was claimed by participants to be influential to their practice. This discourse appears to fall within the domain of Nature of Science (NOS). The Ontario Grade 9-10 Academic Science curriculum identifies NOS as a focus of student learning, and states that it should be based on the following three general tenets:

- what scientists, engineers, and technologists do as individuals and as a community
- how scientific knowledge is generated and validated, and what benefits, costs, and risks are involved in using this knowledge
- how science interacts with technology, society, and the environment (OME, 2008)

Participants seldom spoke about NOS directly; several were not sure what NOS referred to. Despite the lack of familiarity with terminology, participants' described activities that focused on NOS, particularly the second NOS tenet. For example, Joanne said, "I think that real science, the science that scientists do is not, you don't read about it in a book, you get your hands dirty and touch stuff, and I think that's valid, that's a valid sort of thing" (Interview 1). The discourse here privileges doing physical activity, such as the experimental activities many teachers consider to be the trademark of science, and suggests learning about these things more abstractly, such as through textbooks, is a somehow less ideal approach. Frances provides another example of how teachers enact learning about NOS, through lessons focused on 'the scientific method', stating:

> I teach the scientific method, and I say "You have to play by the rules; otherwise if you don't control your variables, and you have 15 different things (variables), then you don't know which one worked". (Interview 2)

There are several discursive elements of interest in this statement. Michelle is conveying to students a singular method of doing science, one in which there are rules to guide conduct. Although other participants had a less structured view of how science is done, the teaching of a single method of doing science was uniformly enacted (see proceeding section on *cookbook labs*). There is an individualistic discourse in Michelle's statement as well, identified by her frequent use of "you" and "your". This individualism works with a discourse of 'ownership' and control when Michelle states "control your variables". The discursive, or *companion meaning* (Östman, 1994, 1996, 1998) is that students own and control the materials they are engaging with through the methods of science. This is a discursive theme that was frequently encountered when participants described how they engage students in science methods, and will be discussed in greater detail in Chapter 6.

There was a general lack of discourse related to the NOS tenet: what scientists, engineers, and technologists do as individuals and as a community, and; how science interacts with environment (MoE, 2008). I make note of this because, I would suggest, it is within these NOS considerations where constitution of nature might be examined. Other features common in NOS discourse, such as breaking myths of science being objective, or that science is a socio-cultural endeavor, with particular values and beliefs, were not frequently observed among the participants, even when directly questioned about NOS.

Formulaic, 'Cookbook' Laboratory Activities and Investigations

The 'cookbook' lab was among the activities most frequently described by teachers related to methods of science. This type of activity, also described by participants as the 'recipe' lab, 'formal' lab, and 'traditional' lab, involves students in a step-by-step procedure designed to produce expected results (Pedretti, & Bellomo, 2015). A frequency of 3-4 cookbook labs per teaching unit was commonly claimed by the participants. Cookbook labs meet some of the expectation of Overall Learning Goal 2 - to develop the skills, strategies, and habits of mind required for scientific inquiry (MoE, 2008). Cookbook labs give students some experience in practicing methods of science, while 'discovering' known scientific concepts in the process. Zoltan spoke of his use of cookbook labs when asked how he usually engages students in science methods in the following statement:

> More often, it's the recipe lab, unfortunately, because we are stuck for time. Most times its recipe book...like, here's the recipe, go. Here's your data, what do you think? Because we just don't have the time to do what we would really like to do. (Interview 1)

Every participant had similar comments about the use of cookbook labs: they are not ideally how they would like to teach science, but they were efficient in *teaching knowledge*. This conceptualization of efficiency connects this science practice to discourses of performance, and accountability identified in Chapter 7. The cookbook lab was seen by participants as being effective because the knowledge learned through these methods is reliable, predictable, and proven, making these methods effective in ensuring students learn required science content, which could be evaluated and therefore used to determine students performance.

Inquiry

Participants frequently spoke about the need for students to be engaged in inquiry. Inquiry in school science typically engages students in activities that are more 'open-ended' than cookbook labs. Inquiry experiments often start with a question, ideally posed by the student, who then assembles the procedures and materials needed to answer that question (Pedretti & Bellomo, 2015). Although inquiry has become a catch-all term in many locations encompassing many types of student investigation (Pedretti et al., 2006), ideally in inquiry, students have greater degree of freedom to explore their own interests than they would in a traditional science investigation. Inquiry is valued by many science educators because it is seen as providing a more 'authentic' (Calabrese-Barton, 2012) experience for students, similar to what `real` scientists do. School science in Ontario is, apparently, committed to inquiry, as evident in the second Overall Learning Goal, which identifies inquiry as an expectation (MoE, 2008), and the abundant amount of time participants spent discussing inquiry. Steve, for example, said "In terms of being a scientist, science is very much about doing, so I try to include a lot of inquiry based stuff in my practice, because I just think that's the way science is done" (Interview 1). Zoltan expressed a similar view about the reasons for doing inquiry, stating:

> In doing inquiry, I guess we are making them into scientists and they have a better appreciation of making a hypothesis, asking a question, coming up with predictions, doing a lab, and saying, that was a bust, what are we going to do now? (Interview 1)

The discourse here suggests clear conceptions of what a scientists does; make hypothesis, ask questions, predicts outcomes and does experiments in laboratories. Although these things may be true of many scientists, this discourse also represents a somewhat stereotypical view of a scientist. The implication in this discourse is that scientists' understanding of nature occurs through logical-deductive practices done in the laboratory (Hodson, 2009). Participants were almost unanimous in the frequency of inquiry, agreeing they engaged students in inquiry "once per unit, if I can" (Ellen, Interview 1). Given that there are typically 4 units per school year, it appears students are typically engaged in inquiry activities approximately 4 times per grade in 9 and 10 Academic Science. Janet described how often she engages students in inquiry in the following quote:

> So in each of those (four) strands I make sure there was an open inquiry, so one in which they develop a question, design an experiment, run the experiment, and develop conclusions. (Interview 1)

The amount of student choice and agency described by Janet here represents a relatively student-directed and open ended form of inquiry. A potential issue some science educators see with such open-ended inquiry is that the teacher has little control over the knowledge students obtain in these experiences, and therefore they may be less effective in drawing students to the knowledge prescribed in the curriculum (Mathews, 2002). In recognition of this, other participants used a more directed form of inquiry, such as Zoltan, who described how he engages students in inquiry about light in this statement:

> Some things are great through inquiry like we teach refraction through inquiry, like here is a glass block, put it down, go. What the heck happened here? What happened? They have only a few materials, and there are only so many things you can do with the materials, so they all arrive quickly at the procedure to observe refraction, reflection, and properties of light. The same thing happens when we give them mirrors. Give them a curved mirror and say "go play". (Interview 1)

The discourse here suggests the activities Zoltan thinks are effective through inquiry are those in which students won't have many choices about how to proceed, effectively being directed toward the known knowledge and concepts expected to be learned in the unit. This type of inquiry is often described as guided inquiry (Pedretti & Bellomo, 2015), whereby the teacher designs the activity so as to limit variability and results. This often is done by having the students answer the same question, or answer slightly different questions based on the same basic experimental procedure.

Participants described how inadequately prepared many teachers and students are for inquiry based learning. Teresa spent considerable amount of time speaking about this, perhaps because she has spent some time as a science coordinator, stating,

> I noticed some kids in my grade, they are Grade 9's, and are in high school with absolutely no idea how to ask questions, or do any inquiry based stuff, they don't know how to ask a question, or form a hypothesis. So, were bringing in science teachers to do labs, inquiry based labs, using the Smarter Science framework. So, the push is coming from our science coordinators primarily. (Interview 1)

Teresa here identifies an issue in school science, that is, that although science inquiry is one of the 3 overarching goals in the Ontario Grade 9-10 science curriculum (MoE, 2008), many teachers are uncomfortable with inquiry approaches, and continue to teach science through more traditional lecture and formulaic laboratory based instruction practices (Hodson, 2009). There was general agreement with this sentiment; for example, Janet stated "I think the push is now more getting into inquiry, so I guess even though it may be a bit against the grain, there is a push happening." (Interview 1). Inquiry learning could potentially be an important practice in school science that enables humans to develop interconnected relationships with nature, because a feature of inquiry is students asking and answering their own questions, which could, potentially, involve inquiry on nature.

Science, Technology, Society and Environments (STSE)

Many science education scholars (e.g. Bencze, 2008; Hodson, 2009; Pedretti & Bellomo, 2015) suggest teaching science should include learning that connects science to technology, society and environments. The first Overall Expectation of the Ontario Grade 9 and 10 Science Curriculum, which states: “*To relate science to technology, society, and the environment*.” (OME, 2008, p. 4), was a common topic of discussion during interviews with certain participants. STSE is frequently based on social ‘issues’ related to science and/or technology. These issues are often termed Socio-scientific issues (SSIs), or, in the context of STSE education, can be considered social issues connected to science, technology, society and the environment (STSE issues). These topics are issues because there is disagreement about the role of science in the production of these social issues, and its use in their solution. Participants spoke of using STSE issues in their class to engage students and develop the critical decision making skills that are a goal of STSE education. For example, Steve commented:

> And in Biology we do cells to organs to systems. So we'll end up with the digestive system, respiratory system, etc. I also throw in articles; I like the article “Chemicals that act as hormone disruptors that feminize males”. So I tell the boys your junk is going to get smaller and it’s not going to work. And they say that’s not cool. And I say that’s not the real problem. The real problem is your cel. phone in your pocket. (Interview 2)

Steve’s description of how he uses an STSE issue to engage students is representative of the ways these issues are frequently used in school science; that is, as add-on content, used after more traditional science knowledge and skills are learned. The companion meanings (Östman, 1994; Roberts, 1998) this may communicate are that STSE issues are not as important in science as the high status knowledge and skills that are typically taught first. Perhaps even more concerning is the anthropocentrism in the practice described in Zoltan’s statement. This discourse constitutes nature as a problem citizens should be concerned about because of the harmful effects this problem has to human populations. Using the framework developed by Lief Östman (1994, 1996, 1998) for anlysisng human relationships with nature, the way nature is discursively constructed in Zoltan’s description is one of “Human Beings as Threat”. According to Östman, this discourse constitutes “ human beings as threatening themselves and other living organisms; language used does not ascribe value to nature; communicates the idea that human beings have no moral responsibility or obligation when dealing with nature” (Östman, 1994, 1996, 1998). The way Zoltan described the value of this STSE issue was as an issue that engages students by leveraging student’s own self-interest. This would appear to contain anthropocentric assumptions about nature.

Other ways of teaching STSE were described by participants as well. Teresa, for example, explained how she engages students in taking action, or activism, on STSE issues relevant to them in her following statement:

> I do a cel. phone experiment where the kids measure their reaction time while using the phone, and we relate that to driving. And of course they find that while texting, it takes them a longer time to catch a dropping ruler when they are focused on texting. So, in the past I have extended that to kids making posters about texting while driving. I remember one group made a poster that I thought was quite clever titled "shut up and drive". They wrote a PA announcement, their results were announced on the PA system, so that's about the limit of the actions we have taken, they haven't gone out and boycotted things or written to governments and stuff. (Interview 1)

Teresa's description of this activity gives a clear, if limited, illustration of what activism in science can look like. Science activism, generally termed STSE-activism (Pedretti, 1996) or research informed activism (Bencze, 2008) describe a number of related pedagogical approaches in which, ideally, students do science research on an issue relevant to themselves and their communities, and use that research as cultural capital to affect social change for the betterment of the community. Although the activity described by Teresa appears to be an engaging and positive experience for herself and her students, the discursive prioritization is on the social, the human, rather than nature.

The position of STSE in the curriculum discursively constitutes it as, ideally, a curricular priority, and an organizing lens through which to plan units. The possibility of basing student learning on STSE was described by Teresa, who said: "Ideally I wouldn't even teach science in units, I would have STSE themes and topics and integrate the expectations from every unit. Unfortunately this is very hard to do." because "It's so against the grain, the tradition. And if other teachers in the department aren't doing it, it really limits what I can do" (Interview 2).

Participants most often spoke of environmental learning and learning about nature within the context of STSE. Although STSE can include learning related to nature, according to Janet,

> The new curriculum, I feel everything, from the first goal (STSE) on, it has to do with technology, you know, how does this have a value to society, how is technology

> involved with it...some of it talks about sort of environmental degradation, but very rarely do you see written in the curriculum anywhere, to explore it IN nature.....it's like explore data, explore graphs, it doesn't really ever specify in the curriculum, experiences IN nature, connections within and between nature. (Interview 2)

Janet indicates in this statement the Ontario curriculum prioritizes students' connection to technology and society rather than connections to the natural world.

**Assessment and Evaluation**

Assessment in Ontario Grade 9-10 science is based on knowledge, investigation, communication and application (KICA) achievement criteria. These criteria are consistent across all subject and grade levels in Ontario, although differentiated to be relevant for each subject and grade level. In speaking about the achievement criteria, Ellen said "we are expected to value all of these things, we are expected to account for all of these categories." (Interview 1). Although teachers assess students for these criteria in a variety of ways, Ellen's use of "account" suggests a quantitative evaluation of students' achievement in each category; indeed, reports of student achievement in Grade 9 and 10 are numerical accounts; students are provided a number grade for each subject, derived from numerical scores for each achievement criteria. Generally, the participants spoke positively about the achievement criteria, explaining they provide a concrete way to justify students' grades. For example, Steve stated,

> The report card is one single numerical grade, but in my mark book each achievement categories has its own grade, so I have found it useful to do it this way because I can go back and tell parents their investigative skills are lacking, or their application skills are lacking. (Interview 1)

Steve here links student assessment to parental expectations. The language Steve uses suggests the quantification of student achievement for each category is "useful" because this is what parents expect. The implication is that evaluations of achievement that are not numerical may be less useful because these are less acceptable by parents. In addition, participants like the achievement categories in the science curriculum because they have some flexibility as to how each category is weighted in a student's final grade. Speaking of this, Ellen stated:

> I have to include in the course overview at the beginning of the year, the weight of each of these. We decide on this, and we all use the same marking scheme. So, K might be 20% of the whole course. Whatever the breakdown, they all add up to 70, because we assign a summative assessment at the end of the course at 30%. (Interview 1)

The apparent flexibility Ellen speaks of resembles the flexibility found within the learning expectations of the curriculum. Teachers have the ability to prioritize certain types of science learning above others, and this will be weighed accordingly through more frequent evaluation and greater weighing of relevant achievement criteria. The fact that at Ellen's school a summative assessment falls outside of the achievement categories appears to provide further possibilities for flexibility in student assessment.

Other policy documents were also identified by participants as influencing science teaching practice, such as *Growing Success* (MoE, 2010). Growing Success outlines goals and strategies to engage students in learning and assess and report on student achievement in all school subjects. The document identifies the "Learning skills and work habits", students need for contemporary and future citizenship, and defines *Performance Expectations* by which to evaluate student achievement. The document contains frequent reference to economics, work, jobs, and performance, as well as more democratic educational principles. For example, one of the first rationale statements supporting the existence of Growing Success states:

> Education directly influences students' life chances – and life outcomes. Todays global, knowledge-based economy makes the ongoing work in our schools critical to our students' success in life and to Ontario's economic future. As an agent of change and social cohesion, our education system supports and reflects the democratic values of fairness, equity, and respect for all. The schools we create today will shape the society that we and our children share tomorrow.
>
> (MoE, 2009, p. 6)

The word economy occurs twice in this short discursive sequence. The global, knowledge based economy is discursively constituted as a purpose of schools, by the use of the clause "ongoing work in our schools". The future is constituted through an economic lens through phrases such as "Ontario's economic future". Democratic values, fairness, and equity are undefined, yet these terms frequently occur in economic discourse, which embeds these terms with particular meanings, often unrelated to more socially just interpretations (Means, 2013). Such discourse, for example, frames equity as an "individual's right to compete on a (legally) equal basis for social opportunities' and 'the concept of individual meritocracy" (Alexiadou, 2005, p. 115). This "naïve perspective" (Lingard & Mills, 2007, p. 237), however, does not address any of the wider structural inequalities causing different forms of exclusion. Again, the relevance and meanings of documents such as this will be discussed in greater detail in chapter 9; I present this analysis here simply to identify the contextual relevance this discourse may have on teaching practice.

**Lessons Selected by Participants**

Participants were asked to select three lessons as exemplars of their teaching practice. These lessons were selected according to the following criteria: i) The one activity the teacher feels is the most representative of the way they want students to engage in science (the best thing they do in their program all year); ii) An activity that is 'typical' of how they engage students in science inquiry, and; iii) An activity in which the goal was to learn about nature. These documents were co-evaluate with participants to understand how nature is constituted in the activities they choose. Participant comments about these lessons, and passages of text from the document outlining lesson procedures, are presented in the proceeding results chapters. The most relevant lessons are fully documented in the Appendix. The lessons participants choose, along with a brief description, is provided in Tables 4.2, 4.3 and 4.4, below.

Table 4.2. Best activity done all year

| *Participant* | *Best activity done all year* | *Description* |
|---|---|---|
| *Zoltan* | Bell Ringer/Exam | Students engage in various timed activities, at individual stations, that represent the topics they covered during the school year. Activities |

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| | | include: experiment with light rays; testing for reflection, and refraction; investigating animal systems, and; performing chemical reactions. |
| *Joanne* | STSE/inquiry on personal technology devices | Students investigate where our technology comes from (manufacturing) and the adverse effects to primarily society and humans of the technology they use. |
| *Heather* | Frog dissection | Pairs of students perform a dissection of a frog. Students identify internal organs of the frog, and make comparisons between the frog's internal organ systems and those of mammals. |
| *Teresa* | Cellular phone/STSE project | Students measure how reaction time is effected while texting on a cellular phone, and develop public awareness campaign based on their findings. Students must identify and control variables, and use quantitative data to support their findings |
| *Ellen* | Daphnia Project | Students investigate the effects of adding or removing various environmental factors on the growth of the small invertebrate, Daphnia. Students must identify and control variables, and use quantitative data to demonstrate scientific principles involved in sustainability. |
| *Alice* | Orange juice clock | Students inquire about what makes the most efficient dry cell to power a clock by |

| | | |
|---|---|---|
| | | controlling and manipulating variables involved in making a dry cell. |
| *Steve* | Germ ecology study | Students investigate various ecological factors in their schools related to germs that can cause cold and flu, do various science investigations, and use their findings in community directed activism to address the issue |
| *Frances* | Periodic Table activity | Students learn about elements by completing a worksheet in which they must identify characteristics of certain elements, such as number of electrons, protons, and model its atomic structure, using the periodic table for data. |
| *Janet* | Pop-bottle terrarium | Various plants and other living things are contained in plastic pop-bottles, and students control the environmental conditions to determine the effects on the health of the ecosystem inside. |

Table 4.3. How students are typically engaged in science inquiry/experimentation

| *Participant* | *Typical science inquiry or experiment* | *Description* |
|---|---|---|
| *Zoltan* | Penny Lab | Students investigate how many drops of water can be placed on the surface of a penny |

| | | |
|---|---|---|
| | | before it over-flows. Students must identify, and control variables, and analyze quantitative data to determine this. |
| *Joanne* | Aspirin lab | Students perform chemical tests on various brands and strengths of aspirin to determine differences in the mount of active ingredient (acetylsalicylic acid acid) in each sample. Students must collect and analyze quantitative data to draw conclusions. |
| *Heather* | Plant Growth Lab | Students germinate beans to test the effects various environmental conditions, such as light and humidity, on plant growth. |
| *Teresa* | Helicopter (Whirlybird) Lab | Students investigate properties of flight using a paper helicopter they cut out. Students to ask and answer their own question about what effects the flight of the helicopter, using practices of science investigation, such as identifying and controlling variables, and analyze quantitative data |
| *Ellen* | Rocket Lab | Students investigate properties of flight using a rocket they make out of straws, elastic bands, and cardboard. Students ask and answer their own question about what effects the flight of the rocket, using practices of science investigation, such as identifying and controlling variables, and collect and analyze quantitative data. |

| | | |
|---|---|---|
| *Alice* | Orange Juice Clock | Students inquire about what makes the most efficient dry cell to power a clock by controlling and manipulating variables (such as using orange juice as the electrolyte) involved in making a dry cell. |
| *Steve* | Superball Lab | Students make a bouncy ball using household chemicals. They then experiment to make the ball more bouncy by altering the chemicals used to make the ball. |
| *Frances* | Periodic Table Activity | Students learn about elements by completing a worksheet in which they must identify characteristics of certain elements, such as number of electrons, protons, and model its atomic structure, using the periodic table for data. |
| *Janet* | Film Canister Rockets | Students investigate properties of flight using a rocket they make out of film canisters, water, and Alka-Seltzer tablets. Students ask and answer their own questions about what effects the flight of the rocket, using practices of science investigation, such as identifying and controlling variables, and collect and analyze quantitative data. |

Table 4.4. Teaching students about nature

| *Participant* | *Activity that teaches about nature* | *Description* |
|---|---|---|
| *Zoltan* | River study | Students take insect and water samples from a local river system to determine the health of the ecosystem. Students must identify species and perform chemical tests on the water. |
| *Joanne* | Water STSE activity | Students inquire into the way water is used around the world, and examine their own practices related to water use to emphasize the importance of water conservation |
| *Heather* | Mud Lake Field Trip | Students go to Mud lake, a local ecosystem, to partake in various nature observation activities, and identification of tree species in the area. |
| *Teresa* | Maple Syrup SOS | Students go on a hike, and learn about maple syrup production, and how climate change is having an effect on this. Students conduct a maple tree population survey of a particular area, and use this data to draw conclusions about the health of the ecosystem |
| *Ellen* | Ecology report | Students investigate, using the internet, an ecological issue of their choice, and write a news report on it. |
| *Alice* | Pop bottle terrarium | Various plants and other living things are |

| | | |
|---|---|---|
| | | contained in plastic pop-bottles, and students control the environmental conditions to determine the effects on the health of the ecosystem inside. |
| *Steve* | Germ Ecology Study | Students investigate various ecological factors in their schools related to germs that can cause cold and flu, do various science investigations, and use their findings in community directed activism to address the issue |
| *Frances* | Ecosystem in a jar | Various plants and other living things are contained in one jar, which is sealed but connected to another jar with fish. Students control the environmental conditions to determine the effects on the health of the ecosystem by evaluating the health of the plants and fish. |
| *Janet* | Daphnia Project | Students investigate the effects of adding or removing various environmental factors on the growth of the small invertebrate, Daphnia. Students must identify and control variables, and use quantitative data to demonstrate scientific principles involved in sustainability. |

Participants occasionally used a single activity to represent more than one lesson criteria; for example, Steve selected the Germ Ecology Study to represent the best activity he does all year, and as an activity to teach students about nature. The Daphnia Project and the Pop-Bottle

Terrarium were also selected by different participants as examples of different types of lessons. Ellen, for example, used the Daphnia project as the best activity she does all year; Janet selected this as an activity that teaches about nature. Results of the evaluation of these lessons for how they constitute nature will be presented in Chapters 5 and.6.

# Chapter 5: Epistemology of Nature

> *The Daphnia, if they (the students) aren't careful about the setup, if they aren't careful about how they make the treatments, they will end up killing lots of Daphnia. Now they are only Daphnia, and it's like well, it's a shame, but, I have millions of them, and there are millions of them out there, it's not like we are experimenting on people, the point is, did you (the student) learn something?* *(Ellen, Interview 2)*

This chapter discusses epistemology of constitutions of nature. Epistemology is a branch of philosophy concerned with theory of knowledge. Epistemology studies the nature of knowledge, the rationality of belief, and justification. Epistemology is often explained as 'the way one comes to know what they know'. In the context of this study, epistemology is related to how participant practices direct students to come to know nature. In other words, what are students expected to do to gain knowledge of nature, and; what knowledge of nature is gained by these practices? This chapter focuses primarily on the science methods teachers engage students in, in their study of nature. It is an examination of, primarily, the physical interaction (or not) between students and nature described by participant lessons.

A question that needs to be addressed at this point is, 'what is nature?', and does school science disrupt or maintain separation between humans and nature. There is often a tendency of research and scholarship about nature to reify human separation from it by, for example, distinguishing untouched, natural areas as 'nature'; nature that is man-made, or brought into urban environments, as some other form of nature; and human products and activities as un-natural (Horkhiemer & Adorno, 1976; Stibbe, 2001). When we collapse this artificial dichotomy, however, one can argue that everything is nature, including the things humans do and create. This is problematic, however, because eliminating difference among nature can validate all human behaviors, including those detrimental to nature, on the basis they are all 'natural'. This validation can silence the moral and ethical thought required to work through human relationships with others, as self-aware beings (DeLapp, 2011). On the other hand, it is also not the intention of this research to reify binaries and dichotomies. The position of this research is that similarities and differences between entities (humans, other species, other materials) exist, and those differences need to be understood, not so that value can be attributed to each entity to maintain a hierarchy, but to provide the intellectual leverage from which humans, as sentient beings, can learn to deal with differences, making moral and ethical decisions about how we interact with other entities in our environment. This research is interested in the implications of dichotomies of nature maintained in school science, in relation to moral and ethical questions about human behavior to each other, ‘others’, and the material world around us.

Since most of the activities selected by participants involved students in ‘doing something to’ nature’, questions of *power* are evoked. Power is a taken for granted term, often undefined, even in scholarly writing. Power, generally, implies “the possibility to influence others” (Handgraaf, Van Dijk, Vermunt, Wilke, & De Dreu, 2008, p. 1137). On the other hand, power, in the Foucauldian sense, is not something that one person or powerful group 'has' and wields against weaker opponents. Rather, power is diffuse, circulating in a capillary fashion around and through institutions, reaching “‘into the very grain' of those who are made subjects through their involvement in discourse — parents, children, prisoners, teachers, therapists, clients, claimants, lawyers, employers, and so on” (Foucault 1980, p.39). Although power is often described as existing in relations between people, many environmental scholars consider power to exist in relationships between humans and nature (e.g., Dryzek, 1997); for example, Latour (2004) suggests the existence of power relations between humans and non-human actors. Such relations are implicit in human practices that are detrimental to nature, such as cutting down a forest. The immediate, conscious practice of the human, influences the forest, causing change and damage to the forest. This can be seen as the result of power. In this chapter, I use power in both Foucaultian sense (how discourse oppresses nature), and in the more conventional sense (how methods of science exert influence over nature). For example, one can imagine science teacher practices that direct students to enact physical investigations of nature, in which they are ‘doing something to’ nature, that are demonstrations of power. This chapter is thematized according to the methods participants used to engage students in learning about nature. Although many of the themes appear similar, I’ve attempted to distinguish them by the degree to which the methods can be viewed as explicitly detrimental to nature. For example, ‘utilisation’, one of the themes, implies using nature, but not necessarily doing damage to it. Themes of ‘controlling’ or ‘dominating’ nature suggest greater detriment, and the teacher practices examined in these themes generally engage students in harming nature. The intention of the differentiation into these themes is to have some basis to make ethical and moral judgement about the justifiability of these practices in school science. The question this chapter seeks to answer is: *What* *epistemological relationships are present in the way nature is constituted by participants' practices and discourse?*

**Teaching science indoors**

The physical structure of school was frequently described as setting limitations on how participants could teach about nature in science. A preference for teaching inside a classroom was demonstrated in the activities selected by participants; of the 23 activities, only 2 include an outdoor aspect. The difficulty of establishing connected relationships between students and nature due to the physical confines of the school building was noted frequently by participants. Alice, for example, suggested:

> I also wonder if it's (disconnection from nature) about the building we are in, the whole institute...right...in the building, we are not outside, we are not in an open classroom...so people that are very environmental are still not that ready to go outside and have an outdoor classroom. (Interview 2)

Alice suggests in this comment that being enclosed in school is somehow antithetical to developing connected relationships with nature. Connection with nature, both physically and cognitively, may be necessary for the development of biocentric orientations, which put the value of nature as central in ethical considerations and practices (Hodson, 2009; Taylor, 2010). Her statement "teachers are not that ready" implies that habitually teaching indoors does not prepare a teacher to teach outdoors, and that perhaps this creates a form of resistance to the idea of taking children outside of school to learn.

A related issue in the development of spatial relationships with nature is the distance of many urban classrooms to natural environments. Espousing similar metaphors of "disconnection", the notion of urban schools having little access to nature was made by participants. Joanne, who works in a school in an urban center of Ontario, commented:

> Part of my problem (in taking children outdoors) is that I teach right downtown. So all we have that's green is a (sports) field, and that's being reseeded right now. (Interview 1)

Joanne identifies a phenomenon common to contemporary industrialised society; the use of technology has improved human's ability to design dwellings that are seemingly independent of nature, and instead are interconnected by social technologies (plumbing, electricity) that enable congregations of families in urban centers. As urban centers grow, people and structures in the center of cities, including schools, are increasingly separated from 'natural' areas (Latour, 2004). Joanne's comment illustrates a contemporary reality for many educators, a reality that prevents, in many cases, teachers taking students to natural sites where they might develop perceptions of interrelationships and holism with nature, as opposed to more reductive relationships with nature that often occur in school science (Hart, 2003).

### Learning science outdoors

Although the majority of practices described by participants are meant to be done in science classrooms or laboratories, when the intent is to teach specifically about 'nature', several participants described lessons in which they take students outside. Heather, in particular, commits a large amount of time in her science class to outdoor learning, stating:

> That (teaching outdoors) is totally my approach, I have chosen to make that my stance, when my students walk into my classroom they know the focus is some type of theme toward the environment, and students pick my class because they know we are going to go outside and do things outdoors. (Interview 1)

Heather choose for her lesson focusing on nature an outdoor activity she does at Mud Lake, which is a 15 minute walk from her school, and one of the most bio diverse urban areas in Canada. In this activity, the students use a dichotomous key to classify plants in the area, and make biological drawings of things in nature they were interested in. Heather describes this activity in the following quote:

> When we walk to Mud Lake, there are horsetails there, and we talk about that, and that all of them should touch things and smell things. I do one activity when we are on the path and we just stand there, and for 2 minutes, just be silent, and, just to slow down, and to

> listen, and ideally they can listen to the birds. And we experience things we probably would never have in class. (Interview 2)

Although the activities Heather describes are focused on science process skills of observation, such practices may be valuable to developing a sense of interconnection with nature (Hart, 2003; Orr, 2004). In this activity, students are asked to actively perceive nature in a way they make not be accustomed to. Perception is not a passive experience, but an active behaviour, directed by existing mental schemas and prior knowledge (Swain, Kinnear & Steinman, 2011). Activities such as this may expand mental schemas and knowledge, influencing subsequent perceptions of nature (Orr, 2004). Guided perception and observational experiences, such as those described by Heather, can be effective for the development of more biocentric relationships with nature (Taylor, 2010). Zoltan also takes his students out for a guided activity he calls river study, in which students classify aquatic insects to determine the health of the river ecosystem. Zoltan speaks of this outdoor experience in the next statement:

> We are so used to being in a science classroom, and viewing science a certain way, and when we go outside and see something different, it's a different experience, and a different way of doing science. (Interview 1)

For Zoltan, taking students outside represents something different, something outside of the norm of science teacher practice, which requires a different way of interacting with nature. This different teaching environment appears to create tension for many participants, imposed by the perception of having to develop different learning experiences for students than those they would be engaged in, in the science classroom (Hart, 2003; Rickinson, 2005). Indeed, tensions between science teaching and taking students outside can be seen in the following comment made by Frances:

> It's (teaching outdoors) hard. I mean, we could do a lot of wheat classification because there is so much of that around. I'm not a big fan of....it's awful to say, but I'd rather take them to Cartwright's Ecological Center, because, they are better at this (teaching science outdoors) than I am. (Interview 1)

Frances claims teaching outdoors is hard for her, however, she could do a classification activity, which is a well-established school science practice (Pedretti & Bellomo, 2015). The clause "I'm not a big fan of" suggests she is unsatisfied with this activity, or of taking students outside at all. Indeed, stating "they are better at this than I am" indicates a lack of confidence in her ability to teach students outdoors. The activity Frances suggests she could do, classification, is an analysis of features of perceived (or prescribed) salience, requiring perspectives of distance and objectivity toward the object of analysis (Cobern, 1991; Nisbett, 2003). Such analysis is typical of "Western worldviews" (Catton & Dunlap, 1980) and the implied separation between the observer and nature required for such analysis may not be ideal if the intention of the lesson is to develop biocentric relationships (Taylor, 2010). Even Heather, the most ardent supporter of outdoor learning, questions the outdoors as an effective context to teach skills, processes' and knowledge of science, stating:

> Honestly, I think the only real thing I'm teaching them about science is the power of observation...and I guess communication.....I have to say there aren't a lot of scientific principles that I'm really proving here. (Interview 2)

Heather's claim that she's not able to prove many scientific principles outdoors, demonstrates an epistemological difference between learning science outdoors, and indoors. The way students typically know nature outdoors (observing) is different than the way they come to know it indoors (as established science knowledge and principles) (Östman, 1998). This is perhaps another reason why many science teachers do not take students outdoors; since experiences learning about nature outdoors may not be seen as able to provide effective context for teaching the skills and knowledge valued in school science education, the outdoor learning experience is not valued in school science (Hart, 2003; Rickinson, 2005).

Although teaching science outdoors does not guarantee students will establish biocentric relationships with nature, many scholars suggest outdoor education is important for this reason (Hart, 2003; Orr, 2004). Teaching science outdoors, however, may require different forms of teaching practice than those developed for the classroom (Bowers, 1997; Rickinson, 2005). Participant discourse related to outdoor learning suggests a lack of confidence in teaching science outdoors. Much of this appears to stem from the belief that teaching about nature outdoors may not be ineffective to instill the skills and knowledge valued by science teachers.

## Oppression of nature

Many scholars claim that power in discourse is a feature of not only what is said, and how it is said,  but also of what is not said, and how it is not said (e.g. Foucault, 1980; Östman, 1998). Participants had difficulty speaking about teaching nature, struggling for words, and ways to conceptualise their lessons from the perspective of nature. Speaking of this phenomenon was Janet, who said:

> Wow, it's really difficult to answer some of these questions….nature…I`m just not used to thinking about my science lessons like that. I mean, nature is in there, I guess it's a study of nature but we just never talk about nature. (Interview 2)

Instead, discussions were dominated by 'institutional discourse' (Smith, 2005) related to curriculum, assessment, social expectations of the community, and teacher performance.  When directed to speak specifically about the subject or topic of lessons, participants used language typically used in science to represent nature. These discourses can be said to be powerful, oppressing language explicitly about at nature. These discourses are the topic of Chapter 7. 'Getting at' nature in teacher practice was, therefore, a significant hurdle of this research, and was achieved largely through discourse analysis of what and how teaching practice *was* spoken about, as well as what *was not* spoken about.

### Coming to know nature through the language of school science

When layers of institutional discourse were penetrated, the language participants used to speak of teaching practices related to nature tended to obscure nature. By this I mean, nature was not talked about as 'nature', but rather through science terms that represent nature as an object. An example of such discourse is seen in the following instructions to students about designing a rocket, in the Rocket Lab, selected by Ellen:

**Hints for Sound Experimental Design**

- Identify an **easy way to measure your two variables**. Ease of measurement often also means accuracy and precision. “No way of measuring” means you should not use that variable.

- Pick a practical or **realistic range of treatment levels** for your independent variable. Too few will not give much useful information. Too many will not be achievable or realistic.

- Ensure that you have **as many replicates as you can in the time allotted** without sacrificing the variety of treatment levels you picked. A good way to do this is to estimate how many replicates you will be able to do and divide it by the number of treatments.

- **Collect some preliminary data** (e.g. test launches) to identify any shortcomings or omissions in your design. e.g. Are you confident in the accuracy and precision of your measurements? Will you be able to do as many replicates as you expected? **Refine your design** before continuing the data collection.

Figure 5.1. Student procedures for the “Rocket Lab”

In this set of instructions, natural phenomenon is obscured by terms such as variables, treatment levels, replicates, and data. Variables in this passage are factors about the rocket students will vary, to test their effects on flight, such as mass of the rocket, or length of the rocket. “Treatment levels” refers to the different quantities of the variable that will be tested, such as testing the effect of different masses or length on the flight of the rocket. Data refers to the flight of the rocket. Although the use of this language appears benign, this same type of language is found in activities that investigate what might be more typically considered nature, such as the Daphnia project. For example, the procedure in the Daphnia Project states:

> If your group’s experiment experienced a lot of untimely *Daphnia* deaths, consider the following in your analysis and presentation:

- Generate a hypothesis regarding the cause of death: was it linked to a treatment effect?...uncontrolled variable?...exceeding the range of tolerance of the species?...exceeding the limiting factors of the ecosystem?...exceeding the carrying capacity of the ecosystem?

- What would the next steps be in order to determine the cause of death of your research organism?

- How sustainable was your ecosystem? How did it compare with other groups examining the same variable in other classes?

Figure 5.2. Student procedures for the “Daphnia Project”

This procedure contains similar language to that used in the Experimental Rocketry lab. For example, “exceeding or limiting the factors necessary for survival of the Daphnia” are termed “treatments”, and the effect is has on the Daphnia (whether it lives or dies) is termed “treatment effect”. The factors necessary for life are themselves termed “variables”. The term used to describe the Daphnia, “research organism”, appears to discursively alter conceptualisation of the Daphnia, from that of a living organism, which many students “would like to become attached to” (Ellen, Interview 2), to merely another component of a scientific experiment. This discourse also contains other meanings related to nature, which will be discussed in subsequent sections in this chapter. What is important here in relation to epistemology is that, students are coming to know nature through discourse, and that discourse is inscribed with knowledge of nature produced by science. This discourse removes, substitutes or alters certain terms for the nature under study, replacing them with the language of science, so that ‘nature’ is no longer present or apparent (Östman, 1998); in effect, the power of this scientific language discursively oppresses nature. These scientific substitutions for nature are features of what Östman (1998) terms classical nature language. As Östman (1994) suggest, this language comes to replace other, more personal language students could use to talk about nature; such personalisation of nature is important for humans to develop interpersonal and inter-related relationships with nature, foundational to biocentric relationships (Taylor, 2010). This discourse potentially produces a way of knowing nature for students, so they come to see it as an object, with limited utility or interest except as an object to study for science (Östman, 1994).

Coming to know nature through social interaction

One of the few approaches to teach about nature participants were able to describe with confidence was discussing nature with students. Zoltan, for example, described engaging students in learning about the environment through class discussion, stating:

> I have a pamphlet, where they do a PMI (pluses, minuses, and interesting things) chart on recycling e-waste, and what is the consumer's responsibility to recycle all this stuff. So you end up talking about the environment, and recycling all this stuff, like how often do they change their cellular phones, and stuff like that, so anytime we can talk about the wider environment, we do, and we will use any thin wedge we can to bring it in.
>
> (Interview 1)

Although Zoltan used this as an example of a discussion about nature, the learning experience he describes is primarily about humans (students). The discourse used by Zoltan constitutes the individual ("the consumer") as being of primary responsibility for the production and recycling of this waste. Zoltan uses technology, students' cellular phone, to gain their interest, because, as Zoltan claimed "they (students) are interested in technology, stuff in their everyday lives…nature, no so much" (Interview 2). In addition to the subject focus being on the human (the student), absent is any mention of corporate production of e-waste, or their responsibility to address this problem. Using similar discourse in describing how she speaks to students about pollution of Lake Ontario Joanne said:

> I tell them, everything that we dump into Lake Ontario, it gets into our water system. So when we do the water activity, that's where we are getting our drinking water, and this is what we are putting into it, and the students say, that's not cool. Yeah, live with it.
>
> (Interview 1)

The discourse used by Joanne to speak about the way the river is polluted is very similar to that used by Zoltan: for example, in the clause "everything that we dump into Lake Ontario", the actor doing the polluting is clearly identified as "we" - the teacher, students, and other people that they know. This places responsibility for polluting and, by implication, not polluting, on the everyday citizen. The subject focus appears to be, quite clearly, the human, actions taken by humans toward water, and the detrimental effects of these actions (pollution) on humans.

Excluded and suppressed by the power of this discourse is consideration of water itself, intrinsic value water may have, or the effects of polluted water on other nature. As in Zoltan's statement, there are also errors of omission, such as silences around other agents who are likely more responsible for polluting Lake Ontario, such as corporations in the Greater Toronto Area and surrounding coastal communities (Environment Canada, 2004). By pinning the agency for pollution and habitat destruction in Lake Ontario on "people", this discourse makes it appear as if ordinary laypersons are largely culpable for this environmental devastation. This is a dated and incorrect view, given the evidence that in the past few decades, habitat loss has occurred not as much because of the activities of people, but through globalised exploitation of land and natural resources by corporations (Laurance, 2010; Rudel, Defries, Asner & Laurance, 2009). This appears to be a case of nature, oppressed by a powerful discourse of 'environmentalism' (Dryzek, 1997). This discourse constitutes the relationship humans have with nature as one in which we, as individuals, utilise and threaten nature (Dryzek, 1997). The response of nature to this human threat is to become less habitable, less hospitable, threatening the quality of human life. This discourse sets up humans in continuous conflict with adversarial nature (Bowers, 1997; Orr, 2004). Such relationships oppress aspects of nature that are not directly connected to human prosperity, such as its intrinsic value, and value to other forms of life, making it difficult to develop more holistic and mutually beneficial relationships with nature (Taylor, 2010). Another example of this discourse is found in the next statement made by Ellen:

> The whole unit is about sustainability, and sustainability is about survival. So, can we survive without tress? Even if we have an ocean full of algae that's going to provide us with oxygen, we need the building materials, we need the shade, we need the erosion control. We need the…..there's a lot of things that trees will provide us for, so, deforestation, not a great thing, because of the lack of tress, even if it didn't effect water flow or flooding, or erosion issues, or something, people would notice the lack of shade, the lack of ah, aesthetics. (Interview 2)

Ellen identifies "we" as the subject of survival throughout this statement. Human needs are prioritised above those of any other organism, or nature. Indeed the tree is constituted as simply a resource for human use, and betterment of human life. Such discourse values nature only according to its use for humans, but is silent on intrinsic value of nature.

When participants were asked why the students themselves were the focus of lessons, rather than nature, the common response was “that’s what engages them” (Steve, Interview 2). Participants’ uncritical acceptance of using anthropocentric interests is problematic, however (Sharma & Buxton, 2015). Rarely did participants describe introducing the idea, for example, that nature itself may have intrinsic value, and that science may not account for this, and use this as a discussion point with students. As Sharma & Buxton (2015) suggest, these types of discussions with students are a way to disrupt dominant anthropocentric discourses of nature that may be contained in science education.

Aristotle has said that “humans are by nature social animals” (2000), suggesting that our absorption and attention to the human, characteristic of anthropocentric discourse, is in fact part of our own nature to socialise with other humans. Students are typically interested in social activities, and materials, that they have affective relationships with; in other words, they care about them, they are important in the daily life of the student, and they feel a degree of confidence in and mastery over (Alsop, 2005). David Orr (2004) suggests this sets up a reality in which the outdoors is likely not a part of many students everyday life, and they are more engaged with social activity and human-produced technology than nature (Orr, 2004). Teachers could start to disrupt this anthropocentric discourse by redirecting class discussion to aspects of nature students generally may not consider in science (Steele, 2011).

**Utilisation of nature**

Many of the lessons participants described engaged students in experiences in which they were utilising materials. Utilisation implies the use of something intended for specific purposes. In nature discourse described by Dryzek (1997), utilisation is analogous to viewing *nature as a resource*, which he describes as the explicit and directed use of nature and/or the environment for human prosperity. In many activities selected by participants, utilisation of nature occurred simply from using nature as the object from which to learn science. This purpose resembles Östman’s (1994; 1996; 1998) description of *Induction into Science* subject focus. Induction into science views nature simply as a resource, an educational tool for teaching students science concepts; no moral obligations are associated with this particular stance (Östman, 1998). The

Daphnia activity exemplifies utilization of nature/induction into science. This focus is clear from Ellen's statement about the Daphnia experiment, below:

> We can use the Daphnia as a mechanism, or as a tool for learning something, or we can use its properties, like we have to rely on its properties in order to use it as a tool for learning about sustainable ecosystems. We are setting them up, we are setting these Daphnia up to experience some conditions, to see what they do, right, but we are doing things to them to make it do something, we are trying to understand its nature.
>
> (Interview 2)

In this experiment, every student sets up a Daphnia culture. Ellen uses the metaphor "a tool for learning" to describe the use of the Daphnia, clearly suggesting the "Induction into science" use and subject focus. In other words, in this activity, the Daphnia are being utilised, as a resource, to learn particular science knowledge and principles. The potential companion meaning in this use of nature is that its value lies in its ability to provide humans with useful knowledge (Östman, 1998), in this case, knowledge valued by science. Students can come to value the science methods they use in the Daphnia experiment simply as the way to learn the skills and knowledge needed to do well in science (Oakley, 2012).

Connected to utilisation is ownership, a term frequently used to describe student relationships with the materials and activities they engaged with. Ownership can be defined as in possession of, or to have something; or that something belongs to a person. Ownership is a term frequently found in educational discourse, referring to 'ownership of learning' (Pedretti & Bellomo, 2015). Student ownership of learning typically results from engagement in learning activity they designed, or made decisions about, giving them a sense that they 'own' the learning experience. Since students own the learning, it is more personally relevant to them than an experience designed by another person, such as the teacher (Alsop, 2005). Personal relevance induces affective responses that strengthen the learning experience (Alsop, 2005; Swain, Kinnear & Steinman, 2012). The idea of student ownership was frequently discussed by participants, in relation to open ended activities in which students were involved in designing the activity. For example, Alice said about the Orange Juice Clock: "I think they have control in that it's their (students') ownership, that it's their experiment, and they are doing it, and they are investigating a question they are interested in" (Interview 2). Ellen had similar observations about ownership and control related to the Daphnia activity, stating:

> Oh, well they have ownership, meaning they are controlling what the treatments are made up of, they are controlling how many organisms they put in there, they are in control of how often they get feed and how well they care for the animals, they are in control of…yeah, they are responsible for the life of the animal. (Interview 2)

Ellen explains that because students are making decisions and choices about the materials, in effect controlling the environment and the life of the Daphnia, they feel they own the Daphnia. Ellen uses objective language, "the animal", to describe the Daphnia; this language discursively constitutes the Daphnia as an object (an animal), which 'distances' (Roberts, 1998) the idea of the Daphnia as a living organism. Seeing the organism as an owned object instead of a living being makes it easier to utilise, removing much of the emotional attachment and sense of moral obligation the individual may develop for the organism if they see it as a living creature, similar to themselves (Oakley, 2012; Östman, 1998).

Utilisation of nature need not necessarily be problematic. Every part of nature 'uses' other parts of nature in various ways for survival. First Nations and Aboriginal peoples, typically seen as having sustainable relationships with the 'land', use the land for the propagation of their people, and maintain appreciation and respect for the land even while using it (Kawagley et al., 1998). As Dryzek (1997) suggest, utilisation becomes problematic when features such as 'ownership' become attached to it, and moral and ethical questions are not asked about why nature is being utilised. Utilisation of nature in school science appears to be primarily directed towards learning skills and knowledge associated with science, and valued in science education. Rarely did participants express asking, or engaging students in asking, questions about why nature is being utilised in science class, and did they need to utilize so much (does every student need to have their own Daphnia culture?). Open critical discussion with students about the reasons nature is utilised in school science, could work toward disrupting discourse that constitutes nature simply as an object for study. Oakley (2012) suggests, occurring along with these discussions, are practices that at the same time cause students to appreciate and respect the nature they are utilising in school.

**Manipulation of nature**

Many of the lessons participants choose engage students in activity in which they are manipulating nature. Manipulation can be understood as different from utilisation in that it implies causing nature to change in ways that are in opposition to its own agency. Manipulation suggests altering or making changes by creative or unfair means, to suit one's purpose. According to Aikenhead and Ogawa (2007), most Eurocentric sciences are seen as manipulators of nature. Interestingly, the word originates from French, initially meaning to handle apparatus in Chemistry (Merriam-Webster, n.d.). Manipulation in educational discourse often refers to interaction with specific educational materials (nature) using the hands, and is the root for the term "manipulatives", which are specific materials used to learn in certain subjects, such as counting blocks in mathematics. According to these meanings, activities in which students were conducting some type of science investigation, which account for 19 out of 23 activities, engage them in practices of manipulating nature. Participants used the term manipulate frequently during discussion about the lessons they selected. For example, Alice said about the Pop Bottle Terrarium activity:

> We are *manipulating* the variables in that situation. We are changing, manipulating things to try to mimic changes in ecosystems. So I guess we are doing more than controlling, we are controlling, but there are specific results or reasons for that control, particular outcomes we want because of that control. (Interview 2)

The implicit definition of manipulation in this statement is strikingly similar to those provided in the opening paragraph. Students are expected to change the growth conditions of plants in the artificial ecosystem of the Pop Bottle Terrarium, which Alice states is an act of manipulation. Since the plants in the terrarium are nature, there are assumptions about nature implicit in the discourse of this text. Assumptions such as 'we can manipulate nature' and 'it is ethically acceptable to manipulate nature in science' are two such assumptions. Ethical validation for manipulating is provided in the clause "there are specific reasons for that control". These reasons are, apparently, learning science knowledge about ecosystems. This text appears to represent "induction into science" (Östman, 1998), in which nature's value lies simply in its use to learn science. This provides ethical license to manipulate nature however one wants, to achieve scientific understanding. Discourse related to manipulation can be observed in the student procedures for building the Pop-bottle Terrarium, which states:

> Your teacher will demonstrate how to build a pop-bottle terrarium. Observe carefully and take notes to help you later in writing your own procedure. Using the Steps to Inquiry worksheets, fill out:
>
> - What did I observe?
> - What am I wondering?
> - What could I change or vary about factors affecting plant growth?
> - What could I measure or observe about plant growth?
> - What will I change and not change?
> - What is the question I want to explore?
> - What is my prediction?
>
> Write a procedure with the independent, dependent and controlled variables clearly outlined.

Figure 5.3. Student procedures for “Pop Bottle Terrarium”

Instructions in the text that asks students what they could change about the ecosystem that would effect plant growth represent a discourse of manipulation. Students are made aware of the notions of independent and dependant variables, natural phenomenon that is meant to be manipulated to conduct a valid scientific experiment (Hodson, 2009). The discourse contained in the activity text constitutes nature inside the terrarium as little more than an educational device, meant to be manipulated, to learn scientific principles and knowledge. Students are explicitly directed to manipulate nature, by changing the life conditions that allow the plants to grow, prosper, and survive. There is no ethical question assumed in the discourse, such as whether humans should, or have the right to, do this. Validation for this manipulation occurs in the recognition that in science, nature use is for science exploration, and production of knowledge, silencing ethical consideration of these practices (Fensham, 1988). The implication, or companion meaning (Östman, 1998), appears to be that nature is something that can be manipulated for human purposes, and that we do not have to consider the morality of this practice, because it has already been determined (by someone) that the value of manipulating nature (gaining knowledge about it) outweighs the negative effects of this (possible detriment to nature) (Fensham, 1988).

A specific form of manipulation, closely related to science, is control. Human control over nature is validated in anthropocentric perspectives, which view nature as subservient to humans (Nimmo, 2011). Control of nature is the signature feature of the benchmark of scientific inquiry- the controlled experiment (Hodson, 2006). Eurocentric scientists, generally, delimit the validity of their own scientific knowledge by its ability to predict, which is inextricably tied to an ability to control phenomena and events (Aikenhead & Ogawa, 2007). Control in school science is usually viewed as a positive feature of students' relationship with materials, because identification and control of factors in the experimental design is seen as critical to the validity of the experiment (Fraser & Lee, 2009; Hofstein & Lunetta 2004). Control over materials suggests expertise in science methods, and adequate understanding of the context, enabling students to shape their interaction with materials in order to obtain scientifically valid data about the phenomenon under investigation (Hodson, 1998). The Pop-bottle Terrarium, the Ecosystem-in-a-Jar, the River Study, the Daphnia Experiment, the Penny Lab, the Whirly-bird Lab, the Plant Growth Lab, the Orange Juice Clock, the Rocket Lab, and the Aspirin Lab each engage students in science practices that attempt to control nature. Speaking of control in the Pop-bottle Terrarium activity, Alice said:

> So, yeah, I do think...just the language implies that we have some kind of control over the variables, but we are manipulating the variables in that situation. So sustainable ecosystems we do a pop bottle terrarium, so the idea is to mimic, we'll do one, for acid rain, so they'll change the variables within the pop bottle to mimic the effects of acid to rain study what acid rain will do, so they are changing, so they do feel they have control over the variable (Interview 2)

Alice describes students controlling artificial ecosystems by altering the chemical composition of the materials in pop bottles. Alice claims the students feel they are in control of these artificial systems. In this activity, there is a normalisation of control, which can silence ethical dilemma pertaining to controlling nature (Östman, 1994, 1996, 1998). This discourse represses nature by representing it as variables or factors (Mitchell, 2003). These terms potentially construct a concept of nature striped of intelligible essences except those of utility to the predictive validity of scientific experimentation (Aikenhead & Ogawa, 2007; Nisbett, 2003). Heather spoke of the importance of student control in the Plant growth Lab, "students control whether that plant lives or dies, they control whether it gets snapped and is dead, they control whether they stop feeding it water, what it needs to live." (Interview 2). The procedure for this activity, shown in Figure 5.5 demonstrates how the text engages students in practices to control variables that effect the growth of the plant.

Procedure:

Note: Mung beans should not be soaked in water; they should be moistened with the damp paper towels. The bottles should not have excess water in them prior to the lab.

1. After giving the students information about plant growth, have them write a hypothesis about the relationship between the experimental variables and plant growth.
2. Assign students to a soda bottle size (0.5, 1, or 2 Liter). There should be equal numbers of each size soda bottle distributed among the class.
3. Have students place 10 Mung beans in their soda bottle.
4. Each student should rip one paper towel into several pieces (approximately 1 inch by 1 inch) and place them in their soda bottle.
5. Students should fill the cap of their soda bottle with water and pour the water into the soda bottle. No more than this amount of water is required.
6. Securely tighten the cap and do not reopened during the experiment.
7. Assign the students to light and dark treatments. Each size bottle should have at least two light and two dark treatments.
8. Record the treatments.
9. Cover dark treatment soda bottles with aluminum foil.
10. Place all bottles near the windowsill so the light treatments will receive sunlight. Keep both light and dark treatments to maintain as equal

environments within them as possible. However, note that light treatments will be exposed to higher temperatures.

11. Each day, have the students measure and record the length of the sprouts to the nearest mm using a metric ruler. Record the length of five sprouts and calculate the average. Record this information. Students will record data for 10 days.
12. At the end of each recording for the day, have the students calculate averages for each treatment.
13. After 10 days, create a line graph with the x-axis representing time in days and the y-axis growth in length. Use a different line showing averages for each of the treatments. There should be a total of 6 lines.
14. Have students draw conclusions from their data and results. They should compare their experimental results to their original hypothesis. If their hypotheses are not supported by their results, encourage students to explore reasons for the lack of support. Do the results lead to new hypotheses? Students (and scientists) learn from experiments that seem to have failed because hypotheses are not supported. Hypothesis testing involves an evaluation of the causes of patterns and observations. One is not always correct about those causes at the outset.

Figure 5.4. Student procedures for “Plant Growth Lab”

These procedures direct students into practices in which they selectively manipulate the environmental conditions of plant. For example, in step 2 of the procedure, students are told to place the Mung beans in different sized containers, with different volumes of soil, to determine how this affects growth of the plant. In Step 9 of the procedure, half of the bottles are covered with aluminum foil to prevent the plant from receiving light. These practices are done to isolate the effect of only one factor (i.e. light/no light). The various growing conditions are controlled, so that only that one growth factor, among many, varies. By controlling growing conditions, students can acquire knowledge about plant growth that is seen as valid because it was obtained in a controlled scientific experimental procedure. Since this is its primary purpose, once this purpose has been fulfilled, the plant can be disposed of, without further moral or ethical consideration (Östman, 1998).

Participants also discussed the concept of control in relation to student learning, and how they engage with the materials involved in investigations. Activities that give students some control of the learning activity include: The Orange Juice Clock; The Frog Dissection; The Rocket Lab; The Daphnia Project, and; The Germ Ecology Study. For example, Heather spoke of the control students have in the frog dissection, stating:

> They are in control of the tools they are going to select. Some of them make choices along the way to see what is more efficient or maybe they need to cut a little bit further. Some of them will just go ahead and make the decision for themselves. So there is a level of control there, they can control the rate at which they do the dissection, some of them are fast, and some are really slow. They can control which organs they choose to remove. (Interview 2)

Heather indicates that students have some agency in deciding the procedure they follow to dissect the frog. Other participants also prioritised activity that gives students some control of their learning, justifying this by explaining that control allowed students to see "they have an effect, they can effect change, or not, effect change" (Frances, Interview 2). Such approaches are valued because they are seen as more engaging for students (Alsop, 2005; Pedretti & Bellomo, 2015). Engagement likely results from the activation of affective aspects of learning, and emotional responses to seeing effects of the decisions they make (Alsop, 2005). Student control of learning may also be valued because it represents the kind of agency many educators would like to develop in students so they can become active citizens, involved in social decision making and activism (Bencze, 2008). Our ability to control can also be viewed as a positive attribute, a Western cultural belief that is valued and perhaps dominant in Eurocentric societies (Catton & Dunlap, 1980). A sense of control, and even mastery over the environment is a common feature of Western systems of thought, and may be inculcated in children through socialisation at a young age (Bowers, 1997; Orr, 2004). Providing students with experiences in which they are in control, can therefore be seen as a way to foster these cultural attributes in students through school science, and in particular, reify them through methods of science, directed at the material world/nature (Bowers, 1997).

The normalised practice of exerting control over a living natural system in school science has the potential to empower and habituate these types of behaviors in individuals (Oishi & Graham, 2010). As Aikenhead & Ogawa (2007) have claimed, the implication of these practices is that science and scientists (and humans in general) are able to, and should, control the material/natural world, in order to understand it. The high status of the 'controlled' experiment does not go unseen by students (Pedretti & Bellomo, 2015). As reported by Lundqvist et al., (2009), students are likely to value practices associated with control in school science because of the high priority these practices have in science education (Lundqvist et al, 2009). The resulting companion meaning is that control of nature is necessary to learn skills and knowledge prioritised by school science, while de-prioritising intrinsic qualities of nature not accountable through controlled experiments. Participants were generally unaware of these companion meanings, and did not engage students in discussion about them, or alter teaching practice to disrupt this notion. Although these behaviours may be limited to the science classroom, their continuous practice combined with companion meanings that indicate the value of 'control', may influence how students perceive and enact relationships with nature outside of school science (Oishi & Graham, 2010).

**Dominance of nature**

Dominance of nature has been described as a characteristic of anthropocentrism (Boddice, 2011; Nimmo, 2011), as well as science (Aikenhead & Ogawa, 2007). Although dominance is similar in some respects to control, and may exist in varying degrees, it seems to suggest greater levels of influence, and submission of the dominated to the point where agency, will and purpose of the dominated are oppressed. I use dominance in this thesis to represent practices that demonstrate very high levels of oppression of nature, where human interests are detrimental to nature.

Participants were asked directly about the relevance of the concept of dominance to the lessons they chose. There was significant resistance to the idea that their lessons (or science) engaged students in practices that dominated nature. An example of this resistance can be seen in Frances's comment about the Ecosystem-in-a-Jar activity, of which she said:

> There a difference between control and dominance. Dominance implies that you want to subjugate, and whether it's a connotation or not, if you want to dominate, it implies that you almost want to push somebody down, but you want to control absolutely what's going on, and in that sense, sure, we dominate the chemicals, but can you dominate a thing? They (humans) are living organisms. So, can you dominate a thing? No, in my view. But, can you dominate a plant? To me, you can't say dominate, without having an emotional component, since, as far as we know, plants don't have feelings, or at least we haven't recognized them yet, so, I don't know if dominant in this case is appropriate. (Interview 2)

The language of this statement appears to indicate that Frances does not view nature as having agency, or purpose, other than for human use. This may be a common conception among people from Western societies (Bodice, 2011; Latour, 1987). When you consider the interdependence of nature, however, ideas of human dominance and submission appear more valid; for example, if we cut down a forest, it may be justifiable to view that as an oppression of the trees ability to support other components in its ecosystem that depend on it. What appeared to be unsettling for participants was a notion of dominance that revolved around conscious and intentional power and control over something that causes some form of oppression or harm. For example, Janet said:

> Dominance…well, we control, in science we try to control variables, and maybe we think we can control..and we direct students to control…but we don't purposely control to do harm, if we do, that's not the intention, or we are not aware of it…at least I don't think we are. (Interview 2)

Janet's beliefs about unintentionally harming nature, although shared among other participants, demonstrates how invisible the reproductive phenomenon in institutionalised, everyday teaching practice can be. Despite participants' resistance to the idea of their lessons reproducing dominant relationships or practices with nature, several of the lessons appear to do this. The most obvious examples are the Daphnia Project, the Pop Bottle Terrarium, The Ecosystem-in-a-Jar, the Plant Growth Lab, the Frog dissection, and the River Study; these lessons include science practices that are enacted to obtain knowledge about living organisms and/or its' ecosystem, often at the expense of the life of the organism. Dominance is suggested by the lack of value for nature implied in the next comment by Frances:

> We do the Ecosystems-in-a-Jar, you have your aquatic environment with a fish, and then you have a terrestrial on top, and you have the string connecting the two so that the water from the bottom would go to the top...and there is a straw so the oxygen from the top would go down, and the $CO^2$ going up, and it is cool, and the kids would have to measure to see how long they could keep it going...and you had some kids that by the end of the semester the water was clear and it (the fish) was still going strong they could take it home, the whole bit. Others it (the fish) died within a week. (Interview 2)

The "cool" experimental design is constituted as being of most value in this activity. Unfortunately, this experimental design in many cases caused the fish to die. In other words, in this activity students are being socialised to use science practices that often caused the detriment and death of a living organism, regardless of how they may have felt about doing that. They are being told, by the teacher and texts outlining this activity, to enact procedures that exert power over life, oppressing and subjugating that life to suit the purposes of science.

The River Study selected by Zoltan also engages students in practices that could be considered dominant over nature. In this activity, students 'sample' an area of a particular stream or river to collect water and invertebrate specimens that can be used to indicate the health of the ecosystem. To collect invertebrate specimens, students are expected to walk in the stream, and forcibly disturb the stream bed to dislodge these organisms from their habitat. This practice is described in the following procedure given to each student, below:

## COLLECTING YOUR SAMPLE

1. Begin sampling at your downstream limit (i.e., first transect) and at a point as close to the bank as possible.
2. Place the D-net close to the stream bottom. making sure that no macroinvertebrates can pass beneath the net.
3. Hold the net so that the current is flowing into the net.
4. Stand and kick to a depth of ~5cm upstream of the net by kicking back and forth across the current.
5. Slowly shuffle along the transect towards the marker on the opposite stream bank. Be sure to keep the net close to the stream bottom when kicking.
6. Pick up unembedded rocks along the transect and carefully rub their surface to dislodge any attached bugs and collect them in the net.
7. Once at the opposite bank, walk upstream along the stream edge to the next visible marker and repeat steps 2 to 7 until you have sampled along all of the marked transects at your site (see Figure 3).

Figure 5.5 – Student procedures for sampling a stream bed (Ecospark, 2013)

The procedure in steps 4 and 5 specifically directs students to "kick" back and forth across the current, to disrupt the organisms living there so they can be captured by the D-net. In addition to kicking, students are told in step 6 to dislodge rocks from the stream bed, so that bugs living on these may be captured and collected. These practices cause the submission of the lives of these animals to human activity and interests. Although the language of the procedure has been designed to be at a level accessible to students, it uses deterministic and mechanistic language, which creates distance and separation between what students are expected to do, and nature. For example, the act of taking captive living organisms is called "sampling", and the organisms themselves are termed "the sample", which, in scientific discourse, implies distance and ethical ambivalence to the dominant actions outlined in the procedure. In addition, there is no instruction here that suggests students should be careful with, or respectful of, the organisms and ecosystems they are disrupting, or replace the organisms once they have been counted. The outcome of these procedures is the collection of living organisms, which are put in collection jars, taken to the classroom, and counted. The ratio of certain insects to others indicates the relative health of the stream. Once this quantification is finished, the insects are disposed of.

After prompting, some participants realised there was a degree of dominance to the science practices they engaged students in. For example, Heather described some of the 'hidden messages' in dissection in the next statement:

> Some of them have asked what else do you dissect at school and I say we stop at fetal pigs, you know, like what else can you dissect, and what else can you order, and I've shown them the catalogue of what else you can order, and they are like, "oh my God, you can get all of these things", especially living organisms. So there is that whole sort of ethical piece, the hidden message of dominating, owning nature. (Interview 2)

As Heather suggests, practices such as acquiring preserved frogs from a bucket for dissection, and the ability to order numerous other living and preserved organisms from catalogues, potentially sends several messages to students about human relationships with nature. The frogs and living organisms in the book represent life/nature that humans have decided to terminate in order to satisfy certain scientific and educational goals. The result of this practice of domination, the dissection of animal specimens, is a semiotic representation of human domination over the animals students are dissecting (Oakley, 2012). Student questions about where specimens come from suggest they are trying to 'work out' the human practices involved in acquiring and preparing these specimens (Oakley, 2009). Unless students are engaged in discussion about the ethics of such practices, assumptions about our right to enact these practices may be internalised, unchallenged (Oakley, 2012; Östman, 1998). Although Heather did say "we try to have that (ethical) discussion when we do the dissection" (Interview 2), the fact that students *still* engage in dissection, sends the discursive message that it is acceptable to rear, kill, and sell animals for scientific and/or human purposes (Oakley, 2012). It is ironic, perhaps, that Heather, ostensibly the most environmentally oriented participant, chose the Frog Dissection as the best activity she does all year. The skills of dissection and knowledge of vertebrate anatomy prioritised in science teacher culture, and the Ontario curriculum, appear to have a dominating influence in Heather enacting this activity. This choice may be evidence of how ruling relations of school/school science override individual meaning and affective orientations (Smith, 2005).

**Biocentric relationships**

There were some experiences described by participants in which students may be able to develop more environmentally beneficial, or biocentric, relationships with nature. Biocentric relationships with nature are those that value living nature above all else, and put living ecosystems in the center of ethical and moral consideration and decision making (Taylor, 2010). Educational experiences most effective in developing biocentric orientations in students likely occur outdoors, interacting with nature in relatively unstructured ways. These experiences allow students to construct personal knowledge of nature, rather than existing science knowledge of nature learned through prescribed science education activity (Orr, 2004). Some of the intentions of these forms of education are to develop an appreciation of other living organisms, and to develop a value for intrinsic qualities of nature (Hart, 2003; Taylor, 2010). Unfortunately, only Heather selected an activity, the Mud Lake field trip, intended to foster biocentric orientations in students. According to Heather:

> I want them to try and interpret the nature around them, try to just know the names of some things, that all of them should touch things smell things. I do one activity when we are on the path and we just stand there, and for 2 minutes, just be silent. And, just to slow down, and to listen, and ideally they can listen to the birds, some birds I know the calls for and some I don't. And we draw on the kids in class, to see if they know what some of these things are. (Interview 2)

These activities permit the construction of different forms of knowledge about nature than what would typically occur in prescribed science activities. On this field trip, students are asked to make nature observations, and several other relatively unstructured activities, to connect with nature. The practices students are expected to engage in can be seen in the activity sheet students' use at Mud Lake, below:

**Stop 3 – First Fork in Trail**
*Focus Looking for Birds*
● Blackcapped chickadees will likely greet you as you enter the trail
● Other birds that you are likely to encounter year-round in this area include: nuthatches (watch them walk down tree trunks), woodpeckers (downy small, hairy medium, pileated large)
● You'll frequently see crows, ravens, red-tailed hawks, blue jays, and cardinals and hear a variety of sparrows and warblers, catbirds, fly catchers, and red eyed vireos
● Since 248 species of birds have been seen in or from Mud Lake and 52 species have been known to nest there, this area is one of the best birding sites in Ontario

**Stop 4 – Bridge**
● Take care, no leaning over water
● Try another 2 minute sit spot like you practiced earlier (discuss similarities and differences between the two locations) you should be able to hear the rapids in the nearby Ottawa River.
● On a sunny day from April to early October you'll likely see turtles basking on logs (painted, snapping, and if you're very lucky the endangered Blandings turtle)
● Check out the water for a variety of tadpoles and frogs, and the shoreline for snakes (garter and northern water)
● There are also likely to be water birds including Canada geese (please don't feed them, as they get quite aggressive), ducks (mallard and wood), herons (great blue, green, and black crowned night)

Figure 5.6 Student procedures for "Mud Lake Field Trip"

The language in this procedure is in stark contrast to the classical nature language (Östman, 1998) demonstrated in other texts supplied by participants that contain student procedures for science activities. For example, it is suggested that students "encounter" "see" "hear" and "check-out" the various types of nature in the area, instead of observe, collect, measure, count or other typical scientific practices. Sitting and being silent in nature is a practice in which the assertive, analytical perceptive practices of science may disengage, enabling a different type of interaction, conducive to perceiving interconnection with nature (Orr, 2004). These open-ended procedures describe qualitative observations, and unguided interactions with the ecosystem, allowing for the development of various relationships with, and knowledge of, nature. Heather's intention for this activity was for students to "interpret" nature, which, to her meant "for them to be able to see that nature is a part of us, and we are a part of it…it (nature) has beauty and value in its own right" (Interview 2). Just being present in nature can be an unsettling and novel experience for students who have grown up in urban environments, and may be more attached to technology, than nature (Orr, 2004). Such experiences can develop an *appreciation of nature*, and a sense of care or *stewardship*, that may be difficult to achieve if students do not physically interact with nature (Dryzek, 1997).

Students may have biocentric affective responses to nature simply from being outdoors (Orr, 2004; Taylor, 2010); in the stream study Zoltan chose as his activity focusing on nature, students are physically interacting with nature in a river ecosystem. These relationships are, however, unpredictable, and not the primary goal of the lesson. The intention of the lesson appears to be to use the river ecosystem as a vehicle from which science knowledge can be acquired (Fensham, 1988). Although Zoltan described having a class discussion about the interconnection of water ecosystems, relating that back to the water students drink, he admitted many students

> don't think about their connection to nature. Now, that's not all of them, for some kids it can open their eyes, some kids get it right of the bat. But those are the kids who would make an effort to sit down and watch a nature documentary. Some kids will just get off being in nature, this is so cool, and others will say, no, this is so boring. (Interview 2)

Zoltan is suggesting that students who become aware of relationships and are engaged with nature in this activity are those who are already interested in and likely familiar with, nature. It is important to note, however, that, unlike in Heather's activity, the practices students are engaged in are rather typical science practices that analyze, quantify and collect nature contained in the river ecosystem. These practices result in manipulating, controlling and dominating nature, possibly causing students to see nature as an object to be utilised (Bowers, 1997). These practices likely limit the potential of this activity to allow the development of more biocentric student relationships with, and knowledge about, nature.

Other activities participants choose or discussed also appear to have potential to aid in the development of biocentric student relationships with nature. Ellen and Heather both noted emotional attachments students develop toward the Daphnia and bean plants, respectively, used in activities they teach. Heather, for example, said,

> Some students will name their plant, that's something you do to a living thing. I've had students who used to miss class, not miss class, because they don't want their plant to die.

> They will be upset if their stem is broken, and they do recognize that as a living thing, they say "oh no my plants dead!!" and they can be pretty upset about it, because, they are like, I've watered it and taken care of it and then its dead. (Interview 2)

Naming a plant, and expressing grief over its death, demonstrates a degree of emotional attachment to the plant. Student's distinction of the plant as a "living thing" also suggests a hierarchy of nature, however, in which living things are valued more than non-living. Similar affective responses toward the Daphnia were noted by Ellen, who said "the students find them cute, and get distraught when they die" (Interview 2). Again, a hierarchy may be interpreted in this valuation of the Daphnia by students – seeing human characteristics, such as the Daphnia being cute, is a typical anthropomorphisation humans apply to non-human nature, increasing its perceived value because it has human-like qualities (Oakley, 2012). These responses indicate the multiple meanings students derive from these experiences, however, and that biocentric responses still may occur in activities that have been described primarily as ones in which student practices are generally more anthropocentric. These responses are unplanned, unintended, and spurious results, however, of lessons in which the implicit discursive outcome has been to utilise nature as a resource to learn science (Östman, 1994; 1996; 1998). Responses such as these point out the complexity of human behavior, and that discourse is not necessarily deterministic (Giddens, 2006). In other words, engagement in anthropocentric practices does not omit the possibility of developing biocentric orientations. Ellen's description of many students developing emotional attachment to the Daphnia is an example of how even in controlled interactions with nature, spontaneous connections, emotional responses, and the development of intrinsic value for nature, may arise.

The outdoor activities described by Zoltan and Heather above offer insight into the institutional relations that may coordinate how science is taught, and resist engaging students in unconventional activity outdoors. Heather was the only participant of the nine who did not have a 'team' to coordinate her practice with. As will be discussed further in Chapter 7, science teaching teams, and the resources shard by teams was one of the most influential systems of teacher coordination indicated by participants. Teams contribute to the development of teaching materials that are shared, and there is a common 'vision' of the curriculum, limiting individual interpretation. Without team accountability, Heather is, as she said "able to do my own thing" (Interview 1). Choice and goals related to environmental education embedded in the Ontario curriculum enabled Heather’s enactment of the outdoor activity to Mud Lake. Zoltan, on the other hand, who also described a strong environmental ethic during interviews, spoke frequently about how the team he worked with coordinated each teachers practice. Zoltan’s team develop teaching resources and assessments, such as the River Study, aligned with common science education values and principles. These materials are then shared, limiting individual teacher agency to enact practices that deviate from the community. This is a significant variance in the institutional organisation of Zoltan’s and Heather’s schools that can reasonably explain differences in their outdoor science lessons.

## Chapter Findings and Analysis Summary

Practices in school science necessarily set-up certain relationships with, and constitutions of, nature (Hart, 2005). School science practices identified by participants most frequently engage students in practices that oppress, utilize, manipulate, and dominate nature. Much less frequently, participants described practices intended to develop in students’ appreciation of nature, a sense of interconnection with nature, and value for nature based on its own intrinsic qualities. The constitutions of nature resulting from epistemological practices identified in activities selected by participants are summarized in Table 5.1.

Table 5.1. Constitution of nature in epistemological practice

| Activity | Description | Discursive themes observed |
|---|---|---|
| Aspirin lab | Students perform chemical tests on various brands and strengths of aspirin to determine differences in the mount of active ingredient (acetylsalicylic acid) in each sample. Students must collect and analyze quantitative data to draw conclusions. | Oppression of nature<br>Utilization of nature<br>Ownership of nature<br>Manipulation of nature<br>Controlling nature |

| | | |
|---|---|---|
| Plant Growth Lab | Students germinate beans to test the effects various environmental conditions, such as light and humidity, on plant growth. | Oppression of nature<br>Utilization of nature<br>Ownership of nature<br>Manipulation of nature<br>Controlling nature<br>Dominating nature |
| Bell Ringer/Exam | Students engage in various timed activities, at individual stations, that represent the topics they covered during the school year. Activities include: experiment with light rays; testing for reflection, and refraction; investigating animal systems, and; performing chemical reactions. | Oppression of nature<br>Utilization of nature<br>Manipulation of nature<br>Controlling nature |
| Cel. Phone/STSE project | Students measure how reaction time is effected while texting on a cellular phone, and develop public awareness campaign based on their findings. Students must identify and control variables, and use quantitative data to support their findings | Oppression of nature<br>Utilization of nature<br>Manipulation of nature<br>Controlling nature |
| Rocket Lab | Students investigate properties of flight using a rocket they make out of straws, elastic bands, and cardboard. Students ask and answer their own question about what | Oppression of nature<br>Utilization of nature<br>Ownership of nature |

| | | |
|---|---|---|
| | effects the flight of the rocket, using practices of science investigation, such as identifying and controlling variables, and collect and analyze quantitative data. | Manipulation of nature<br><br>Controlling nature |
| Daphnia Project | Students investigate the effects of adding or removing various environmental factors on the growth of the small invertebrate, Daphnia. Students must identify and control variables, and use quantitative data to demonstrate scientific principles involved in sustainability. | Oppression of nature<br><br>Utilization of nature<br><br>Ownership of nature<br><br>Manipulation of nature<br><br>Controlling nature<br><br>Dominating nature |
| Ecology report | Students investigate, using the internet, an ecological issue of their choice, and write a news report on it. | Oppression of nature<br><br>Utilization of nature |
| Ecosystem-in-a-Jar | Various plants and other living things are contained in one jar, which is sealed but connected to another jar with fish. Students control the environmental conditions to determine the effects on the health of the ecosystem by evaluating the health of the plants and fish. | Oppression of nature<br><br>Utilization of nature<br><br>Ownership of nature<br><br>Manipulation of nature<br><br>Controlling nature<br><br>Dominating nature |
| Frog Dissection | Pairs of students perform a dissection of a frog. Students identify internal organs of the frog, | Oppression of nature<br><br>Utilization of nature |

| | | |
|---|---|---|
| | and make comparisons between the frog's internal organ systems and those of mammals. | Ownership of nature<br><br>Manipulation of nature<br><br>Playing with nature<br><br>Dominating nature |
| Germ Ecology project | Students investigate various ecological factors in their schools related to germs that can cause cold and flu, do various science investigations, and use their findings in community directed activism to address the issue | Oppression of nature<br><br>Utilization of nature<br><br>Ownership of nature<br><br>Manipulation of nature<br><br>Controlling nature<br><br>Dominating nature |
| Helicopter (Whirlybird) Lab | Students investigate properties of flight using a paper helicopter they cut out. Students to ask and answer their own question about what effects the flight of the helicopter, using practices of science investigation, such as identifying and controlling variables, and analyze quantitative data | Oppression of nature<br><br>Utilization of nature<br><br>Ownership of nature<br><br>Manipulation of nature<br><br>Playing with nature<br><br>Controlling nature |
| Mud Lake field trip | Students go to Mud lake, a local ecosystem, to partake in various nature observation activities, and identification of tree species in the | Biocentric relationship with nature<br><br>Utilization of nature |

| | | |
|---|---|---|
| | area. | Intrinsic value for nature |
| Orange Juice Clock | Students inquire about what makes the most efficient dry cell to power a clock by controlling and manipulating variables (such as using orange juice as the electrolyte) involved in making a dry cell. | Oppression of nature<br><br>Utilization of nature<br><br>Ownership of nature<br><br>Manipulation of nature<br><br>Controlling nature |
| Penny Lab | Students investigate how many drops of water can be placed on the surface of a penny before it over-flows. Students must identify, and control variables, and analyze quantitative data to determine this. | Oppression of nature<br><br>Utilization of nature<br><br>Ownership of nature<br><br>Manipulation of nature<br><br>Controlling nature |
| Periodic Table Activity | Students learn about elements by completing a worksheet in which they must identify characteristics of certain elements, such as number of electrons, protons, and model its atomic structure, using the periodic table for data. | Oppression of nature<br><br>Utilization of nature |
| STSE/inquiry on personal technology devices | Students investigate where our technology comes from (manufacturing) and the adverse effects to primarily society and humans of the technology they use. | Oppression of nature<br><br>Utilization of nature<br><br>Ownership of nature |

| | | |
|---|---|---|
| Pop-bottle terrarium | Various plants and other living things are contained in plastic pop-bottles, and students control the environmental conditions to determine the effects on the health of the ecosystem inside. | Oppression of nature<br><br>Utilization of nature<br><br>Ownership of nature<br><br>Manipulation of nature<br><br>Controlling nature<br><br>Dominating nature |
| River Study | Students take insect and water samples from a local river system to determine the health of the ecosystem. Students must identify species and perform chemical tests on the water. | Biocentric relationship with nature<br><br>Oppression of nature<br><br>Utilization of nature<br><br>Manipulation of nature<br><br>Controlling nature<br><br>Dominating nature |
| Film Canister Rockets | Students investigate properties of flight using a rocket they make out of film canisters, water, and Alka-Seltzer tablets. Students ask and answer their own questions about what effects the flight of the rocket, using practices of science investigation, such as identifying and controlling variables, and collect and analyze quantitative data. | Oppression of nature<br><br>Utilization of nature<br><br>Ownership of nature<br><br>Manipulation of nature<br><br>Controlling nature |

| | | |
|---|---|---|
| Water (STSE) activity | Students inquire into the way water is used around the world, and examine their own practices related to water use to emphasis the importance of water conservation | Oppression of nature<br><br>Utilization of nature |
| Maple Syrup SOS | Students go on a hike, and learn about maple syrup production, and how climate change is having an effect on this. Students conduct a maple tree population survey of a particular area, and use this data to draw conclusions about the health of the ecosystem | Biocentric relationship with nature<br><br>Oppression of nature<br><br>Utilization of nature |

My analysis of the findings in this chapter contains an obvious criticism of many school science practices.  It is not, however, the intention of this thesis to suggest all of these practices be changed or eliminated, for several reasons. First, I personally struggle to conceive of ways to do science differently - science educators, including myself, have been subject to dominant discourses that empower these practices, making it difficult to think about, and enact, different form of science education. The findings of this thesis are an initial step to disrupt this dominant discourse, providing some of the intellectual tools and perspectives needed for others to examine science teacher practice, and develop new practices that can expand the scope of nature inquiry in science. Secondly, many of these practices are prioritised in science education because they are effective in teaching students valued and important science knowledge (Hodson, 2006). While agreeing with this, I would suggest that questions must be asked of the companion meanings (Östman, 1998; Roberts, 1998) inscribed in these practices, criticisms of these meanings be made transparent, and suitable alterations to practices occur if deemed necessary by science education communities.

How an individual comes to know nature, an epistemological approach, is one way to examine constitution of nature. Students in school science generally come to know nature indoors. Learning nature indoors is beneficial for learning science, because it allows the teacher to control the learning environment (Stevenson, 2007), ensuring the valued learning activities are enacted. It also enables intense focus on the small part of nature that is of interest, making the likelihood that knowledge acquired will be relevant to prescribed learning expectations (Hart, 2003). Learning science outdoors was infrequently described by participants. In learning science outdoors, however, students can experience different perceptions of nature, and see its interconnection, which is conducive to biocentrism (Chambers, 2008). Science methods described by participants require students to interact with nature in ways that effect and influence nature, for the purpose of (re)producing science knowledge. Effects that are directly detrimental to nature result from practices in which students manipulate, control and dominate nature. Frequent enactment of these practices may normalise these behaviors, establishing ways to know nature based on control, manipulation, and even dominance, as the status quo (Bowers, 1997). The socialisation of these behaviors in school science has implications for everyday life – students may not see boundaries between what they do in science, and how to interact with the material world outside of school (Oishi & Graham, 2008). In other words, the way students are socialised to interact with nature in school, can influence how students will behave toward an insect they see in their home, the plants and animals in their local environments, or whether or not they decide to engage in social action for animal protection, preventing habitat loss, or deforestation (Bowers, 1997; Crompton & Kasser, 2009). The discursive message related to epistemology and school science is that nature serves humans – most basically, as material on which to practice ways to know the world around us (Östman, 1994, 1996, 1998). This assumption removes much of the ethical and moral deliberation about how humans should interact with nature that should occur in school science and society more widely. Constituting nature as a material on which to practice human ingenuity gives licence to practices of manipulation, control and dominance that contribute to environmentally detrimental citizen orientations (Bowers, 1997; Crompton and Kasser, 2009).

If nature is seen as a tool for the development of science skills, then goals and purposes of science will shape the knowledge produced about nature (Aikenhead & Ogawa, 2007; Kawagley et. al, 1998). In other words knowledge produced about ‘knowing’ nature is that knowledge which somehow advances the scientific enterprise. This knowledge typically conveys established ways of knowing nature, in order to produce knowledge that can be utilised for human progress and development (Latour, 2004). Said another way, skills and practices designed to know nature must be useful (to humans). Aesthetic or spiritual ways of knowing nature are less valued because they make limited contribution to economic systems (Pierce, 2013). Ways of knowing that produce knowledge of nature's physical properties, which are needed to use nature for economic purposes, are most valued (Gilbert & Sakar, 2000). As Joanne said, "Science seems to be a descriptor of nature" (Interview 1). In school science, knowledge products (Woods, 1998), pre-existing science knowledge based on descriptions of nature, are prioritised (Apple, 2004). These are replicable forms of knowledge that can be reproduced through known science practices, such as those contained in the activities selected by participants. The knowledge produced in these practices is seen as scientifically valid; therefore practices producing this knowledge are prioritised in school science (Hodson, 2009). These considerations make such practices desirable for science teachers who are held accountable for student learning (Apple, 2004).

One of the primary reasons participants claimed they do not take students outdoors is because they cannot control how, or what, students are learning in the uncontrolled outdoor environment. The majority of activities discussed by participants, occur indoors, where they have abundant knowledge about how to teach science, and have more control of student learning (Pedretti & Bellomo, 2015). Control of learning is required, because, as participants stated frequently, they are accountable for what students learn. In science education, students acquisition of science skill and knowledge is the primary expected outcome (Apple, 2004). In Ontario, these expectations are described in the provincial science curriculum. Thus, teacher practices that engage students in oppressing, utilising, manipulating and dominating nature are way to teach them the experimental procedures optimised to reproduce the skills and knowledge valued and privileged in school science. Thus, engaging students in activities in which they are controlling nature, in order to control their learning, appears to be a significant 'hook' into the institution of school, tied to the curriculum, and assessment policies, with trans-local implications. These, and other, institutional factors coordinating how science teacher practice constitutes nature, are discussed in greater depth in Chapter 7

A natural question after considering these results may be, how else could science, and school science be done? My intention in this chapter was to problematize epistemological constitutions of nature in school science, more so than science. As many scholars have pointed out (e.g. Bencze & Elshof, 2004; Hodson, 2009; Lederman et al., 2002) NOS practices done in school science often are inaccurate representation of the way professional science is done. Although study of nature indoors does occur in science, in fields such as ecology and various sub disciplines of biology, the majority of research occurs outdoors, in nature. In these research settings, scientists frequently form more personal, and connected relationships with nature, and this is increasingly accepted in science discourse, rather than seen as an introduction of “bias” or loss of validity of the research (Gilbert & Sakar, 2000; Nicholson, 2013). In addition, study of nature indoors may be at times necessary, because it provides scientists with the isolation needed to make focused observations on a specific part of nature (Mitchel, 2003; Nisbet, 2003). The production of knowledge through conventional epistemological methods of science has resulted in significant advancements in human health, social development, and individual well-being. These aspects of science epistemology should be, and are, celebrated in school science. Frequently in science, however, moral and ethical considerations about practices that may be detrimental to nature are evoked (Gilbert & Sakar, 2000). These considerations have, over time, resulted in alterations to, and reduction of, many practices that are detrimental to nature (Nicholson, 2013). For example, computer simulations are increasingly used to model the effects of various factors on natural systems, limiting the use of animals for laboratory testing (Oakley, 2009). These considerations were not described by participants of this study, and infrequently occur in school science (Hart, 2003).

At the very least, school science communities could evaluate the environmental ethics of the practices with which they engage students and nature. As noted previously in this chapter, the primary ethic inscribed in the majority of practices described by participants is sharply human-centric; to teach students science knowledge that may be useful to them in some way, such as in post-secondary education or to acquire a job (Pierce, 2013). This appears to represent an anthropocentric environmental ethic (Gewirth, 2001; O’Neill, 1997). Even if the intention of these activities is more *utilitarian* (Regan, 1983/2004), which can provide a degree of equality between humans and nature, analysis strongly suggests school science practices result in knowledge of nature of utility to humans, not nature. Indeed, knowledge of nature for nature’s sake is alarmingly absent in the teacher talk and texts evaluated in this research. Even in infrequently described non-anthropocentric activities, which were classified as biocentric, a range of more nature-centric perspectives, such as deep ecology (Naess, 1973) are not apparent. These biocentric lessons potentially extend moral and ethical consideration and value to living organisms, but not non-living nature. This is potentially problematic when considering the interconnectedness of all of nature, and the value of non-living natural components to sustenance of ecosystems. As Naess and others (e.g. Bookshin, 2001; Plumwood, 2007) suggest, an ethic such as biocentrism is still based on a form of rationalism, and dualisms (living nature-non-living nature), that they consider to be the base of environmental problems to begin with. Consideration of other environmental ethical positions could make clear the human-centric ethic inherent in lessons and activities, and provide alternative ways to view school science and the purposes of science education.

As Derek Hodson (1998; 2006; 2007) suggests, science learning for contemporary students may require a greater focus on learning *about* science, than how to *do* science. I suggest that consideration of how the methods and language of science potentially sustain ways of knowing nature based on dominance, and the consequences of this, must be part of learning *about* science. Providing students with understanding of the relationships with nature embedded in science methods can improve their capacity to think about nature holistically, improving sciences' contribution to more sustainable relationships with nature.

# Chapter 6: Ontological Constitutions of Nature

> *We are starting to learn about laws and models, so the idea of the electron model, atomic structure, just a model, so I give them these little containers, they aren't allowed to open it, but they can do anything they want to try to find out what's in there. And they have to come up with a diagram of what is inside, so I'm reviewing with them what a diagram is, and what a model is, and was the model successful, and what could you tell and what couldn't you tell.* (Ellen, Interview 1)

Human practices and discourse constitute nature as particular ontological entities (Hodson, 2009). Ontology is a branch of philosophy that deals with being, becoming, existence, and reality. Stated more simply, ontology deals with questions concerning what entities exist or may be said to exist, and how such entities may be grouped, related within a hierarchy, and subdivided according to similarities and differences. Specific practices people engage in, and ways of communicating about nature, construct a conception of what nature is. The human construction of nature stems from the assumption that nature is knowable (Aikenhead & Ogawa, 2007). Yet, there are limitations in what we can know about nature that influence our ontological constructions of it, and many of these limitations may be culturally embedded. For example, in science, nature is typically described through physical features that can be predictably observed using the human senses (Cartwright, 1999: Mitchell, 2003). These practices may contribute to the development of human perceptive apparatus that makes perceiving nature in any other way, difficult, if not impossible (Kawagley, 2005). The notion that nature may have *intelligible essences* that are not observable with sensory apparatus is typically not a consideration of science (Nicholson, 2013). Intelligible essence, however, a notion first postulated by Aristotle, suggests that every part of nature has individual qualities and characteristics which may include spiritual, and other qualitative aspects, as well as material aspects (Aikenhead & Ogawa, 2007). In essence, science, particularly school science, includes a conceptualisation of nature as various types of simplified material objects that can be observed, stripped of subjective human interpretation (Mitchell, 2003). This chapter presents data on how participants' practices and discourse produce representations of nature. The research question answered in this chapter is: *What ontological representations of nature are prioritised in participants' practices and discourse?*

**Understanding what nature is**

The idea that nature is knowable is one of the characteristics of Western sciences, and eradicating mystery in nature by knowing it is one of its key goals (Aikenhead & Ogawa, 2007). Every lesson chosen by participants, therefore, contained the assumption in discourse that nature is knowable through science. The Pop Bottle Terrarium is a good example of a science lesson that attempts to eradicate mystery about nature, in this case, what plants and animals need to survive. The purpose of the lesson, according to Alice, is to "understand what is needed for a sustainable ecosystem" (Interview 2). In speaking about what students are expected to know, Alice said:

> I ask them "What can you measure?" and "What can you vary?" and they would set up their investigation according to that, so some of them might be looking at light, temperature, pH, the number of plants in there, and if you have snails, worms, etc, in the thing, and basically what they are measuring is plant growth. (Interview 2)

Although there are several hidden messages, implicit meaning, or companion meanings (Östman, 1998; Roberts, 1998) inherent to this activity, one of them appears to be that humans (students) can know what affects plant growth by testing controllable components, or variables, that are believed to be necessary for plant growth. This knowledge represents a simplification of the complex and interrelated factors that cause a living organism to grow. Yet, Alice admits "we never really talk about factors we can't measure, or factors we may not know about….the complexity that may be involved. What would the point be in that?" (Interview 2). The companion meaning such an activity may convey is that science can know everything about nature. Being able to understand nature then leads to a host of other assumptions about nature, such as the idea that we can control nature, because we understand it (Dryzek, 1997).

The Penny Lab was an activity frequently discussed during interviews, due to its perceived effectiveness in allowing students to fully understand the natural phenomenon occurring in the lab. For example, Zoltan explained "doing the lab on a simple thing like the Penny Lab, they can see 360 degrees, what are the issues involved with this, what's going on. (Interview 1). In the Penny Lab, students are working with water, a penny, and a dropper, to investigate how many drops of water will fit on the penny before it overflows. Using these simple materials, students are able to understand how small differences in the materials and procedures effect the result, such as which side of the penny they are dropping water onto, or how much dirt or corrosion is on the penny. Ellen said, for example:

> If it's simple enough that they understand it, it's simple enough that they feel they can control it, because that's the thing about the Penny Lab, it's very simple, right, and the variables are easy to see, so they are controlling it, and they understand how to control it quite well. (Interview 2)

Both Zoltan and Ellen identify the importance that students are able to understand the variables involved in an experiment in order to engage with it, making it an effective learning experience. In order for this understanding to occur, the experiment must be simple enough so that students can, as Zoltan says, understand what's going on. Zoltan's phrase "what's going on" suggests there is something specific students are to 'know' in this activity, and that by making the experiment simple enough, students can arrive at this knowledge on their own. Enabling students to 'control' the experiment to obtain the correct knowledge, then, represents the 'bench-mark' school science investigation (Hodson, 2009), in which they are controlling the environment to (re) produce valued knowledge.

Teresa summarizes the potential effects of these labs on students in regards to messages about understanding nature in her following quote:

> I can't speculate what they are thinking, but certainly, the hidden message is that we can understand all the variables, if we try hard enough, that's the message the activity sends, that we can understand nature, whether they perceive it that way or not, I don`t know. (Interview 2)

The fundamental presupposition of Eurocentric sciences that nature is knowable stems from mystery in nature, creating the need to know nature, which leads to investigations aimed at eradicating that mystery by generating knowledge comprised of generalized descriptions and mechanistic explanations (Aikenhead & Ogawa, 2007). The idea that nature can be understood appears to be an unproblematic assumption, but it raises questions about *what* is understood, *limits* of human understanding, and *how* is understanding of nature represented. Particularly relevant to school science is how understanding of nature is conveyed by students, and what forms of 'evidence' of understanding are valued by teachers. The remainder of this chapter explores representations of nature, and how these are seen as evidence of student understanding of nature.

**Objectification of Nature**

Practices that engage students in learning knowledge about nature can cause students to come to perceive nature as something distant and separate from (or close to) them (Fensham, 1988; Hart, 2003). These practices typically involve learning about nature through language/discourse in which abstract knowledge about nature is communicated to students (Kilbourn, 1998). What can be observed of nature is enormously complex, and therefore difficult to perceive holistically. Science, therefore, tends to represent nature as discrete entities that are identifiable through human observation (Mitchell, 2003). One of the most simplistic representations is nature as an object. Key to objectification is conceptual independence, or separation, from the entity being objectified (Mitchell, 2003). In science, this separation occurs in the language used to describe and explain natural phenomenon, termed *nature language* by von Wright (1991). The main convention of classical nature language is that "nature has to be dealt with in isolation from and *separate from* the human being" (emphasis added) (Östman, 1998, p. 60). According to Östman (1998), this occurs through the use of depersonalised language, speaking of nature as a thing, and the use of words such as "is", "are", "the", "consists of" and "contains". These words give statements specific ontological value; that they represent true knowledge about entities that are physically and conceptually separate from us. In other words, these are distinct entities, different from the self, and located outside of the self, therefore there is conceptual separation from the self (Cobern, 1991). Such language can be seen in many of the activities participants selected. For example, "Investigating water: The chemical of life" is a Grade 9 Academic Science activity in which students learn about the chemistry of water, and inquire about various social issues related to global water use, such as water shortages, the commoditisation of water, and pollution of the oceans by plastic water bottles. The activity starts with a "Water Facts" sheet, shown below, from which information about water can be used to create a 'graffiti wall'.

- ❑ About 70% of earth is covered in water; 97% of the Earth's water is found in the oceans.
- ❑ Water is a universal solvent.
- ❑ Water has high surface tension-capillary action.
- ❑ Water has high specific heat index.
- ❑ Water plays an important role in weather (snow, sleet, freezing rain, rain, melting ice causing flooding, etc.).
- ❑ Up to 60% of the human body is water

| Body Part | %age of Water by Weight |
|---|---|
| Brain | 70 |
| Lungs | 90 |
| Lean muscle | 75 |
| Blood | 83 |

- ❑ Babies are made up of more water than adults (about 78% water by weight).
- ❑ Some organisms are 90% water.
- ❑ 220 million urban residents in the developing world lack a safe source of drinking water near their homes.
- ❑ Agriculture consumes 60-80% of the fresh water resources in most countries; this percentage can reach as high as 90%.
- ❑ 90% of urban sewage in the developing world is discharged into rivers, lakes, and coastal water ways without any form of treatment.
- ❑ Canada has 25% of the world's wetlands, the largest amount in the world.
- ❑ The Great Lakes contain 18% of the world's fresh surface water.
- ❑ You can survive a month without food, but only 5-7 days without water.
- ❑ Approximately 300 L of water are needed to make 1 kg of paper.

Sources:
Environment Canada http://www.ec.gc.ca/eau-water/default.asp?lang=En&n=11A8CA33-1
The World Bank Group
http://www.worldbank.org/depweb/english/modules/environm/water/index.html
United States Geological Survey http://ga.water.usgs.gov/edu/

Figure 6.1. Water facts

The various statements about water, or entities related to water, in this text, constitute these entities through the use of "is", "the" and "are" in almost every statement. For example, the statement "water is a universal solvent" discursively reconstitutes water as a thing (a universal solvent). This constitution provides conceptual distance from what water may mean to students through its connection to them in their everyday lives, such as something they drink (need), bathe in, and may enjoy recreationally (Östman, 1996). Other statements marginalise personal relationships that could narrow the separation between the object and the student. For example, the statement in the activity "Up to 60% of the human body is water" objectifies and separates the human body from the reader, other-ing it from the self, potentially creating conceptual distance through its depersonalisation (Chambers, 2008; Östman, 1998; Sharma & Buxton, 2015). In other words, the statement conceptually constitutes the body as some 'other', different body, in some distant other place, not the student's own, in the here and now. This distancing could be nullified through more personalised language, such as 'Up to 60% of *your* body is water'. The inclusion of the self (your) personalises the connection between the body and the reader, narrowing the conceptual distance between these entities constituted by the more depersonalised statement.

Scientific language that creates conceptual separation, or other-ing, distancing the reader from the objects described in the language, is also demonstrated in the Daphnia handout given to students. Although this text was written by Ellen, and some concessions to make it more personal are apparent, classical nature language (Roberston, 1998) still dominates the text. We can see this language in the first 3 paragraphs in the student handout describing the activity, presented below.

**Designing a Sustainable Ecosystem: Culturing Daphnia**

Ecosystems may be dynamic, but they are also sustainable, continuing on without intervention to maintain them as all of the components will allow nutrients to cycle continuously through them. Their diversity can also help them resist occasional pressures or disturbances without the entire system failing. Our species (*Homo sapiens*) regularly modifies or recreates ecosystems for our own purposes (e.g. logging, agricultural field). Successful, sustainable attempts are those that understand and accommodate organisms and their natural cycles.

You will be investigating factors that may affect the success of a stable population of an aquatic organism, *Daphnia*. These organisms are common lab animals used for physiology, toxicology, ecological and evolutionary research as well as being an interesting representative crustacean for invertebrate biology students. Being able to keep a culture of live animals going all year round is very useful, so you will be experimenting to determine factors that may limit the ability of one of these cultures to produce a continuous supply of individuals.

**Basic Biology**

*Daphnia* are freshwater crustaceans (related to crabs, shrimps, and lobsters) and there are more than 100 *Daphnia* species worldwide. They can be found in almost any size of body of water, but fish and other predators can exclude them from a habitat. They use their many hair-lined limbs to filter particles (e.g. algae, bacteria) out of the water as food. The animals we will be using are fed on algae, so their gut is easily visible as the squiggly green line along the length of their body. They can live in very high densities when food is readily available.

Figure 6.2. “Designing a sustainable ecosystem: Culturing Daphnia” student handout

The language in this text constitutes complex nature as abstract entities; for example, nature that is co-dependent on other nature, living together in a relatively defined location, is termed an “ecosystem”, phenomenon that causes failure of these systems are “pressures” and “disturbances”, the Daphnia in various places in the text are called “organisms”, “crustaceans” and “cultures”. Such abstract conceptualisation makes it difficult for the reader to ‘connect’ with the concept, creating conceptual distance between the phenomenon being represented and the reader (Östman, 1998; Sharma & Buxton, 2015). Ellen’s attempts to personalise the text by substituting abstract terms used to describe the Daphnia with “animals”, a concept which students likely would have more emotional connection to, and therefore this terminology may constitute less conceptual separation between the student (self) and the *Daphnia sp.* (other). Another apparent personalisation is her use of "our" in the phrase "our species". However, the effect is this personalisation is reduced by the use of "species". Instead, more inclusive words such as "we" might have been substituted for "our species", personalising the text more, and narrowing the conceptual separation between the student (self) and the object being described (other humans). The fact that communication in science, and school science, text rarely uses such personalised language (Hodson, 2009) means that conceptual separation from nature is the discursive status quo.

In addition to conceptual independence, nature, as an object, is understood according to how science understands the characteristics of the object (nature). In speaking of this, Joanne said "More and more, I feel like science is just a descriptor of nature" (Interview 2). Description of nature was a practice frequently found among the activities students selected. For example, several activities featured the classification of nature observed or collected outdoors. In one of Heather's activities, a field trip to Mud Lake, students are asked to classify trees. Explaining how students do this, she said "they have a dichotomous key, which lists physical characteristics of the trees, and they identify them that way" (Interview 2). When asked about the purpose of classifying trees in the activity, she explained:

> Well, I guess that's where the science is. They don't get much else scientific out of the experience. At least with this, their observations are collected, and categorized, and meaningful in a scientific way. It's more systemic that just unguided observation, being in, or appreciation of, nature, which don't really have a place in science. (Interview 2)

Heather's statement identifies what she believes is valuable about nature in science; the organisation of selected observations into categories, which are used to produce scientific knowledge about *what nature is*. Her view is that non-systematic engagement with nature, such as simply "being in" nature, is not valued in science; the implication of her statement is that in unguided or non-systemic engagement with nature, there is no way to know what students are learning. In other words, these experiences are not reliable in ensuring students learn the science knowledge valued in science education. Her inclusion of this classification activity in this outdoor lesson suggests it's done to optimise student observation of nature so that the required knowledge is (re)produced.

Another activity that demonstrates nature as an object is the periodic table activity chosen by Frances as the best activity she provides for students all year. In this activity, students are "taken on a guided tour of the periodic table" to "learn about the elements" (Interview 2). The activity asks students to identify properties of elements, such as their atomic number, atomic mass, melting point, density, and atomic model, in order to understand the Periodic Table (See Appendix X for complete activity). For example, in the first page of the assignment, below, students are asked to identify characteristics and features of certain elements, such as gold:

Purpose

To examine the arrangement of the elements on the periodic table of elements, and to look for patterns of similarities in the elements grouped in columns and rows.

Observation and Discussion

Use your periodic table, the appendix D hand-out and your notes to complete this activity.

1. Examine the periodic table. Note whether the elements are solids, liquids, or gases at room temperature.
   a) Which **chemical symbols** represent the **eleven** elements that are gases at room temperature? (0.5)

   b) Give the **name** of **two** elements that are liquid at room temperature. (0.5)

2. Look at the symbols and atomic numbers of the elements.
   a) What is the atomic number of helium? ____________________ (0.5)
   b) What is the atomic number of gold? ____________________ (0.5)
   c) What is the symbol of the element with atomic number 22? ____________________ (0.5)
   d) What is the symbol of the element with atomic number 33? ____________________ (0.5)

3. Look at the atomic masses of the elements.
   a) What is the rounded atomic mass of aluminum? ____________________ (0.5)
   b) What is the rounded atomic mass of silver? ____________________ (0.5)
   c) What is the symbol of the element with atomic mass 40.1? ____________________ (0.5)
   d) What is the symbol of the element with atomic mass 83.8? ____________________ (0.5)

Figure 6.3. Periodic table activity, student worksheet

Discourse analysis using Östman's (1998) framework for nature language suggests the text of this document contains discourse that objectifies nature. Such language is silent on the epistemic processes that have worked to produce this science knowledge about nature. In other words, the discourse contains the assumption that this knowledge is 'true', rather than a socio-cultural product based on particular perspectives, interpretations, and values (Tobin & Roth, 2007)

This discursive assumption creates companion meanings that there is a truth about nature, which is discernible by everybody all the time, using the human senses (Östman, 1998). For example, the phrasing "what is?" used frequently in the questions on this page suggest the elements have definite, true physical features that can be observed using the senses (in this case, augmented by technology). Features such as atomic mass and atomic number are salient physical features of these entities, and come to define, with other salient features, what an element is, according to science. However, there may be other 'intelligible essences' related to these elements, such as personal or emotional value for, for example, gold, that are not included in the description of nature valued in this activity. Activities such as this, therefore, potentially *socialise* (Hart, 2003) students into conceptualising nature as an object, with observable and true physical characteristics. These characteristics are discrete units of knowledge (Apple, 2004) that are transmittable, reproducible, and quantifiable, thus they act as an efficient commodity from which to deliver and account for science learning (Woods, 1998). Practices of objectification, by prioritising certain salient features, and not others, hide the complexity of nature, as well as imply that, what is described is all there is to observe about natural entities (Gilbert & Sakar, 2000).

## Reassembling Nature

Reducing nature into discrete objects, with discernible physical features, is an attempt by science to deal with the complexity of nature by dividing it into manageable parts (Cartwright, 1999). This foundational presupposition holds that Eurocentric science can understand ''the structure and function of the whole in terms of the structure and function of its parts'' (Irzik 1998, p. 168). To do this, many scientists break down (reduce) complex phenomenon into simple parts, factors, or variables amenable to measurement, conceptualization, and experimentation. The "whole" can then be understood through the integration of these partial and fragmented bits of knowledge. However, the "whole" eludes most disciplines in science, which still create artificial boundaries around "whole" entities in order to understand this larger system, within which reduced parts fit, without necessarily seeing the interconnection of these larger systems with each other (Gilbert & Sakar, 2000). How nature is re-assembled in the activities selected by participants is presented in the following sections.

Nature as a model

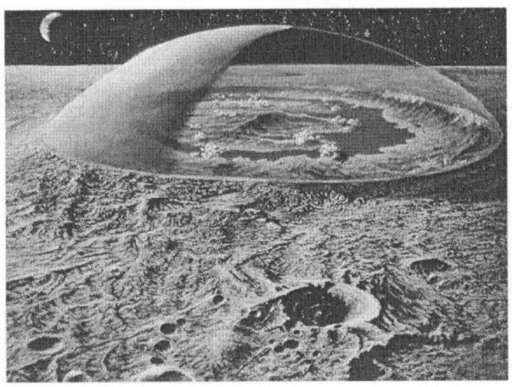
The organisation and integration of parts of nature is done in several ways in science; one of these is through description by a model. Although there are different kinds of models, a scientific model can be thought to be an idealised or simplified representation of natural or human-made phenomenon (Mitchell, 1993). Practices that engage students in modelling nature were frequently discussed by participants. For example, Steve said, “I teach students to use models to understand something better, use a model to communicate it better, using a model as a current hypothesis.” (Interview 1). The *Pop Bottle Terrarium*, *Daphnia Project*, *Exploring the Modern Periodic Table* and *The Whirlybird Lab*, are all examples of activities selected by participants that include some type of modelling of natural phenomenon. In the *Pop Bottle Terrarium* and *Daphnia Project*, students are expected to create a smaller-scale model of a living ecosystem. For example, Janet said:

> It really is a miniature representation of an ecosystem. So students can see how the ecosystem works on a small scale that they can grasp. It recreates the system, so students can understand the variables, understand what’s happening. (Interview 2)

Janet identifies several of the features of a science model in this comment – it simplifies natural phenomenon, it’s a representation, and it’s often a small-scale version of that phenomenon. Discourse in this statement, such as “it really is a miniature representation” suggests a high degree of certainty about the ability of a model to represent nature. Text sequences such as “students can”, discursively constitutes nature as something which can be modelled by students. Additionally, sequences such as “the ecosystem works” and “understand the variables” suggest the model represents everything of interest and value in nature. Such discourse potentially marginalises other aspects of nature that are not represented in the model. Similar discourse can be seen in the brief experiment description for this activity, below:

## Pop-Bottle Terrarium Experiment

The ability to create a self-sustaining, enclosed environment might allow humans to eventually colonize the Moon or Mars. NASA is interested in repeating the Biosphere II experiment, but on a smaller scale. As part of the planning team, you've been asked to design and carry out an experiment of an enclosed ecosystem.



Growing plants in colonies on the Moon or Mars would provide humans with food, and oxygen. A small-scale ecosystem can be set up where a plant sealed in a pop-bottle. This can be completely self-sustaining because of the cycling of water, carbon, oxygen and other nutrients in the bottle.

There are many factors that are important in making a plant grow best.

Your teacher will demonstrate how to build a pop-bottle terrarium. Observe carefully and take notes to help you later in writing your own procedure.

Figure 6.4. Student procedures for the pop-bottle ecosystem

The first clause of text in this activity description suggests the possibility of humans modelling an ecosystem; this possibility is verified in the second sentence, by the term "repeating", which suggests modelling of ecosystems has already taken place. Thus, the students understanding of human ability to model nature (ecosystems) is transformed from one of possibility, to reality, by the discourse in this text. Additionally, assertions about models being a true and realistic representation of nature are found throughout the text, using phrases that connect the possibility of modelling an ecosystem, such as "can be", with the reality of creating a model.

Certainly creating models are important practices in school science, as they allow students to grapple with the complexity of nature, by reducing it into a simplified representation that may make learning about nature more manageable (Hodson, 2009; Mitchell, 2003). However, the reduction of complexity inherent in a model may "punctualize" (Latour, 1987) nature. Punctualization is a phenomenon described by Latour, in relations to networks, in which the complex relationships associated with an entity (actor) are become invisible, or purposely hidden from view. From a perspective of punctualization, viewing nature as a model, explicitly and implicitly, suggests there are certain features about nature that are of value (to science), and these are included in the model. These valuable features are represented in the model as objects, which students must acquire knowledge about. A model can be said to be a relatively complex objectification of nature, which provides discrete compartmentalised knowledge of nature. In school science, students are required to acquire this objective, compartmentalised knowledge as evidence of learning. Other features of nature can't be observed, or are of little value in the context of goals of science, so these are not represented in the model, and therefore these do not become part of the model. The potential consequence is that students come to know nature as the model they learn in school, instead of the complex and holistically situated entity of nature that in actuality it is (Mitchell, 2003).

Mathematical models of nature

A privileged form of scientific modelling occurs through quantification of nature. Quantification is based on the assumption that nature is composed of matter with knowable, objective mathematical relationships (Aikenhead & Ogawa, 2007). Quantification of these relationships through counting, or mathematical equations, provides status and significance to the scientific disciplines that use quantification. Practices that engage students in quantification were prioritised by participants. An example is the River Study, described by Zoltan. This activity was developed by Ecospark Canada (Ecospark, 2013), who take school children to rivers around Ontario to investigate the health of the river ecosystem. Students collect scientific data, such as numbers of aquatic insects present, by collecting and classifying insect specimens. Classification is done by identifying and counting certain body parts of the insects. Figure 6.5 demonstrates how students are expected to classify the insects they collect.

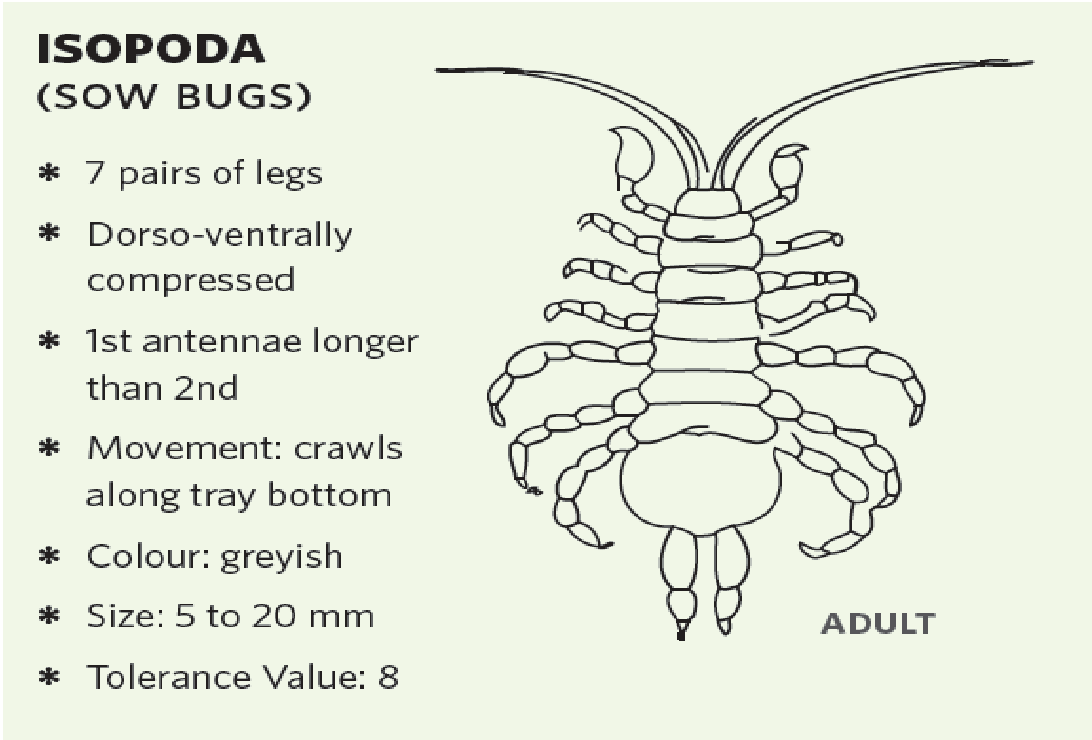



Figure 6.5. Student procedures for classifying Arthropods in a stream (Ecospark, 2013, p. 19)

The sow bug is identified in this text through objective mathematical relationships. Students are asked to objectify the insect numerically, potentially oppressing qualitative, human, or spiritual attributes they might otherwise be interested in (i.e., stripping it of intelligible essences) (Aikenhead & Ogawa, 2007). The practice of mathematical objectification is one of the highest status practices in science, which "concerns itself with quantity and not quality'' (Little Bear 2000, p. 83). Although the students in this activity are doing some qualitative observation as well, priority is placed on quantifying phenomenon within the river ecosystem to determine its relative health. In other words it is the quantification of variables (numbers of insects, turbidity of water, free oxygen) that determines the health of the ecosystem, not the qualitative data that is seen as important. Qualitative observation is used primarily in this activity as a way to determine what to count.

Other participants also expressed high value for activities in which students are quantifying natural phenomenon. Ellen, for example, speaks of measuring characteristics of the rocket, the activity she selected as a typical science investigation. In this activity, students are able to make changes to a basic rocket design, to test how these changes affect the rockets' flight. Ellen explains how she engages students in determining what characteristics they could investigate in the following statement:

> We brainstorm a bunch of ideas on what they can measure, what are some of the variables, pitch, yaw, center of gravity, payload, length of the rocket, size of fin, location of fins. I want them to launch at least 30 times....and then, once they are done, they understand ideas like variation, replicate, so they get the idea that how the experiment is designed is flexible, but that ultimately you want reliable data, you want accurate data, you want to be able to see a trend in the data, you want outliers. (Interview 1)

Data in this activity is numerical, based on quantifiable characteristics of the material with which students are working. The rocket is therefore constituted as a source of data, whose value lies in the numerical data it can reliably produce for students. In other words, students are using the rocket as simply a way to understand and learn science (Östman, 1998). The clear prioritisation of quantifiable characteristics of the rocket potentially devalues affective responses students may have that could result in different relationships and intentions (Nidsam et al., 2013).

Related to the collection of quantitative data is the value participants place on students performing calculations. Ellen was particularly articulate about engaging students in performing calculations related to the Daphnia activity, stating:

> This (Daphnia project) has a variety of variables that are associated with it. When there's a peak in the population, suddenly the food plummets, and then the kids can sort of see the cycles, when they plot it (using a population simulation program) they can actually see it, and we can talk about things like, instead of just defining log growth or exponential growth, or whatever, we can actually show them this is what happens. (Interview 2)

In this statement, the discourse suggests the data represents the reality of population changes that occur, rather than the living and dying Daphnia themselves. For example, Ellen states the students can actually "see" the cycles after they plot the data using the computer program; before they do this, they can only "sort of see" the cycles. In addition, the demonstration of growth using the data and the computer program is valued in this discourse, rather than what is seen through direct observation of the Daphnia populations the students care for. This discourse constitutes the mathematical representation of Daphnia population cycles as more valuable than actual observed cycles.

Also prioritising calculation was Zoltan, who expected students to be able to calculate various natural relationships pertaining to light during the Grade 9 unit on optics. At the end of the year, Zoltan gives students a *Bell Ringer* activity, which he selected as the best activity he provides for students. The bell Ringer is a summative examination that tests students' ability to perform skills and knowledge pertaining to the units they studied over the school year. Students move from station to station on lab benches in the back of the room, where they have 9.5 minutes to perform the prescribed tasks at each station. One of the 6 stations provides this procedure to students:

<table>
<tr><td>Station</td><td>Neatly and clearly print your answers to the following questions in the space provided below. You are permitted 9.5 minutes per station + 30 seconds travel time.</td></tr>
<tr><td>5<br>Light Bench<br>(circle which station you are at)<br>5a)<br>5b)<br>5c)<br>5d)<br>5e)</td><td>Light Bench – Use your recorded data to calculate the focal length (f) of the lens provided & m<sub>d</sub> & m<sub>h</sub> for magnification.<br>Use GUESSS - Show all calculations [6 (f) +4 (m) marks working + 6 marks accuracy=16]<br><br>Observations      Neatly & Clearly show <u>ALL</u> Calculations:<br><table><tr><th>d<sub>o</sub></th><th>d<sub>i</sub></th><th>h<sub>o</sub></th><th>h<sub>i</sub></th></tr><tr><td></td><td></td><td></td><td></td></tr></table></td></tr>
</table>

Figure 6.6. Student procedures for light bench station in "bell ringer" exam

Although there is nothing obviously problematic with this activity, the prioritisation of performing calculations and mathematical representations pertaining to light, privileged by its inclusion on this summative examination, may contain companion meanings (Roberts, 1995; 1998) that these mathematical formulations are the most valuable thing there is to know about light. Light, learned in school science then, potentially, becomes a set of equations and mathematical relationships to students, rather than a complex natural phenomenon that is, and can be, valued in other ways.

Practices that prioritise quantitative representations of nature suggest modelling nature mathematically and abstractly is valued in school science in Ontario. Subsequent use of these abstractions allows an individual to describe and predict nature without actual physical contact with or direct observation of the natural phenomenon of interest. Quantification of the natural world is another way to constitute nature as understandable, and that it has repeatable and consistent properties and principles that can be discovered through processes and methods of science. Knowledge of quantifiable principles and process of nature is the commodity of exchange between school science and the student (Apple, 2004). This knowledge is pre-existing, and teacher practices draw students toward the acquisition of this knowledge, so that quantification of learning itself can occur (Dorey, 2013).

## Nature is a puzzle

Reductionist perspectives in science often result in seeing disconnected pieces, which then must be re-/assembled as a sort of ‘puzzle’, the exact structure and function of which is unknown, but can be known by assembling the individual pieces of the puzzle (Nicholson, 2013). Joanne uses a puzzle analogy to help students understand chemical reactions when teaching chemistry, stating:

> And the other thing is, they can see these (atoms, elements) as puzzle pieces that need to be put together and can they make compounds from this stuff. I use puzzle pieces that they put together. (Interview 2)

The discourse in this statement conveys value in viewing nature (atoms/elements) as pieces of an unknown, but solvable, puzzle (how compounds are made). The term “need” conveys an imperative that the unknown about these puzzle pieces (nature) must be eradicated, a solution must be found. Thus, seeing nature as a puzzle that can be solved by putting together in a certain way the smaller, better understood pieces, represents a way of 'knowing' nature.

Constituting nature as a puzzle was a common theme, particularly in activities related to chemistry. Zoltan's *Bell Ringer*, Frances's *Periodic Table activity*, and Joanne's *Testing Aspirin Lab* all engaged students in solving puzzles in which the shapes of atoms or its components were meant to fit together to solve a puzzle, typically a compound or type of reaction. As an example, the procedure for a station in Zoltan's *Bell Ringer* is provided below.

Station 4E - **Chemistry - Making Compounds**

1. Arrange the puzzle pieces [each puzzle piece is an ion] to make a chemical compound.
2. Record the chemical formula of this compound on your answer sheet.
3. **YOU SHOULD BE ABLE TO FORM AT LEAST 7 DIFFERENT IONIC COMPOUNDS**
4. Record the chemical **name** of **TWO** of the ionic compounds formed on your answer sheet
5. Close the folder when you are finished.

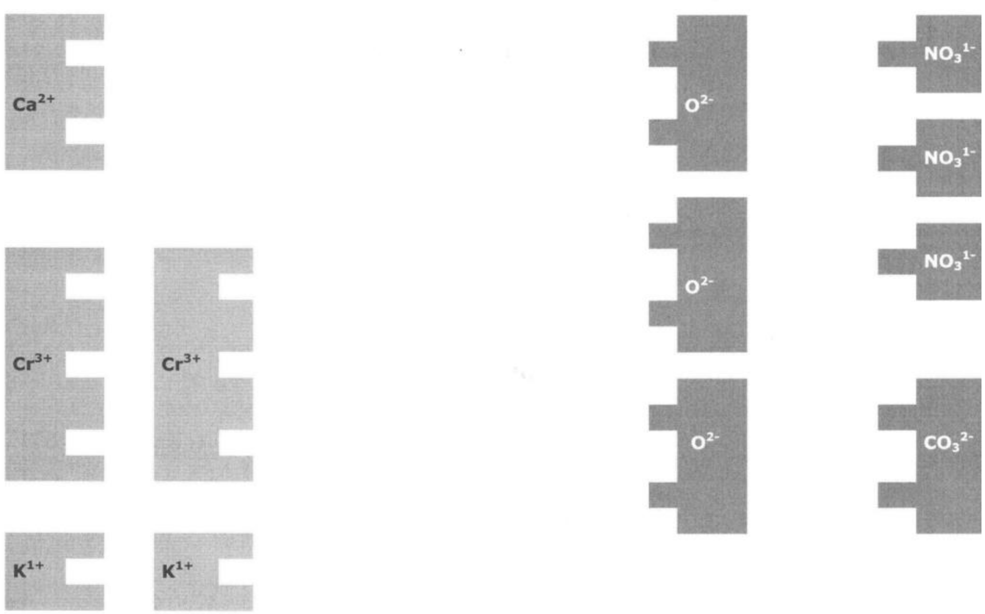



Figure 6.7. Student procedures for making compounds in "Bell Ringer" exam

The discourse in the procedure, and the shapes of the elements, depict elements as pieces of a puzzle that fit together in specific ways to make a compound. For example, the procedure identifies the elements as "puzzle pieces", and suggests there are 7 arrangements of the pieces that will solve a puzzle (making 7 different ionic compounds). As with the other types of modelling, conceptualising elements as puzzle pieces may be an effective way to engage students in learning about nature, because complex nature, in this case the material organisation of an compound, is simplified into something more understandable to students (Nicholson, 2013). However, this discursive constitution marginalises other ways of understanding elements, potentially causing students to conceptualise then primarily as simplified materials whose shapes allow them to fit together (Mitchell, 2003). Such conceptualisation, as in other types of models, is a punctualisation (Latour, 1987) that prioritises certain knowledge, while eradicating complexity, and other 'intelligible essences', that also could be associated with the entity. Thus, what is punctualized are only certain features and characteristics of nature, knowledge of which students need to know in school science.

## Nature as a machine

Knowledge about nature is often comprised by generalised descriptions about its parts, that fit together in certain ways and have a particular function, with a discernible design, similar to a machine or other human-made structure (i.e., a building, or a city is used as a metaphor for a plant or animal cell) (Aikenhead & Ogawa, 2007). An implication of this metaphor is that there is 'intent' in nature, and often this intent is embedded in the designs through which we conceive it. The intent, and designs that represent it, are often those that have utility for advancing scientific understanding and/or utilisation of nature (Bowers, 1997; Dryzek, 1997). The Frog Dissection chosen by Heather as the best lesson she does all year, it is an example of a lesson which implies nature has a particular design. For example, Heather said

> To actually go through the procedure and opening up the frog, for example, and finding the eggs, and finding these different pieces, especially they start seeing how some of these different structures have a different design, so, why is that? (Interview 2)

Heather describes the internal parts of the frog as pieces, and structures, and that they have a design. The question at the end of this comment suggests that Heather expects students to understand that there is an intention in the design, that the structures are designed that way for particular reasons, related to particular functions. This same discourse is found in Grade 9 and 10 science textbooks (Hoeg, 2013) and in the Ontario curriculum, in which one of the *fundamental concepts* is *structure and function*. This fundamental concept "focuses on the interrelationship between the function or use of a natural or human-made object and the form that the object takes" (Ontario Ministry of Education, 2008, p. 5). It is important to point out however that structure and function are already reductionist conceptualisations of complex systems, the intention of which is constituted through human-centered perspectives. Thus, the way design is constituted here is a human centered reduction of a living system that makes invisible those inter-relationships and intrinsic values that are unrelated to human intention or purpose (Sharma & Buxton, 2015). Conceptualising a design in nature focuses attention on the parts and operation of that singular piece of nature that is of interest, but such singular focus limits viewing nature in the context of larger and interdependent systems (Gilbert & Sakar, 2000; Nicholson, 2013).

One of the most common conceptualisations of design is that of a machine. A machine is used because it's an analogy humans are familiar with, and simplifies design into inputs and outputs, related to its structure (Gilbert & Sakar, 2000; Nicholson, 2013). A machine analogy is useful when looking at discrete living systems, such as the intake of food, processes of digestion, and the excreted output, in animals. The description of a frog's internal system as a simplified system, like a machine, is demonstrated in the worksheet Heather gives to students, a section of which is seen in Figure 6.8, below.

In the pharynx, there are several openings: one into the **esophagus**, the tube into which food is swallowed; one into the **glottis**, through which air enters the **larynx**, or voice box; and two into the **Eustachian tubes**, which connect the pharynx to the ear. The digestive system consists of the organs of the **digestive tract, or food tube, and the digestive glands**. From the esophagus, swallowed food moves into the **stomach** and then into the **small intestine**. **Bile** is a digestive juice made by the **liver** and stored in the **gallbladder**. Bile flows into a tube called the common bile duct, into which **pancreatic juice**, a digestive juice from the pancreas, also flows. The contents of the common bile duct flow into the small intestine, where most of the digestion and absorption of food into the bloodstream takes place.

Indigestible materials pass through the large intestine and then into the **cloaca**, the common exit chamber of the digestive, excretory, and reproductive systems. The **respiratory system** consists of the **nostrils and the larynx**, which opens into two **lungs**, hollow sacs with thin walls. The walls of the lungs are filled with **capillaries**, which are microscopic blood vessels through which materials pass into and out of the blood. The **circulatory system** consists of the **heart, blood vessels, and blood**. The heart has two receiving chambers, or **atria**, and one sending chamber, or **ventricle**. Blood is carried to the heart in vessels called **veins**. Veins from different parts of the body enter the right and left atria. Blood from both atria goes into the ventricle and then is pumped into the arteries, which are blood vessels that carry blood away from the heart.

Figure 6.8. Student procedures for dissecting a frog

This text demonstrates 'classical nature language', in which the root metaphor is a machine (Östman, 1994; 1996; 1998). The language used in the introductory paragraphs suggests the frog is composed of 'parts' with openings for 'inputs', such as the esophagus, which is described as the "tube into which food is swallowed". Other machine analogies include the comparison of the digestion system to a "food tube", and the heart as being composed of "receiving chambers" and "sending chambers". These terms convey mechanistic function to the organs and systems they are used to describe. Each organ is described as having one function, which is, generally, the collection and passing on of material, to the next organ, in a linear sequence of events, like the processing of material in an assembly line or manufacturing plant. Additionally, certain key terms are highlighted, suggesting their importance. These terms represent the important parts of the system students must remember, or, the most important knowledge they must acquire. The 'intention' of each of these systems is the singular processing of food, air, or waste. When asked about her intentions for learning in the frog dissection, Heather said:

The main things I am expecting is that they can see the location of where the heart is, are

> there vessels leading from the heart to the lungs, so they can see the path the blood takes, and so they start looking at that connection, they might be able to look at a few of the different types of blood vessels and where they are going to, so that relationship between the lungs and the heart, and the blood vessels, is something I really want them to be able to explore, and see firsthand. (Interview 2)

Heather describes the physical relationship between components in the system, and the pathways in which material (blood) flows between them, and is processed (oxygenated). Again, the discourse here assumes singular functions of organs that process material in a linear progression, suggesting the workings of a machine. Like the other ways of conceptualising nature discussed in this chapter, seeing nature as a machine simplifies the complexity of nature, and perhaps conveys misconceptions about the living systems, their functions, and value. Indeed, it appears as if the frog and its systems are simply material, an object with certain features and characteristics that are of utility to the students in their understanding of organ systems that are similar to those of humans.

**Biocentric conceptualisations of nature**

Biocentric conceptualisations of nature were observed during interviews, although infrequently. Biocentric conceptualisations of nature can be described as those in which nature is more than an abstract 'other', such as an object, model, quantity or machine. Although it is impossible to determine precisely how nature is conceptualised by students, potential biocentric conceptualisations were identified through participants' claims of affective student responses, and language characteristic of what Kilbourn (1998) terms "organicist". Organicist language constitutes nature relationally (i.e., parts understood in relation to the whole), phenomena is understood in relation to other phenomena, and phenomena are explained in relation to other phenomena. Such language can be seen in certain participant statements about nature. For example, Heather said about the Mud Lake field trip:

> I want them (the students) to see that the trees are not just a tree, that's its part of nature, it's connected to birds that live in it, insects that live in it, and that these animals are connected to it. And they are all a part of a larger ecosystem, a lake ecosystem, and that

> this ecosystem is right in their back yard, or not far from it, so it's also connected to them. (Interview 2)

In the first sentence, Heather indicates she wants students to see the tree is more than a tree, suggesting an awareness that the tree may be punctualized (Latour, 1987) - other meanings that the tree could have may not be part of students' conceptualisation of it. The language used by Heather contains frequent use of the word "connect", and the phrase "part of", terms that are typical of organicist language, and its root metaphor, which is integration/whole (Chambers, 2008). Although Heather's intention may have been for students to see the trees as more than a tree, the primary activity students do with the trees in the Mud Lake field trip is to classify them, which potential produces a more scientific, objective conceptualisations of the tree.

Conceptualisations that are oriented toward biocentrism are also present in participants' descriptions of students' responses to some activities. For example, Ellen said about the Daphnia experiment:

> When the students start experimenting with the Daphnia, they say "Wow, living organism, it's so cool, and it's so cute", not in the conventional fuzzy puppy kind of cute, but it's worth something, it's neat, and they do get upset when they kill them. (Interview 2)

The emotional response students have to the Daphnia is a way to bridge epistemological and ontological separations with that entity (Alsop, 2005; Orr, 2004). Ellen indicates students value the Daphnia (it's worth something), students find it interesting ("neat"), and "cute", words that would not be used in science due to their lack of objective description, and suggestion of subjective, emotional observation.

The plant growth activity Heather chose also potentially allows students to conceptualise nature in ways that are less objective than those described in previous sections. In this activity, students plant quick growing bean seeds, and test their growth under various conditions, such as with or without sunlight, varying amounts of water, fertiliser, and soil. This provides them with some understanding of the conditions plants need to grow. In the process of investigating plant growth, students see the plant go through many changes; Heather describes this experience in the next statement:

> I think they find it really cool when it actually gets flowers and gets beans, the fact that it changes. I think they think that's really cool and then when they get the bean, and then they get the seed, and they think, OK, I have the seed so I can grow another one. So they see that cycle there, that is something that is self-reproducing, then, that represents a living thing. (Interview 2)

Heather indicates an affective student response (they find it cool) to the changes students see as the plant grows. These changes possibly disrupt a conception of nature as a static thing, or object, while at the same time, affecting an understanding of the plant as a living thing. The student response in both of these examples can be interpreted as a response to nature that is like themselves; this indicates perhaps nature that is closer to humans is seen as more valuable, a reification of a hierarchy of nature (Horkheimer & Adorno, 1976). Indeed, Heather indicates this, stating: "I really believe that they respond to animals, living things, things that are more like them, much more than nonliving things, or inanimate life" (Interview 2). This orientation is anthropocentric, however, and evokes questions about the ultimate value of these affective responses if they are involved in reproducing systems of thought that devalues much of nature (Bowers, 1997).

Text containing organicist nature language was observed infrequently in the documents participants selected for the second interview. One document that does contain some of this language is the *Investigating Water* worksheet, which was part of the activity by the same name, chosen by Joanne as a lesson about nature. To obtain answers for the worksheet, students must watch a YouTube video on water, which draws students' attention to ethical and moral considerations pertaining to human consumption of water, potentially broadening and deepening students' conceptualisation of it. A sample from this worksheet is provided below:

## BLM 5.6-3a Investigating Water: Part One: Answer Key

### Worksheet 1: Water for All, Let Justice Flow

View the following video from the Canadian Catholic Organization for Development and Peace. Fill in the following blanks while viewing.

http://www.youtube.com/watch?v=dozeuixiC90&feature=related

1. The quality of **life** is directly dependent on the **quality** of water. Having **daily** access to clean water should be a **guaranteed** right for all. Approximately **1.1 billion** people do not have access to drinking water.

2. **2.5 billion** people live without adequate ways to purify their water. **1.5 million** children are killed by water-borne diseases each year.

3. Human **activity** can be a serious source of water **contamination**. Open pit **mining** and **industrial** agriculture can both cause damage to water resources.

4. The other threat to water availability in the global south is the **privatization** of water. The sale of bottled water has become a symbol of the **commoditization** of water. This has helped to develop a **culture** of **paying** for water.

5. In the global north the amount of bottled water consumed is **decreasing**. In the global south the amount of bottled water that is being consumed is rapidly **increasing**. Water bottling **companies** are buying up more water **sources** and denying access to local **communities**.

6. The choice faced by many people in the global south is to **drink** impure water or to ***pay*** for bottled water, because sources of water have been **purchased** by bottling companies.

7. In Canada, most people have a choice between drinking **clean** water from the **tap** and **buying** bottled water.

8. **One** in five Canadians drinks only bottled water. During 2003-2006, the federal **government** spent **8.6** million dollars to provide bottled water in **public** buildings even though clean tap water was available.

9. Explain what the Canadian Catholic Organization for Development and Peace is asking Canadians to do. What are the intended effects of this action?

Figure 6.9. Student worksheet in "Water/STSE activity"

Students' attention is drawn to issues such as water quality, access to water, contamination, and privatization of water. These issues potentially become associated with the conception of what water is, altering students existing conception of water as something that "just comes out of the tap" (Joanne, Interview 2). Although the text here possibly broadens students' conception of water, this occurs through the addition of human-centered interests and perspectives. Water is constituted as a human concern and responsibility, and its value is based on how it contributes to human welfare, which can be considered anthropocentric concern for nature (Chambers, 2008). Additionally, the discourse in this worksheet adheres to classical science language in that it constitutes science knowledge about water as fact through the use of objectifying language, such as "is" (Östman, 1998). This language is silent on how this knowledge was obtained, and disallows the readers' involvement in its construction. The potential effect this has is to create distance between the reader and the concept (water or social issue pertaining to water). In other words, the potential effect of this text to cause students to conceptualise water as having social implications, is moderated and resisted the language used in this text, which distances these issues from students' immediate, local lives.

Description of practices that contain the most biocentric-ally oriented discourse, are found in the Mud Lake activity documents provided by Heather. In the activity sheet below, students are asked to visit various locations long the Mud Lake trail, and to simply make observations using their senses:

**Stop 3 – First Fork in Trail**
*Focus Looking for Birds*
● Blackcapped
chickadees will likely greet you as you enter the trail
● Other birds that you are likely to encounter year round
in this area include: nuthatches
(watch them walk down tree trunks), woodpeckers (downy small,
hairy medium, pileated large)
● You'll frequently see crows, ravens, red tailed
hawks, blue jays, and cardinals and
hear a variety of sparrows and warblers, catbirds, fly catchers, and red eyed
vireos
● Since 248 species of birds have been seen in or from Mud Lake and 52 species have been known to nest there, this area is one of the best birding sites in Ontario
**Stop 4 – Bridge**
● Take care, no leaning over water
● Try another 2 minute sit spot like you practiced earlier (discuss similarities and differences between the two locations) you
should be able to hear the rapids in the
nearby Ottawa River
● On a sunny day from April to early October you'll likely see turtles basking on logs (painted, snapping, and if you're very lucky the endangered Blandings turtle)

● Check out the water for a variety of tadpoles and frogs, and the shoreline for snakes (garter and northern water)
● There are also likely to be water birds including Canada geese (please don't feed them, as they get quite aggressive

Figure 6.10. Student procedures for "Mud Lake Fieldtrip" activity

The language in this text is non-objective, non-authoritative, and welcoming; the reader is asked to partake in activities. Instructions are general, and relatively open-ended, allowing students some freedom of exploration. Instead of providing students with facts about what they will find, they are guided to use their senses, and through this practice, what they might observe. Although there is some descriptive, scientific language present, this is mixed with language that draws attention to 'other' qualities of the nature present, such as "basking" turtles, and chickadees that will "greet you as you enter the trail". The activities instructions ask students to spend time just sitting for 2 minutes, listening, looking, and 'feeling' the nature around them. During this time, they are asked to make comparisons between their new spot and previous ones, which possibly provide enough structure to ensure they are engaged with nature around them. This activity represents an attempt to develop an appreciation of nature (Dryzek, 1997), in which students might see intrinsic value in nature they experience, and recognize (or develop) interconnected relationships with nature around them.

Biocentric practices are instructive, because, although infrequent, they draw attention to components in school science that allows their existence. Heather, more than the other participants, described engaging students in activities with biocentric considerations. Her ability to do this appears to stem, in part, from her isolation as a teacher. Heather did not have to coordinate her practice with a team of other science teachers, which moderates individual tendencies and agency through shared community values and resources. Additionally, the prioritisation of Science, Technology, Society and Environments (STSE), and environmental education, in the science curriculum validates practices and activities that can foster biocentric conceptions of nature (Steele, 2011). Unfortunately, this flexibility is moderated by other institutional components; these will be discussed further in Chapter 7.

**Chapter Results and Analysis Summary**

In our increasingly socially-oriented environments, where encounters with nature may occur most frequently in school science (Steele, 2011), this may be the dominant, and often only way, students are exposed to, and come to understand nature (Hart, 2003; Rickinson, 2005). School science practices identified by participants engage students with objective descriptions of nature, analogies to designs and machines, and quantifications of nature. These representations depersonalise nature, inserting distance between the student and nature, and cause students to see nature as a relatively simple entity that they can know. These science practices contribute to developing or sustaining relationships with nature based on disconnection, distance, and 'other-ing' (Cobern, 1991). The types of constitutions of nature observed in each activity selected by participants are summarized in Table 6.1.

Table 6.1. Ontological representations of nature in participant practices

| *Activity* | *Description* | *Discursive themes observed* |
|---|---|---|
| Aspirin lab | Students perform chemical tests on various brands and strengths of aspirin to determine differences in the mount of active ingredient (acetylsalicylic acid) in each sample. Students must collect and analyze quantitative data to draw conclusions. | Conceptual separation from nature<br>Nature is an object<br>Nature is a mathematical algorithm |
| Plant Growth Lab | Students germinate beans to test the effects various environmental conditions, such as light and humidity, on plant growth. | Conceptual separation from nature<br>Nature is an object<br>Nature is a machine |
| Bell Ringer/Exam | Students engage in various timed activities, at individual stations, that | Conceptual separation from nature |

| | | |
|---|---|---|
| | represent the topics they covered during the school year. Activities include: experiment with light rays; testing for reflection, and refraction; investigating animal systems, and; performing chemical reactions. | Nature is an object<br><br>Nature is a mathematical algorithm<br><br>Nature is a puzzle<br><br>Nature is a machine |
| Cel. Phone/STSE project | Students measure how reaction time is effected while texting on a cellular phone, and develop public awareness campaign based on their findings. Students must identify and control variables, and use quantitative data to support their findings | Conceptual separation from nature<br><br>Nature is an object<br><br>Nature is a machine |
| Rocket Lab | Students investigate properties of flight using a rocket they make out of straws, elastic bands, and cardboard. Students ask and answer their own question about what effects the flight of the rocket, using practices of science investigation, such as identifying and controlling variables, and collect and analyze quantitative data. | Conceptual separation from nature<br><br>Nature is an object<br><br>Nature is a mathematical algorithm<br><br>Nature is a machine |
| Daphnia Project | Students investigate the effects of adding or removing various environmental factors on the growth of the small invertebrate, Daphnia. Students must identify and control | Conceptual separation from nature<br><br>Nature is an object<br><br>Nature is a mathematical |

| | | |
|---|---|---|
| | variables, and use quantitative data to demonstrate scientific principles involved in sustainability. | algorithm<br><br>Nature is a machine |
| Ecology report | Students investigate, using the internet, an ecological issue of their choice, and write a news report on it. | Conceptual separation from nature<br><br>Nature is an object<br><br>Nature is an interrelated whole |
| Ecosystem-in-a-Jar | Various plants and other living things are contained in one jar, which is sealed but connected to another jar with fish. Students control the environmental conditions to determine the effects on the health of the ecosystem by evaluating the health of the plants and fish. | Conceptual separation from nature<br><br>Nature is an object<br><br>Nature is a machine |
| Frog Dissection | Pairs of students perform a dissection of a frog. Students identify internal organs of the frog, and make comparisons between the frog's internal organ systems and those of mammals. | Conceptual separation from nature<br><br>Nature is an object<br><br>Nature is a machine |
| Germ Ecology project | Students investigate various ecological factors in their schools related to germs that can cause cold and flu, do various science investigations, and use their findings in community directed activism to address the issue | Conceptual separation from nature<br><br>Nature is an object |

| | | |
|---|---|---|
| Helicopter (Whirlybird) Lab | Students investigate properties of flight using a paper helicopter they cut out. Students to ask and answer their own question about what effects the flight of the helicopter, using practices of science investigation, such as identifying and controlling variables, and analyze quantitative data | Conceptual separation from nature<br><br>Nature is an object<br><br>Nature is a mathematical algorithm |
| Mud Lake field trip | Students go to Mud lake, a local ecosystem, to partake in various nature observation activities, and identification of tree species in the area. | Conceptual separation from nature<br><br>Nature is an object<br><br>Nature is an interrelated whole |
| Orange Juice Clock | Students inquire about what makes the most efficient dry cell to power a clock by controlling and manipulating variables (such as using orange juice as the electrolyte) involved in making a dry cell. | Conceptual separation from nature<br><br>Nature is an object<br><br>Nature is a machine |
| Penny Lab | Students investigate how many drops of water can be placed on the surface of a penny before it over-flows. Students must identify, and control variables, and analyze quantitative data to determine this. | Conceptual separation from nature<br><br>Nature is an object<br><br>Nature is a mathematical algorithm |
| Periodic Table Activity | Students learn about elements by completing a worksheet in which | Conceptual separation from nature |

| | | |
|---|---|---|
| | they must identify characteristics of certain elements, such as number of electrons, protons, and model its atomic structure, using the periodic table for data. | Nature is an object<br><br>Nature is a mathematical algorithm<br><br>Nature is a puzzle |
| STSE/inquiry on personal technology devices | Students investigate where our technology comes from (manufacturing) and the adverse effects to primarily society and humans of the technology they use. | Conceptual separation from nature<br><br>Nature is an object |
| Pop-bottle terrarium | Various plants and other living things are contained in plastic pop-bottles, and students control the environmental conditions to determine the effects on the health of the ecosystem inside. | Conceptual separation from nature<br><br>Nature is an object<br><br>Nature is a machine |
| River Study | Students take insect and water samples from a local river system to determine the health of the ecosystem. Students must identify species and perform chemical tests on the water. | Conceptual separation from nature<br><br>Nature is an object<br><br>Nature is an interrelated whole |
| Film Canister Rockets | Students investigate properties of flight using a rocket they make out of film canisters, water, and Alka-Seltzer tablets. Students ask and answer their own questions about what effects the flight of the rocket, | Conceptual separation from nature<br><br>Nature is an object<br><br>Nature is a mathematical algorithm |

| | | |
|---|---|---|
| | using practices of science investigation, such as identifying and controlling variables, and collect and analyze quantitative data. | |
| Water (STSE) activity | Students inquire into the way water is used around the world, and examine their own practices related to water use to emphasis the importance of water conservation | Conceptual separation from nature<br><br>Nature is an object |
| Maple Syrup SOS | Students go on a hike, and learn about maple syrup production, and how climate change is having an effect on this. Students conduct a maple tree population survey of a particular area, and use this data to draw conclusions about the health of the ecosystem | Conceptual separation from nature<br><br>Nature is an object<br><br>Nature is an interrelated whole |

The purpose of evaluating activities and practices designed to provide students with understanding of nature is not to say these practices are inherently wrong. Indeed, assumptions of science that nature is knowable have led to an understanding of features and characteristics of nature that have been of enormous utility to human progress (Latour, 2004). It may be that human limitations require us to conceptualise nature in more simplistic ways. This simplification allows humans to focus on aspects of nature that are important to particular goals of science and society. An example is; understanding how a particular drug effects the human body. Medical science has been able to develop drugs to treat various ailments, based on models of human physiology. While these have lead to increased longevity, and improved disease treatments, knowledge of disease itself has revealed the limitations of generalised treatment models, ushering in a new era of personalised protocols customised to individual physiologies

(University Wire, 2016). There are social justice issues, however, connected to who is able to receive such personalised care, and ecological justice issues connected to whether similar scientific consideration is applied to non-human nature (Bowers, 1997; Hart, 2003).

The constitution of nature in school science using scientific constructions could be problematic because these constructions represent one view on nature, which has utility to human social systems (Östman, 1998). These artificial representations do not provide everything there is to know about nature, but instead, provide knowledge that is seen as important to science (Hodson, 2009). In other words, certain, specific features of nature have been selected to be included in these representations, while others are omitted, ignored, or unseen (Mitchel, 2003). Representations such as models, and analogies such as machines, are efficient constructs because they convey the knowledge students must know in discrete parts (Apple, 2004), typically, the parts of the machine, or model (Mitchel, 2003). For example, the procedure in the frog dissection highlighted words such as 'heart' 'atria' 'blood vessel' and 'lung' because these are the knowledge products that are most important for students to learn. This knowledge has utility, because understanding these parts aids in understanding these systems. The frog organs systems are a model for human systems, which can provide understanding of human health and related issues. Students who are expected to study and learn these models, therefore, are receiving knowledge about nature that has been deemed important by others, for reasons not necessarily related to sustaining nature itself, but for human progress and improvement (Bowers, 1997). Indeed, such models are cultural products embedded with the worldviews and socio-cultural beliefs of those who created them (Tobin & Roth, 2007), including particular orientations toward nature. This is clear when examining language of, for example, First Nations people of Canada, and many Asian ethnic groups, in which nature is represented much more inclusively than in the object-based language of Euro-centric sciences (Aikenhead & Ogawa, 2007). Although there are many reasons students should learn the way Euro-centric science represents nature discussed previously, there are compelling reasons to engage students in criticism of these constructions as well. Criticism of reductive science representations is common in science (Nicholson, 2013), and nature of science (Lederman et al., 2002). These criticisms, however, typically centre on the limitations of these perspectives to understand complex systems and predict phenomenon (Gilbert & Sakar, 2000). Seldom do these criticisms extend to how these perspectives constitute nature, how this constitution works toward setting up certain relationships with nature, and how these relationships lead to moral and ethical stances toward nature. Other ontological constitutions of nature were infrequently described by participants and, learning about limitations of representations of nature is unlikely to occur in school science (Hodson, 2009; Mitchel, 2003).

The ontological constitution of nature described in this chapter works to oppress consideration of how this knowledge was constructed, and its purposes, silencing ethical and moral consideration of nature (Östman, 1998). In other words, ontological knowledge is constituted as fact, rather than a product of science that was constructed though certain interactions with nature, and for various purposes. The way these interactions and purposes are communicated through discourse makes ethical engagement with the practices and products of science difficult. This traditional science language conveys a meaning that practices of science are ‘culture and value free’ (Hodson, 2009), which has traditionally been an important claim for validity in science. As analysis in the chapter demonstrates, nature is ontologically constituted pragmatically, in ways that are useful for human purposes and intentions. Allowing more personal ontological constitutions of nature, as advocated for in nature-centric perspectives, may be critical for the development of more sustainable environmental ethics. Discussion between teachers and students about other values inherent in nature, and how value is constituted in the language of science, could be an important entry point for insertion of environmental ethics in school science.

Ontological constitutions of nature contain knowledge of nature; they are semiotic objects constructed by selected knowledge of nature (Mitchel, 2003). Representations of nature are prioritised in school science, suggesting the knowledge they contain is valued by teachers. The use of dominant representations of nature in school science engages students with the knowledge about nature that has been deemed important by the institution of school. As several teachers suggested, school science values objective descriptions of nature, because these are seen as knowledge products that can be attained and accounted for, providing evidence of student learning (Apple, 2004; Woods, 1998). Participants held little value for activities in which there was uncertainty about how students might construct nature, because, as Heather suggested, they “aren’t sure they (students) are really learning science” (Interview 2). Specific, prescribed, objective knowledge about what nature is, is the commodity that the teacher attempts to manage and control. Requirements for the acquisition of specific ontological knowledge of nature, then, appear to be a ‘hook’ (Smith, 2005) that coordinates teacher practice with institutional learning expectations.

# Chapter 7: Ruling Relations of Nature in Ontario Grade 9 and 10 Academic science

> *It's the funniest thing to hear, "I use that too". And when we are looking at our resources and they come in, and they have been teaching for years someplace else, and they come in and they say "oh, you have the same stuff", so, because it works, and for most of us, you will never ever waste time with something that doesn't work.* (Zoltan, Interview 1)

The aim of this chapter is to understand how the institution of school and/or school science might be involved in producing patterns of how nature is constituted by science teacher practice. Data presented comes from institutional texts or practices to which participants aligned their activity. In this chapter I seek to answer the following research question: *What is the social organisation of Grade 9 and 10 Ontario school science, and how does this organisation influence teachers' practice related to how nature is constituted?*

The institutional social relations involved in the organisation of school science were the first phenomenon (i.e. the curriculum) discussed by participants during interviews. Participants stated in great detail the institutional setting within which they work, providing the institutional context that demonstrates relationships between institutional texts and participants' practice. These social relations represent outer layers of institutional discourse which had to be penetrated to get at the teaching practices that constitute nature. Policy texts and institutional practices were frequently identified by participants as coordinating their activity, suggesting teacher discourse and practice is directed at being accountable to these systems of organisation.

### What 'works' in Ontario Grade 9 and 10 Academic Science

The practices and artefacts that are reproduced in institutions are the result of the productive outcome of people shaped by dominant social values and social structures of local environments (Shimara, 1988; Wax, 1993). In other words, practices and artefacts that attain a position of reproduction in are those that have social utility, or, said more simply, are those that ‘work’. When speaking of science at schools, there was significant homogeneity in participants’ espoused educational values and the activities they use to instill those values in students. For example, Teresa said:

> It’s interesting because you talk about these activities that all the teachers use, like this Whirlybird (paper helicopter) one, when all of us came together at this new school, we all brought this Whirlybird activity, even though we were all at different schools. (Interview 1)

The Whirlybird activity mentioned by Teresa is a popular activity in school science, and was mentioned by every participant as an activity they either do, or have done. The investigation is used by many science teachers because it apparently is seen as effective in teaching about science principles and practices that are valued by teachers, and therefore are likely present in science teacher cultures. For example, the Whirlybird activity can be done indoors, in the amount of time designated for a class, covers several curricular expectations, and is assessable by required achievement categories. While many science lessons also do these things, what the Whirlybird activity is particularly effective at is demonstrating the concept of variables, and enabling students to control variables to test a single particular effect (Pedretti & Bellomo, 2015). Several other activities were consistently mentioned by participants due to their perceived unique effectiveness in conveying principles and practices valued by science teacher culture, such as: the Penny Lab; Mystery Boxes activity; Daphnia Lab; Orange Juice Clock; and Pop Bottle Terrarium activity. These activities have existed in various forms in science teaching cultures for decades (Pedretti & Bellomo, 2015). As Joanne said, “there is a culture to share, and it’s a good repository of information, teachers will tell you it works really really well, the stuff that’s in there works really well” (Interview 1). When prompted to explain why these activities are used so frequently, the phrase “they work” was often used, or that these activities are ‘what works’ in school science. Zoltan was the first participant to discuss the idea of what works, stating:

> It’s the funniest thing to see; a new teacher comes in and says "I use that too". And when we are looking at our resources and they come in, and they have been teaching for years someplace else, and they come in and they say "oh, you have the same stuff", so, because

> it works, and for most of us, you will never ever waste time with something that doesn't work. (Interview 1)

Zoltan connects the local with the trans-local in his comment, recognising the sameness in what science teachers teaching elsewhere have developed, which becomes apparent when a new teacher joins the team. He also identifies time as one of the criteria in an activity that works, suggesting that what works is an activity in which the valued learning can be achieved in the limited time allotted to school science. Other criterion that was frequently described was student engagement and relevance to students. However, when prompted, it became clear that what works are those lessons that convey the required learning, the knowledge and skills that are institutionally valued. For example, Alice said, "when it comes right down to it, what works are the lessons and activities that deliver the curriculum" (Interview, 1). Many comments similar to this were made by each participant. Zoltan, for example, said, "we just don't have time to waste on activities that do not teach the curriculum. So, what I choose, what we choose as a department, to teach as a team, are those activities that most efficiently convey the required learning in the curriculum" (Interview 2). The many other characteristics of lessons that 'work' described by participants, such as engaging, active, and relevant, can be seen simply to make the learning experience for students more effective; if learning is relevant, students are likely to be more engaged, and learn better (Hodson, 2009). If students are active, and doing experiments and inquiries, these activities may be engaging because they activate different learning styles than those required for lecture and class discussion; however, experimental activities that 'work' also engage students in science methods that are valued in school science and outlined in the curriculum.

What works is an apt description of the science activities that "make it" into the classroom, where students learn about and practice science, and constitute nature. These 'artefacts' (Hodder, 2003), several of which were analyzed in previous chapters, therefore can be considered the most direct texts related to the constitution of nature in school science.

Resource and Artefact Collection

Participants frequently discussed a collection of resources in their department at school from which they and other teachers drew from to teach science. This was often contained physically in binders, but frequently also held in online repositories. These resources are the science lessons and activities that have been refined and distilled to be the best examples of what the teachers using these resources decide “works”. Speaking about selection of what goes into the shared resource collection was Joanne, who said:

> It’s almost like an edited guide to teaching science, what’s in that binder. Teachers will do things and the result is, they say, oh yeah, don’t try that lab in the book, or don’t try this lab because it doesn’t work very well, this one works, you know, and so that one goes into the binder and the others don’t. (Interview 1)

Joanne indicates a relatively rigorous procedure of selection for what goes into the shared resource collection, in which activities are tried by teachers, and evaluated for suitability as an artefact to be shared and reproduced by other science teachers. Zoltan identified some of the resources shared in his department, stating:

> I am just writing a Grade 9 summative piece for the unit on electricity, so we will all be on the same page so this is what we will all be doing for the unit test. Chapter tests are pretty much the same, and there is a bank of power points, work sheets, chapter quizzes, mini chapter quizzes, and all kinds of stuff, so we share those resources. The bank is on our virtual drives. (Interview 1)

As Zoltan and Joanne suggest, the resource collection in the school science department may include virtually everything a science teacher needs to teach, distilled and refined in a process to optimise the resources so that they work efficiently and effectively to inscribe in students the valued learning. Only Heather worked at a school without the team work and resource sharing described by the other nine participants. The reasons for Heather’s relative isolation were described in Chapter 6, yet her process for developing her own resources was similar to the other participants. For example, Heather said:

> I've created lessons, so of course I have a binder for every single unit for every single course; I have a lot of binders. I tweak them all the time, you know I think that's a really important part of a teacher that if a particular worksheet that you have created or pulled from somewhere isn't working well for you, that you edit or revise it to better match what your priorities are, to make it work better (Interview 1)

Heather's unique situation working without the structure and support of co-teachers allowed her greater flexibility in the choices she makes as a teacher; this agency is evident in her frequent enactment of outdoor education. However, as she indicated in this comment, there is still a selection and revision process of science activities that correspond to certain existing criteria, which she described as her "priorities". These priorities, she claimed, are to align activities she chooses with "units", which are themselves derived from the Ontario curriculum. For all the participants, the curriculum provides a significant set of priorities and filters that are used to decide what makes it into the resource collection, and how to align/adapt, older resources. Activities that 'work' contain the institutional ruling relations relevant to science teacher practice, and the institutional control of how nature is constituted. These represent the material manifestations of the values and beliefs of these communities, and thus can be seen to be artefacts of science teacher culture.

**Science Teacher Culture**

As interviews progressed, it became increasingly apparent that the teaching practices described by participants and discourse located in relevant texts were representative of, and provide boundaries for, a relatively consistent *culture* of Grade 9 and 10 Ontario Academic Science. A culture of teaching may exist when practices, beliefs, values and materials related to teaching transcend an individual or local occurrence of these (Wax, 1993). Thus, a teaching culture, which includes material artefacts that represent certain sets of values and beliefs, can be thought to represent a trans-local enactment of dominant discourses, structures, or "ruling relations". Although individual meaning may account for differences in practice, patterns within practice and materials teachers develop and use, can be seen to represent a system of values and practices, or what might be called a culture (Shimhara, 1988). Excavating through institutional discourse to get at these deeply occurring relations became the focus of ongoing data collection, particularly during the second interview.

Although the science teaching culture described by participants was shaped by numerous institutional relations, it became apparent that culture was *maintained* locally; in other words, science teaching artefacts that contained the values and beliefs communicated in school policy were physically held, maintained, adapted, and coordinated, by communities of science teachers at individual schools. Coordination of teaching practices with other teachers, so that community values and practices were represented in each science class, often was described as the most influential social relation in the profession of teaching. Teresa, for example, gave this answer when asked what is most influential to how she teaches: “The other people I work with. You can’t deviate a lot from what other teachers are doing; you kind of have to keep up with the order” (Interview 1). Frances described a similar experience, stating: “I'm limited by what other teachers do; we all pretty much have to stay in lock-step” (Interview 1). Teresa and Frances are acknowledging the powerful effect of the expectations of other teachers, teaching the same subject. Both Frances and Teresa describe coordination with other science teachers as restricting what they can do, yet also enabling by providing “order” that guides teaching practice. Such a system conserves valued teaching artefacts and practices, resisting change (Shimhara, 1988; Wax, 1993). Alice speaks of this culture as a resource that is helpful to teachers, stating:

> When I first started teaching, I had my research background, so that was my influence coming in, my background, but still, just given the constraints of working, the time, the energy it took, I would fall back on the curriculum documents, the textbook, and the people I was teaching with. (Interview 1)

Alice suggests coordinating with other teachers aided her in a period of her career when she needed support. Her statement also indicates her own preferences were somewhat subsumed by this existing culture. For example, she asserts factors, such as time, energy, coordinating with other teachers, and the curriculum, acted as “constraints” to practices related to her particular interests and orientations. This opposition between individuality, or agency, and constraints, represents an important phenomenon related to institutions: that is, how individual meaning making is partially shaped by dominant practices and discourse (Smith, 1999; 2005).

Describing a somewhat less deterministic teaching environment was Janet, who discussed a more "team" oriented social relation in the next statement:

> I think the people you're working with have a big impact on how you teach, so the schools I have been in have had a very inquiry focused group of people, always looking at how to get as much inquiry as possible into the curriculum, and when I suggested we focus on NOS activities, the people in the department took that on together, so we all, together, kind of developed resources. (Interview 1)

Janet implies there is a conservative nature to teaching teams, in that teams develop teaching resources that are shared and re-used year to year, but there also exists a mechanism of cultural change. Her focus on NOS activities represented novel science approaches, and these became an addition to the local culture which was developed by team members. The development of a NOS focus was not a complete departure from the teams original commitment to inquiry, however, as inquiry involves particular practices for conducting science investigations that are within the scope of NOS learning (Lederman et al., 2002; Pedretti & Bellomo, 2015). Zoltan described a similar process, commenting:

> In this school we have teachers come and go, teachers go on maternity leave, move to another school, there are always new people coming in, and when they look at resources, there are always one or two, hopefully that are builders, not just users, and it's nice, because they say have you ever thought of doing it this way or that way. Sometimes things are left wholesale because nobody is left to support it which is unfortunate, but nothing is permanent (Interview 1)

Although Zoltan describes a process of cultural change, this comment also suggests change and development of activities is still aligned to and coordinated by something. In Zoltan's phrase "doing it", "it" appears to refer to some sort of teaching or learning requirement that is prescribed from outside the local culture. Indeed, when asked what "it" refers to, he said "doing the job, what we are required by the Ministry to do, to teach" (Interview 1). Other participants made similar comments; for example, Joanne said:

> We have a nice little community of science teachers, and we share a lot, and there are values and stuff that we all share, but a lot of these are imposed on us by the ministry, by the curriculum. Like, I *have* to value and teach inquiry (Interview 1)

Clear in Joanne's statement is that the institution has a significant influence on shaping the local cultures that science teachers find themselves in, and are otherwise shaped by a multitude of other factors, such science teaching traditions, beliefs about science and nature of science, and, individual meaning (Pedretti & Bellomo, 2015). Yet, participants' frequent espousal of institutional coordination indicates it as a subsuming role in organising science teacher culture. The proceeding sections discuss how school science cultures, containing the 'rules' that constitute nature, are institutionally coordinated.

## Institutional organisation of school science in Ontario

Among the diverse phenomenon influencing science teacher culture, including the artefacts selected and described by participants in Chapters 5, and 6, were social relations of the broader institution of school in general. One way to conceptualise these are as structure-like phenomena that enable certain beliefs, values and practices, while constraining or marginalising others (Giddens, 2006: Stephenson, 2007). Social relations inherent in the organisation of school were described by participants as conveying some degree of limitation on or control over what and how science could be taught. These social relations were continuously observed throughout both interviews, suggesting the powerful nature of these social relations.

### Physical structure

The physical structure of school was frequently described as setting limitations on what participants could do in regards to teaching about nature in science. A variety of issues related to the physical structure and organisation of schools placing limits on teacher practice were noted by participants. Ellen spoke about the way school is organised, stating:

> We are warehousing children of the same age and the same cohort, its unnatural, it's really unnatural, and when, ever in your entire life, will you be corralled with that many people of the same age? (Interview 2)

This organisation, as pointed out by Ellen, is a human construction, "unnatural" in that school attempts to align development of children with others of a similar age. The implication of Ellen's comment is that it would be more 'natural' to allow children to develop according to their own differing aptitudes and interests. The organisation of children into cohorts according to age to attempt to control their development may therefore be based on assumptions about human control over nature. The schooling of children according to age has become normalised in social discourse, making invisible human relationships with nature that such organisation may be based on (Bowers, 1997).

Adding to the difficulties discussed in Chapter 5 of providing students with access to the outdoors from an enclosed school structure, are strict policies related to taking students out of the classroom. Every participant commented on the strict policy requirements for taking students to local natural sites or on field trips. For example, Zoltan noted, "even in your class, just put on your coats, let's go outside, you should have a permission form for that" (Interview 1). Issues of liability connected to taking students outside of the classroom were discussed by many participants. For example, Ellen said:

> In certain boards you cannot have a kid walk down the hall to the library without getting a permission form. And taking them to a pond where they could potentially slide in and drown. If you can drown in 2 inches of water you can potentially drown on this field trip, doing the required paperwork for something like that is, to be honest, a limiting factor. (Interview 1)

Speaking of liability in taking students outside was also Teresa, who identified the fact that "you have to justify this to take them out, and if you want to take them out on the water, the board lawyers are not happy with that" (Interview 1). Factors such as these were limitations for participants that kept learning most frequently inside the classroom. The science classroom is the location of the vast majority of the pedagogy and approaches that have become part of school science culture, and therefore the indoor classroom is a structure that influences the enactment of human relationships with nature in school science.

Time

The organisation of the school day into discrete subjects with set units of time limits educational experiences to those that can fit in these narrow disciplinary and temporal confines (Stephenson, 2007). Zoltan summarises time limitations at his school well in this statement:

> There is no way our curriculum and the way we shape schools can accommodate science having more time. Everything is fixed into a certain amount of time, so you're stuck in that fixed amount of time. So, you're stuck trying to transmit as much as you can effectively and efficiently, you're stuck. (Interview 1)

The discourse in this statement connects the curriculum and the shape (organisation) of school to time. The conveyed meaning here is that school is a set (fixed), and relatively inflexible (you're stuck) structure; school science is allotted only a part of the temporal organisation of school, limiting instructional time. The clause "transmit as much as you can" suggests a quick delivery of curriculum to accommodate time limitations. Zoltan's use of "effective" and "efficient" suggest there are particular strategies and practices that are better at transmitting the prescribed (curricular) expectations quickly than others. The implication is that, in order for a teacher to do their job, they need to teach the curriculum as quickly as possible to ensure all of it is taught. Time therefore presents limitations as to what teachers can do. Joanne summarises these limitations well in her next statement:

> I would love to do some lovely touch feely discovery stuff, where the kids discover it, and I did use that, but the truth is it takes a lot of time. Every time I turn around, the time I have to teach curriculum is getting smaller and smaller (due to school events and other priorities, ect.), so that becomes a little tricky to do expansive science lessons, so those constraints also exist. (Interview 1)

As Joanne suggest, time induces a pressure that forces the prioritisation of certain learning experiences over others, and restricts activities that are not explicitly required by the curriculum. Indeed, time exerts such influence on teaching and learning, it's often a determining factor even when teaching practice, such as incorporating living nature into lessons, is supported by other institutional factors (the curriculum), as described by Ellen:

> In the Grade 9 course, one of the things they are supposed to do is propagate plants. Well, this was never done, like it's in the curriculum documents, but its like, it takes too long. So we ended up incorporating that (content) it into (lecture on) seed germination and plant hormones. (Interview 1)

Although Ellen and her colleagues altered how plant propagation was done by students, what was not altered was providing some type of learning experience to learn about plant propagation, because this is a curricular requirement. This distinction is important, and evidence of two separate sets of social relations, one of which influence *what* is learned, the other influencing *how* it is learned. *What* is learned, as the proceeding sections have discussed, is largely determined by the curriculum.

Although espousing time as a limitation might be expected, time may be a more critical factor for teaching about nature in ways that might foster interconnected human relationships with it. It takes a considerable amount of time to take children outdoors, or learn about nature in the classroom using living organisms, making these practice impractical (Martin, Bright, Cafaro, Mittelstaedt & Bruyere, 2008). Time, combined with other factors related to science teaching, create a relatively inflexible space for science instruction, most conducive to those activities that have been designed to accommodate and satisfy institutional social relations.

### Across school relations

Trans-local social relations in the form of provincial educational policies, and more local social relations connected to school boards and communities, were described by participants. These were contained in policy documents that were referred to frequently by participants during interviews. These institutional texts (Smith, 1999) carry discourse that can act to co-ordinate teachers' work, aligning it with other teachers in Ontario, in other places and at other times.

The Curriculum

When asked about the factors that most influence their teaching practice, the curriculum was the first thing identified by each participant. Joanne summarised what appeared to be the consensus of the participants, saying "So, definitely the curriculum document drives what I'm going to teach." (Interview 1). Frances also strongly advocated the influence of the curriculum; for example, she mentioned she felt pressure to get through "stuff" (content). When asked where the pressure to get through stuff comes from, Frances replied:

> I would say from the curriculum, I'd say to make sure we're covering the curriculum. Because as much as I would love to do other things with them, if I do other things, it already takes away from the curriculum time, which is a already constrained
>
> (Interview 1)

When probed further on the role of the curriculum, however, it became clearer that teachers have significant flexibility in what they teach, making the curriculum appear to be not as deterministic to teaching practice as participants often claimed. For example, Zoltan noted:

> We all start with the curriculum document, we look at the curriculum the first go through. And then when you tighten it up and you have things running efficiently, you've got a bit of extra time left over, you start to ask, ok, where do we go deeper, where do we go further, do we go outside, or do we teach something deeper, looking deeper into things.
> (Interview 1)

Zoltan's comment suggests that as teachers gain experience teaching the curriculum, they can cover the expectations more efficiently, making available more time to give attention to certain topics. This provides space for teachers to address areas they feel may be lacking in the curriculum. David suggests NOS is one such area lacking in the Grade 9-10 Ontario curriculum, stating:

> In the previous curriculum, there was a bit of a push to start with the scientific method, independent, dependant variables, so a little bit of the NOS, and then move toward the curriculum things. So, I find now, that's not at all written into the new curriculum, so it's something I do on my own. (Interview 1)

NOS is a content area concerned with how science is practiced, including cultural, sociological, and affective aspects of practices and products of science (Hodson, 2009; Lederman et al., 2002). This important area of science education is among the most fertile to draw attention to practices that constitute nature in science (Hoeg & Barrett, in press).The fact that NOS may not be explicitly written into the curriculum, as David explains, suggests teachers must rely on their existing resources and understandings of how science is done. This means, however nature has been constituted in the past in NOS, likely will be reproduced in contemporary Ontario school science, through the use of existing NOS teaching materials.

The curriculum contains both knowledge and skill/practice expectations, to which teachers are expected to align their practice. In other words, the curriculum outlines science knowledge, and science related skills, students must acquire to meet the program requirements. Required science knowledge is found in "Understanding Science Concepts" expectations, and skills are described in "Developing Skills of Communication and Investigation". An example of some expectations can be found in Figure 7.1.

*Sample questions:* What strategies are included in public health initiatives aimed at reducing the incidence of smoking-related diseases? What impact have these initiatives had on smoking rates and associated medical costs? How have health authorities responded to the threat of West Nile virus? What effect does this response have on people's lifestyles? How did various cultures attempt to prevent disease before vaccines were available? What impact have vaccines had on global health?

### B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

**B2.1** use appropriate terminology related to cells, tissues, organs, and systems of living things, including, but not limited to: *absorption, anaphase, capillaries, concentration, differentiation, diffusion, meristematic, mesophyll, phloem, prophase, red blood cells, regeneration, stomate,* and *xylem* [C]

**B2.2** examine cells under a microscope or similar instrument to identify the various stages of mitosis in plants and animals [PR, AI]

**B2.3** examine different plant and animal cells (e.g., cheek cells, onion cells) under a microscope or similar instrument, and draw labelled biological diagrams to show how the cells' organelles differ [PR, C]

**B2.4** investigate, using a microscope or similar instrument, specialized cells in the human body or in plants, focusing on different types of cells (e.g., bone, muscle, leaf, root cells), and draw labelled biological diagrams to show the cells' structural differences [PR, C]

**B2.5** investigate the rate of cell division in cancerous and non-cancerous cells, using pictures, videos, or images, and predict the impact of this rate of cell division on an organism [PR, AI]

**B2.6** investigate, through a laboratory or computer-simulated dissection of a plant, worm, fish, or frog, the interrelationships between organ systems of a plant or an animal (e.g., between the root system and leaf system in a plant; between the digestive system and circulatory system in an animal) [PR, AI]

**B2.7** use a research process to investigate a disease or abnormality related to tissues, organs, or systems of humans or plants (e.g., heart disease, tobacco mosaic virus, wheat rust) [IP, PR, C]

### B3. Understanding Basic Concepts

By the end of this course, students will:

**B3.1** describe the cell cycle in plants and animals, and explain the importance of mitosis for the growth of cells and repair of tissues

**B3.2** explain the importance of cell division and cell specialization in generating new tissues and organs (e.g., the division of stem cells into specialized cells such as muscle cells or nerve cells in humans; the division of meristematic cells to expand and differentiate plant tissue)

**B3.3** explain the links between specialized cells, tissues, organs, and systems in plants and animals (e.g., muscle cells and nerve cells form the tissue found in the heart, which is a component of the circulatory system; granum and thylakoid structures act as solar collectors in the chloroplast to produce carbohydrates for plant growth)

**B3.4** explain the primary functions of a variety of systems in animals (e.g., the circulatory system transports materials through the organism; the respiratory system supplies oxygen to and removes carbon dioxide from the body)

**B3.5** explain the interaction of different systems within an organism (e.g., the respiratory system brings oxygen into the body, and the circulatory system transports the oxygen to cells) and why such interactions are necessary for the organism's survival

Science

SNC2D

BIOLOGY: TISSUES, ORG

Figure 7.1. Specific Expectations from Grade 9 Academic Science Unit, "Biology: Tissues, Organs and Living Things"

As can be seen in these expectations, the knowledge students must learn is specific, discrete, and established science knowledge (Apple, 2004). Students must be able to reiterate (explain), for example, "the primary functions of a variety of systems in animals" (expectation B3.4) (MoE, 2008, p. 75). Separating skill and knowledge expectations, as opposed to including these in a single expectation, appears to provide some choice to teachers in *how* they will teach specific units, topics and concepts (Hoeg & Bencze, 2015). However, there is considerable correspondence between the knowledge and concepts students must learn, and the skills they must perform. For example, Expectation B2.6 states "investigate, through a laboratory or computer-simulated dissection of a plant, worm, fish or frog, the interrelationship between the organ systems of a plant or animal" (MoE, 2008, p. 75). These two expectations together communicate to teachers that students must learn about internal organ systems, and they must do it through some type of dissection. Although there is some flexibility here in regards to what organ systems are learned, what animal is dissected, and whether the dissection is 'real' or virtual, the clear expectation for teacher practice is that students will be dissecting a plant or animal to learn prescribed science knowledge about organ systems. Indeed, one of the reasons Heather does a frog dissection, which seemed out of character, considering her environmental consciousness, is because, as she stated, "its right there in the curriculum" (Interview 2). The correspondence between activities suggested in the curriculum, and long established science education activities, such as the frog dissection, orange juice clock, and penny lab, may not be coincidental. Like other cultures, science education appears to have a strong "cultural memory" (Roth & Tobin, 2009); in other words, the way things have been done in the past have a significant influence o the way things are done presently. Those involved in the development of science curriculum are typically former (or present) science teachers, who have attained senior or administrative roles in the institution (Hodson, 2009). It is no surprise, then, that many of the suggested activities in contemporary science curriculum resemble relatively traditional activities, even in light of science reforms for environmental education, NOS, and STSE. For curricular knowledge and concepts in which there is no closely aligned activity, teachers themselves have access to vast collections of resources from which to select what works to teach particular topics and branches of science knowledge. As Ellen said, "one of the most important parts of my job is to bring the curriculum to life and I do this by taking great science activities, and adapting them to meet new curricular expectations" (Interview 1). What appears to remain constant, regardless of whether curricular developers, or teachers, adapt science activities to align with contemporary curricular priorities, is the enactment of activity that reproduces existing constitutions of nature.

Many activities chosen by participants have a similar relationship to the curriculum as the frog dissection. That is, students are required to learn knowledge and skills that are defined in the curriculum, but this knowledge is linked to a (or several) well established activity (ies) that precedes the recent curriculum. Speaking of this phenomenon was Ellen, who stated:

> It's amazing how much of the curriculum seems designed around what we as science teachers already know works. It makes it pretty easy to use activities we have been using for years, with slight adjustments, to teach the curriculum. The Daphnia activity, it seems like it fits right into certain expectation in the sustainability unit in Grade 9. (Interview 1)

The specific expectations to which the Daphnia activity aligns are found in learning expectations for "Developing skills of investigation and communication" and "Understanding basic concepts", seen in Figure 7.2.

**B2.2** interpret qualitative and quantitative data from undisturbed and disturbed ecosystems (terrestrial and/or aquatic), communicate the results graphically, and, extrapolating from the data, explain the importance of biodiversity for all sustainable ecosystems [PR, AI, C]

**B3.3** describe the limiting factors of ecosystems (e.g., nutrients, space, water, energy, predators), and explain how these factors affect the carrying capacity of an ecosystem (e.g., the effect of an increase in the moose population on the wolf population in the same ecosystem)

Figure 7.2. Specific expectations for Grade 9 Unit, Sustainable Ecosystems

These expectations convey both an activity (interpretation of qualitative and quantitative data), and knowledge (limiting factors of ecosystems) that students must acquire. In the Daphnia activity, students can meet these expectations effectively. Since the Daphnia activity is common in school science, teachers do not need have to create new teaching activities in order to meet these curricular expectations. This is a significant advantage with the limited amount of time teachers have to prepare lessons, making the selection and adaptation of existing teaching materials to curricula a likely occurrence (Hodson, 2009). On the other hand, the Daphnia activity may not be ideal to teach about principles of sustainability, for reasons outlined in Chapters 5 and 6. In fact, the Daphnia activity only fulfils 2 out of 9 expectations for this unit, causing one to wonder why such an activity would be selected by a teacher to 'deliver' the curriculum. The frequency of this activity in science teacher cultures in Ontario, as indicated by participants, suggests there is a degree of pedagogical 'comfort' with this activity, teachers view it as one that 'works', one that they can assess, and this justifies its use to 'deliver' curriculum.

In addition to what and how the curriculum suggests science be taught, it also contains discourse that contains particular constitutions of nature. Although the curriculum does identify learning related to nature, according to Janet,

> The new curriculum, I feel everything, from the first strand on, it has to do with technology, you know, how does this have a value to society, how is technology involved with it...some of it talks about sort of environmental degradation, but very rarely do you see written in the curriculum anywhere, to explore it IN nature.....it's like explore data, explore graphs, it doesn't really ever specify in the curriculum, experiences IN nature, connections within and between nature. (Interview 2)

Janet indicates the Ontario curriculum prioritises students' connection to technology and society rather than connections to the natural world. Janet's notion appears to be supported in the discourse of much of the text of the curriculum. For example, the discourse in the EE goal, "students are to gain understanding of their fundamental connections to each other, to the world around them, and to all living things" (MoE, 2008, p. 12), can be viewed as being human-centered. The ordering, and internal relationships of the text (Fairclough, 2003; Gee, 2011) discursively constitutes student understanding of their relationship with other humans as the most important understanding; relationships to the world around them and nature are of lesser importance. The "world around them" appears to represent society, as "all living things" is prioritised third, and seems to encompass the natural world. The language constructs a one directional effective relationship, from the human, to other humans, to the world around them, and then to nature. These same relationships are embedded in the discourse throughout the Ontario Grade 9 and 10 Science and Technology curriculum, which normalises anthropocentrism, making it difficult for teachers to see, and understand the influence of, anthropocentrism on the way they think about teaching science. This is concerning, considering that this is Ontario's Environmental Education policy, and indicates how deeply embedded, and difficult to detect, anthropocentrism may be in contemporary educational policy (Bowers, 1997; Hart, 2003). Although features of the Grade 9 and 10 Science and Technology curriculum allow for interpretation and flexibility, anthropocentric discourse may act to set limitations on what is possible for readers of this text to think and do (Foucault, 1980). Thus, human relationships with nature found in this discourse remain unchallenged, and shape how teachers speak about, and engage students with, nature.

### Assessment of Student Achievement

Assessment of student achievement can be an overriding factor influencing *how* teachers teach in contemporary schooling (Apple, 2004). Participants indicated assessing student achievement was a significant factor influencing their teaching practice. Assessment was often connected to the curriculum by the participants – they expressed the need to evaluate whether students have acquired the expected learning outcomes articulated by the curriculum. Indeed, it is assessment that appears to provide the institutional pressure, to 'deliver' the curriculum, as opposed to developing learning based on personal motivation, subjectivity, and local community needs (Ball, 2008). According to the curriculum, "Assessment is the process of gathering information from a variety of sources that accurately reflects how well a student is achieving the curricular expectations of the course" (MoE, 2008, p. 22). This statement makes it clear that assessment must be aligned with, and measure, the degree to which students have acquired the learning outlined in the curriculum. Since assessment is so closely aligned with curriculum, this puts tremendous pressure on teachers to teach only what is in the curriculum, since this is all that is accounted for by the institution (Apple, 2004; Ball, 2008). Heather, for example, summarized the importance placed on assessment, and its relations to the curriculum and teaching outdoors (which is an ideal location to teach lessons about nature), stating:

> There are 2 main reasons why teachers don't take their kids outdoors. They say to me, how do you find time to do these things there is so much to cover in the curriculum, and two, they have to do so much for the curriculum so they can write a successful exam...and it's all about sort of the exam and mark generation. (Interview 2)

The implication in this statement is that many teachers, according to Heather, see taking students outdoors as being ineffective at meeting curriculum expectations. A second implication is that the purpose of meeting curriculum expectations is to achieve high numerical scores on high stakes tests. Preparing students for tests, exams and common assessments was a significant social relation influencing teacher practice for every participant. Teresa implicated pressures from assessment when explaining why she often did not teach according to her own motivations and beliefs (to provide STSE based projects focusing on student activism), commenting "the problem is, we are still teaching to a test, we are still giving a sort of communal test, so that really limits what we do" (Interview 1). Teresa suggests here that assessment serves the function of aligning teaching practices, limiting the agency of teachers to diverge from common practices that prepare students for assessments. Zoltan shared a similar experience in his school science department, noting:

> We pretty much all do the same thing, especially for the summative (assessment) pieces. Like I am just writing a Grade 9 summative piece for the unit on electricity, so we will all be on the same page so this is what we will all be doing for the unit test. Chapter tests are pretty much the same, but again there is a huge back of Power Points work sheets, chapter quizzes, mini chapter quizzes, and all kinds of stuff, so we share those resources and go back and forth. (Interview 1)

Such prioritisation of teacher practice and student learning sustains certain cultural practices of teaching that are valued for their effectiveness of preparing students for assessments, while potentially marginalising other practices (Dorey, 2013). Woods (1998) has suggested that pressure to prepare students for assessment, particularly high stakes exam based assessments, has resulted in high frequency of instructional strategies such as lecture, that are viewed by many teachers as efficient in 'covering' curricula that exams are based on. Dominant instructional practices for exam preparation has resulted in a culture of what he terms "knowledge consumption" , in which students and teachers value the teaching and acquisition of pre-formed facts and information (Woods, 1998).

Assessment in Ontario Grade 9-10 science is based on specific knowledge, investigation, communication and application (KICA) criteria. In speaking about these assessment categories, Ellen said "we are expected to value all of these things, we are expected to account for all of these categories" (Interview 1). Although teachers assess students in these categories in a variety of ways, Ellen's use of "account" suggests a quantitative evaluation of students' achievement in each category. Indeed, the criteria measures percentages of achievement in each category, as seen in Figure 7.3

**ACHIEVEMENT CHART: SCIENCE, GRADES 9–12**

| Categories | 50–59% (Level 1) | 60–69% (Level 2) | 70–79% (Level 3) | 80–100% (Level 4) |
|---|---|---|---|---|
| **Knowledge and Understanding** – Subject-specific content acquired in each course (knowledge), and the comprehension of its meaning and significance (understanding) | | | | |
| | The student: | | | |
| **Knowledge of content** *(e.g., facts, terminology, definitions, safe use of equipment and materials)* | demonstrates limited knowledge of content | demonstrates some knowledge of content | demonstrates considerable knowledge of content | demonstrates thorough knowledge of content |
| **Understanding of content** *(e.g., concepts, ideas, theories, principles, procedures, processes)* | demonstrates limited understanding of content | demonstrates some understanding of content | demonstrates considerable understanding of content | demonstrates thorough understanding of content |

Figure 7.3. Achievement Chart: Knowledge and Understanding

This use of percentages in this scheme makes it clear that student learning must be distilled down to a number. The non-specific language in the Achievement Chart (e.g., demonstrates) appears to allow a degree of interpretation about achievement within categories, and therefore teacher flexibility in how they assess students. One can imagine numerous ways to demonstrate learning of knowledge and concepts. However, the specific criterion in each level refers to the requirement that what is assessed is "content", which is reference to the expectations in the curriculum. As demonstrated in the previous section, the curriculum describes relatively specific knowledge and skills, which are aligned to, and by, relatively conservative teaching practices. This system of assessment, then, appears to direct teachers to the selection of (existing), traditional science activities that are proven to inculcate knowledge and skills related to specific topics in the curriculum. These activities engage students in learning interactions that constitute nature in certain ways; thus, the teachers' need for reliable and predictable evaluative methods acts to ensure certain constitutions of nature are enacted.

Generally, the participants spoke positively about the achievement categories, as they provide a concrete way to justify students' grades. For example, Steve stated:

> The report card is one single numerical grade, but in my mark book each achievement categories has its own grade, so I have found it useful to do it this way because I can go back and tell parents their investigative skills are lacking, or their application skills are lacking. (Interview 1)

Steve here links student assessment to parental expectations. The language Steve uses suggests the quantification of student achievement for each category is "useful" because numerical indications of student achievement are what parents expect. The implication is that evaluations of achievement that are not numerical may be less useful because these are less acceptable by parents. Pressure to follow the assessment structures of the province is administered in a top-down approach; assessment policies are "delegated from the ministry, to the board, the boards delegate to the principal, the principal is responsible to monitor the teachers that this gets done." (Ellen, Interview 1). This pressure exists, apparently, because "there is this culture for administration that is data driven" (Joanne, Interview 1). The idea of data-driven performance was described frequently by participants. For example, Janet said:

> It's so funny, because when we think about data, quantitative data is really where it's at for us (as a school), because it's so specific, but we (as teachers) see sort of the problem with just homogenising the results and just reporting numbers and things like that. That hasn't filtered to the administration, they're so bought in to these, you know standardised testing is good, data is where it's at, we are going to set goals based on this data.
> (Interview 1)

The comments made by Joanne, Janet, and other participants, indicate that what is valued by administrators in Ontario schools is the quantification of student performance. This value is apparently prioritised at the highest level of the institution (Ministry of Education), and filters down through the school board to school administrators. This top-down approach to assessment appears to de-personalise the student; more personalised evaluation of students may value other demonstrations of learning that are more difficult to quantify (Dorey, 2013). It also resists engaging students in anything not 'established', because there is little known knowledge about how to assess these experiences (Comber & Nixon, 2009). As a result, teachers typically perform known practices that maximise student learning the knowledge they need to know for assessments, and which can be numerically accounted for (Dorey, 2013; Lingard & Mills, 2007).

The numbers that become attached to students' performance not only are a measure of their success, but also teacher's mastery of science teaching that enables high student performance (Ball, 2008; Linguard & Mills, 2007). Thus, student performance can be used to evaluate teacher performance. In speaking of evaluation of teacher performance at her school, Frances commented:

> If you have 2 different sections, taught by 2 different teachers, if there is a significant discrepancy, it's noted by the principal. The principal, sometimes through the department head, takes note of this, wants explanation, and expects improvement. (Interview 1)

Joanne also speaks of practices used at her school to evaluate science teachers' performance, stating:

> We use the mark book program to record our marks, and it's not unheard of for the principal to ask for them, and they want to know how many pieces of evaluation are you giving, and they want to know if you're using all the categories. Do they always look at them? No. Can they? Yes. Are they used as ammunition on you? If you're doing a shitty job, yes. And then you make changes in your practice to accommodate the administrative pressure (Interview 1)

A "shitty job" indicates Joanne has a conception of what acceptable teacher performance might look like, and this conception is reinforced by the administration. Clues to what is considered acceptable performance can be observed in the *managerial* system described by Joanne; teachers should be evaluating many pieces of student work, and using all of the achievement categories. In other words, a well performing teacher is one who is assessing students thoroughly and often, using common assessment procedures, producing abundant numerical data about student achievement of curriculum expectations.

Participants also spoke of performance expectations from outside of the classroom that influenced their practice. These expectations typically came from parents, who had certain views of school, teaching, learning, and assessment that participants explained exerted pressure on their practice. For example, Joanne commented

> I taught at a school in a community with a very high income when I first started teaching, and the parents at this school were like rabid dogs, and if they could put a wedge, like we (teachers teaching the same subject/grade) had to be super consistent, and it was really intense being there. (Interview 1)

Joanne describes parents as being very involved in the functioning of the school ("they were like rabid dogs"), and had certain expectations of the education system. Kristin's comment "we had to be super consistent" indicates a parental expectation that all teachers are doing the same job, and performing similarly. Parental expectations were particular relevant to student assessment and grading. Heather spoke of this, stating,

> Parents expect kids to have tests and quizzes and all the rest of it. There is a level of expectation, because this is the way things were in my school, so if I was to say, I don't want to give tests I think they are stupid, I want to give a whole bunch of assignments that they take home, the parents would lose their marbles. (Interview 1)

The implication again is that there is social expectation from parents, that students' performance be accounted for in certain, perhaps conservative, ways. Heather claims teaching practices that do not conform to these ideals may be viewed with suspicion by the local community ("parents would lose their marbles"). Much of the scrutiny described by participants from community members is applied comparatively. Parent and students, for example, compare teacher performance from year to year, and are aware of differences in student and teacher performance between different teachers of the same grade. Janet spoke frequently of these comparisons, claiming

> To stay consistent with other teachers, I'd say this is the big issue, because if I teach the same course as somebody else and one of us is perceived to be easier than the other, parents will go bananas over that, right? Kids do too. Right, they'll go, 'how come they only got 3 quizzes and we got 4?' So, consistency is a big issue. (Interview 2)

Each participant spoke of these comparisons as influencing their practice. For example, Frances stated "if she teaches this way and I teach that way, what are parents going to think? I have run into this in the past." (Interview 1). Such expectations typically are related to parent concerns that their students are at the very least being granted equal advantage, and protecting against their child being disadvantaged, by an under-performing teacher (Linguard & Mills, 2007). The effect of these pressures is that teachers will avoid varying their practice significantly from other teachers teaching the same subject, which acts to coordinate what teachers do. Science is particularly important to many parents because they may see it as a vehicle to a successful future. For example, David explained:

> Sometimes they are sitting in math and science because their parents say they are going to be an engineer or the doctor or something. So we have all of these different realities; the reality of what the parents think, assessment, preparing students for university and jobs. (Interview 1)

David's comment indicates parents of his students prioritise math and science because they see it as a pathway to future employment. David's use of the term "realities" for school science priorities, suggests he views these as valid purposes of school science. Social expectations that students should attend university can explain teachers' focus on university preparation. This expectation was identified by most of the participants as having significant influence on their teaching practice. For example, Zoltan stated:

> Things (topics, learning) come up quickly, if they want to survive in a university bound science course, there is no wishy-washing around, because that's not going to serve you well, and the feedback we get from our graduating students who go to university is that, yeah, you guys were tough, but it served us well, and we look at the other people around them, and they feel they are not as well prepared as I am. Our kids who should be going to university are doing well. (Interview 1)

Janet also described social expectation to prepare students for university influencing the way she teaches science in the following comment:

> Before, when I was first teaching, kids would come back telling me they were writing 3-4 formal lab write ups. I'm not hearing that anymore so we have to change the teaching to

> foster this type of learning that they are really going to need." (Interview 1).

Seeing science as a way to, as Burke (2014) claims, participate in a dominant discourse in society, and thus attain cultural capital needed to obtain employment and security, appears to be a key social factor influencing the way participants taught science.

## Controlling Student Achievement

Growing Success (OME, 2010) is another policy document identified by participants as influencing science teaching practice. Growing Success is intended to improve teaching and learning across all grades and subjects, and emphasises the importance of assessment and reporting student achievement. The document is an update to the assessment policies in provincial curricula, and outlines "Learning skills and work habits" that students need for contemporary and future citizenship, and defines "Performance Expectations" from which to evaluate student achievement. Growing Success does not add new assessment procedures to Grade 9 and 10 Science; instead, it reinforces the requirement for teachers to use the Achievement Chart, assess frequently, and the specific procedures to report student evaluation. "Performance expectations" in Growing Success is the term it uses to represent assessment criteria in provincial curricula, many of which haven't been updated as recently as Science. Potential effects of the discourse contained in Growing Success on teacher conceptualisation of science education were observed during participant interviews. For example, Alice stated:

> There is pressure for student performance, there is this Growing Success document, and it outlines what we should do as educators to engage kids, and evaluate their performance, and its more active, right, so instead of sitting in a classroom and listening to someone lecture, they are out finding the answers to their own questions, and developing the sort of skills students need to go into the workforce nowadays. (Interview 1)

Terms Alice uses such as "performance", and phrases "skills students need to get into the workforce nowadays" resemble the discourse in Growing Success, which discursively connects engagement in school science with developing skills and aptitudes that can be measured (evaluate performance), and which are pertinent to future employment. Performance serves as a measure of adequate preparation for a job in science and technology related fields, or university education leading to these jobs (Ball, 2000; 2008). Growing Success, and utilitarian purposes of school were also described by Zoltan, who claimed:

> There's this growing Success document now. It makes it clear that the government has expectations that the education system should produce people who are functional, and work, and are good workers, good business people, good scientists, good entrepreneurs, and maybe good citizens. All that and probably more, they want a lot out of education (Interview 1)

Discourse analysis of this statement suggests that functional, in Zoltan's understanding of government priorities, means the ability to work in science and business related fields, and if they are able to do that, they are approaching what it means to be a good citizen. Provincially disseminated discourse related to preparing students for university and employment was frequently espoused by participants. For example, similar to Zoltan's statement, Heather said "when it comes right down to it, we are preparing them for life after school; jobs, university, taking a place in society." (Interview 2). Heather's description of "taking a place in society" discursively constitutes place as an existing location, created by others in a pre-existing social system. This suggests a utilitarian, structural-functional purpose of science education, rather than a transformative one, advocated by many science education scholars (e.g., Bencze & Carter, 2011, Calabrese Barton, 2012) in which students are prepared to be agents of social change in science education.

The discourse in Growing Success contains frequent reference to economics, work, jobs, and performance, as well as more democratic educational principles. For example, one of the first rationale statements supporting the need for Growing Success states:

> Education directly influences students' life chances – and life outcomes. Today's global, knowledge-based economy makes the ongoing work in our schools critical to our students' success in life and to Ontario's economic future. As an agent of change and social cohesion, our education system supports and reflects the democratic values of fairness, equity, and respect for all. The schools we create today will shape the society that we and our children share tomorrow. (MoE, 2009, p. 6)

The word economy occurs twice in this short discursive sequence. The global, knowledge based economy is discursively constituted as a purpose of schools, through the clause "ongoing work in our schools". The future is constituted through an economic lens through phrases such as "Ontario's economic future". The text claims that the Ontario education system reflects "democratic values, fairness, and equity". These values are undefined in this policy, but these same values occur frequently in contemporary educational policy, which embeds these terms with particular meanings, often different than the socially just interpretations superficially implied by such text (Means, 2013). Growing Success is policy that appears to represent the province of Ontario's attempt to prepare students for future work. It does so by applying an additional layer of policy on top of the assessment policy already in existence for each subject.

This policy communicates, in detail, exactly how teacher must assess students, using the assessment criteria, and how school administrators can monitor teachers and enforce assessment policies. This policy alters the discourse of assessment, to one of performance, which is measured by the achievement of very specific and narrowly defined expectations (Ball, 2008).

**Chapter findings and analysis summary**

This chapter focused on interview data and policy documents identified by participants that elucidate the social relations that coordinate the practice of teaching grade 9 or 10 science in Ontario. The identification of these complex social relations was necessary to understand how institutional factors are involved in how nature is constituted in Ontario Grade 9 and 10 Academic Science.

Knowledge of skills and concepts appears to be the 'hook' between the constitution of nature, everyday teacher practice, and the institution. Participants generally see knowledge as the commodity of exchange between student and teacher during learning activities. Knowledge that is valued among participants of this study fulfills many obligations; it must be represented in the curriculum, it must be assessable through student performance, and, preferably, it must be the result of activities that are already developed in science education/science teacher cultures. This knowledge of nature, both what nature is, and how a person (student) in science should come to attain this knowledge, was described in Chapter 5 and 6.  To learn this knowledge, science teachers frequently require students to engage in epistemological approaches that utilise, manipulate, control and dominate nature. These practices result in ontological representations in which nature is frequently an object, machine, model or mathematical algorithm, the primary purpose of which is to represent known and valued scientific knowledge. This chapter demonstrated the institutional coordination, and 'control' of this knowledge, ensuring that it is the commodity of exchange between student and curriculum in Grade 9 and 10 Academic Science classrooms.

The curriculum is the central repository of institutional knowledge that must be acquired by students, with existing constitutions of nature already inscribed. The knowledge in the curriculum is, generally, existing science knowledge of nature that has been produced in the past, rather than constructed by students, so it is already embedded with assumptions about nature, and represented in constructions, seen as valid in science (Östman, 1994; Roberston, 1998). Although this knowledge is crucially important for students to learn to function as a student, and citizen (Hodson, 2009), as Östman (1994; 1996; 1998) suggests, the fact that it already contains anthropocentric ontological and epistemological assumptions about nature is problematic.

There appear to be several institutional mechanisms that work to ensure this knowledge is taught by teachers and learned by students. One of these is the close alignment of knowledge and skill outlined in the curricula with those in existing, traditional, science teaching approaches and practices. This alignment is so close, that in some cases, the very activity taught by a teacher is specified in the curriculum (e.g., frog dissection). In all cases, there exist curricular expectations that are effectively provided for by activities evaluated in this study. This alignment is so seamless, it appears that much of the curriculum may have been designed with specific activities in mind (Hodson, 2009). In other words, an existing culture of science teaching was influential in the design and development of the science curriculum, enabling a degree of reproduction of that culture.

The requirement to assess student learning is another institutional mechanism ensuring knowledge in the curriculum is taught. Clear in the policy discourse is that, what is to be assessed is the learning outlined in the curriculum. Anything not outlined in the curriculum does not need to be assessed. Assessment is a tightly controlled process, aligned institutionally by assessment policy, broader evaluation and performance policy (Growing Success), and administered through the social organisation of school. The first level of organisation is collection of resources to teach the curriculum that exists in most schools. Each of the activities participants selected for this study came from such a collection. Science teachers are then accountable to the science teaching team itself, to which they must align teaching and assessment practice. Science teams are coordinated by a department head, who is accountable to the school principal. The chain of accountability for learning extends past the principal to the school board, which itself is accountable to the Ontario Ministry of Education. This 'top-down' system of authority, works through these levels to control what teachers teach, so that students are learning the curriculum, which is itself inscribed with specific constitutions of nature. Each of these layers of coordination work together with each other to coordinate the everyday activity of local science teachers teaching in schools, influencing how nature is constituted by the practices they enact. As a result, according to the participants of this study, teachers come to see themselves as "deliverers of curriculum" (Teresa, Interview 1), or, as Zoltan said, in reference to assessment requirements, "accountants of learning" (Interview 2). These layers of coordination, however, constitute nature so that teachers must teach, and students must learn, in specific ways, through anthropocentric perspectives and discourse.

At the same time, this system of accountability can weaken if one or more levels of management are absent or altered. For example, there is enough room for choice in the curriculum to allow variation in teacher practice if institutional factors that account for curriculum delivery are absent. The lack of a teaching team with which a teacher must coordinate, for instance, potentially provides the individual teacher with more agency. This can result in broader and unconventional interpretations of the curriculum, such as those demonstrated by Heather, who bases much of her science course learning about nature outdoors. Although many of the practices she described, from an epistemological perspective, are similar to those of other participants (e.g., classification activities) she was also able to engage students in non-traditional, more biocentric activities (e.g., nature observation; nature artwork). The lack of a team coordinating her practice resulted in reduced institutional pressure on Heather, enabling her to engage students in activities in which they might produce knowledge about nature that is not typically valued in school science.

Together, Growing success, the Achievement Chart, and provincial curriculum, appear to act as a system, or technology, of control (Foucault, 1984). One of the primary intentions of this system appears to be the preparation of students for science and technology related jobs. This may marginalise other purposes of education, such as preparing students to participate in more democratically grounded citizenship (Hoeg & Bencze, in press), or environmental literacy (Hart, 2003), which may require educational experiences that are dynamic, evolving, and locally grounded, and therefore do not fit into rigid systems of control (Means, 2013). School, nor school science, exists in a vacuum, and expectations, values and assumptions about what needs to happen in schools are transmitted from society through discourse communicated to parents, students, and teachers', from outside of school (Hodson, 2009). In this way, discourses that exist in society, such as those prioritising quantification and accountability, can find their way into policy, and teacher practices in classrooms, organising teacher practice in ways complimentary to these systems and expectations.

# Chapter 8: Discussion, implications and conclusions

School is a significant influence in the socialisation of children, and science has been the default subject in which nature is taught (Steele, 2011). It is, therefore, important to know how school science might be implicated in the socialisation of dispositions and practices related to nature. The results of learning experiences are unpredictable. There are many competing discourses in school science, and some of these are aligned with environmental sustainability, and these potentially could result in more biocentric relationships with nature (Taylor, 2010). If, however, school science activity is seen to contain constitutions of nature I have identified in this thesis, resulting learning outcomes for students are concerning. The school science activities selected by participants work to sustain, and possibly magnify, the physical separation from nature students may already perceive (Orr, 2004). These activities can cause students to see nature as prescribed representations, created by other people, that constitute nature according to its utility to human social systems (Östman, 1994, 1996, 1998). These activities allow students to come to know nature through practices in which they control, manipulate, and dominate nature. Although it is impossible to state with certainty the orientations that develop from this socialisation, it seems reasonable to conclude that students are likely to come to see nature as something abstract, a material for human utilisation, and a resource for human advancement. These orientations are detrimental to nature, and are unlikely to foster the production of different forms of knowledge of nature that can result in more sustainable human-nature relationships (Bowers, 1997).

The criticism of Ontario Grade 9 and 10 Academic Science found in this research is necessary to bring to the fore awareness of discourse in science teacher culture that constitutes nature anthropocentrically. Making this discourse visible to those who work within science education, propagating it, is an essential step in the process of changing science teaching practice so that more sustainable human-nature relationships may be learned. The following are the main conclusions drawn from this research:

1. School science practices (re)produce knowledge about what nature is. This knowledge typically portrays nature as a resource, separate and distant from the student, and as reductive constructs, such as an object, model, machine, or mathematic algorithm.

2. School science practices (re) produce knowledge about how to know nature (in science). This knowledge generally constitutes ways to know nature based on oppression, manipulation, control and dominance of nature.

3. Much of the constitution of nature in Ontario Grade 9 and 10 Academic Science is reproduced in conservative, traditional science teaching practices that both align, and have been align to, the curriculum.

4. Constitution of nature is coordinated by the institution of school, controlling the ontological and epistemological knowledge of nature produced in school science. The primary mechanism of control is the curriculum, combined with technologies of accountability, consistent with neoliberalism.

5. Mechanisms involved in the constitution of nature appear to represent neoliberal systems of control. These systems constitute nature by defining (through the curriculum) and accounting for (through assessment and governance) knowledge of nature that is valued in neoliberal social systems. This knowledge is typically pre-existing, objective, discrete, and anthropocentric knowledge of nature.

These results are limited to the practices described in this study; however, the teaching resources participants selected and interpretation of discourse that was identified in these resources, suggest these are part of a wider, trans local science teaching culture that extends to at least within the province of Ontario, if not more widely (Östman, 1994; 1996; 1998; Sharma & Buxton, 2015). This chapter discusses the conclusions presented above; considers the implications of anthropocentrism within school science; suggests reforms that might address issues related to teaching nature, and; discusses limitations of this research.

**1. School science practices reproduce knowledge about what nature is.**

The way nature is constituted by discourse and practice described by participants tends to construct knowledge of nature in which it is an entity that is valued according to how it can serve humans. In school science, this frequently means that nature is seen as simply the object of scientific investigation (Fensham, 1988; Östman, 1994; 1996; 1998; Roberston, 1998). Perceiving nature as an object or human-made representation such as a model, or machine, is a way for humans to grapple with its complexity (Mitchell, 2003; Nicholson, 2013). Perception is not thought to be a passive or random mental process, but rather a conscious act, a behaviour, enabled and limited by existing mental schema (Swain, Kinnear, Steinman, 2011). The worldview of scientists is thought to guide perception of nature through particular lenses, which identify observable physical features that are deemed important to the purposes of science (Cobern, 1991; Mitchell, 2003). Such singular focus on chosen, salient qualities of the object, directs perception exclusively toward those features of interest (Nisbet, 2003). Dominant Western Science discourse appears to 'set-up' this perspective, by constituting nature as an object with measurable and observable properties that often can be explained through mathematical relationships (Aikenhead & Ogawa, 2007). These positivistic commitments direct perception, making it difficult to 'see' whether there is more to know of a rock, or a tree, than what scientific observation produces, such as the size, age, mass or composition of the rock or tree. Are there intelligible essences in nature beyond what is intelligible to science? Many indigenous cultures, based on monist and holistic ontologies in which physical and spiritual experiences are united, believe there *is* more know about nature than can be gleaned through the quantitative gaze of Western science (Ermine, 1995). These indigenous cultures view everything in nature as more or less animate and imbued with spirit (Kawagley et al., 1998). My experience researching bees described in the opening section of this dissertation was one in which the role of scientist and object were reversed, activating different psychological and emotional schemas that seemed to enable a different perception than what was possible as the distant, objective, and dominant science researcher. Contemporary perspectives of science, such as *organicism* are starting to question the limits of science perspectives based on dualistic, human-other dichotomies (Gilbert, & Sarkar, 2000; Nicholson, 2013). Knowledge based on such perceptions may be limited forms of knowledge about nature. When nature is seen as an object that must be reduced, measured and quantified, *holistic* perspectives that may be important in a broader understanding of nature are lost (Gilbert & Sakar, 2000). Holism, which considers parts of a whole as in intimate interconnection, such that they cannot exist independently of the whole, or cannot be understood without reference to the whole, which is thus regarded as greater than the sum of its parts, is a theory increasingly applied in science (Gilbert & Sakar, 2000; Nicholson, 2013). Holistic considerations of nature, and the implied limitations of traditional science perspectives, such as vitalism, provoke questions about whether a science that considers nature as an object and resource for study, can produce the knowledge about nature needed to solve the environmental problems that we face today. Vitalism is a discredited scientific hypothesis that considers living organisms as fundamentally different from non-living entities because they contain some non-physical element or is governed by different principles than are inanimate things (Gilbert & Sakar, 2000).

**2. School science practices produce knowledge about how to know nature (in science).**

It is within nature of science (NOS) theory and scholarship that the research described in this thesis makes the greatest contribution. Science discourse, which tends to be limited to 'describing' the physical world, is silent on the epistemology used to produce knowledge about nature (Östman, 1998). This epistemology is dependent on empirical practices that are frequently oppressive and destructive to nature (Hodson, 2009; Oakley, 2011). Science methods are generally recognised as a component of Nature of Science (NOS) (Hodson, 2009; Lederman et al., 2002). Teaching practices that were frequently described by participants engaged students in objective descriptions of nature, quantification of nature, and science methods that utilise, manipulate, control and dominate nature. These practices place students in positions to create epistemological knowledge – how they should come to know and understand nature. The activities chosen by participants represent what they consider as 'best practices', and 'what works' in school science; in other words, these are the ways most valued in school science to come to know nature. These are, apparently, the most valued practices among the science teaching communities within which they work. These practices are accepted as the normal course of science investigation, and are done "for the good of science", which appears to provide a degree of ethical and moral validation for manipulation and domination of nature (Oakley, 2012; Östman, 1994; 1996; 1998). This is concerning, because it potentially socialises students into practices in which ethical or moral considerations related to uses of nature are silenced. A discourse of 'nature as a resource' (Dryzek, 1997) dominated the language and practices of the teachers who participated in this study, removing much of the ethical and moral dilemma about using it, appearing to marginalise other ways they might value nature.

However, the practices examined in this study tap only a potential of the possible scope of ways to know nature. In addition to learning established science methods of knowing nature, NOS pedagogy can involve students in problematizing these methods, discussing limitations of reductionist perspectives, and challenging the validity of claims of objectivity (Pedretti & Bellomo, 2015). These critical perspectives help students to understand some of the myths of science, and see how science might be practised in ways that are more inclusive to various identities (Shanahan & Neiswandt, 2011). The literature on NOS tenets, beliefs and/or perspectives, however, does not typically consider the generalised anthropocentrism that has dominated fields of Western science, and shapes traditional science methods to investigate nature. NOS discourse appears to oppress nature by prioritises human agency and purpose (that of the scientist), rather than acknowledging intrinsic value or agency in nature (Latour, 1987; 2004). NOS also addresses ethical and moral issues stemming from practices and products of science, such as the relationship between science research and industrial production (Bencze, 2008). Yet, when environmental problems are connected to products and practices of science, a discourse of *environmentalism* is frequently the result, which connects human impact on the environment to detrimental human outcomes, which may result in alienation from, and repress intrinsic value for, nature (Bowers 1997; Dryzek, 1997).

A few studies have identified anthropocentrism as a fundamental assumption of Western science (e.g., Aikenhead & Ogawa, 2007). Much of this scholarship suggests NOS practices in school science may also be anthropocentric. There exists a dearth, however, of empirical research on how NOS practices in school may constitute relationships with nature (e.g., Lederman, et al., 2002). This is a significant gap in NOS scholarship, one that potentially results in misunderstanding and lack of awareness among teachers related to how science practices constitute nature. Such misunderstandings of NOS were apparent among participants in this study, who were generally unaware of how the practices with which they engage students might be oppressive to nature. There was also general lack of awareness of how school science methods might socialise students to particular views of nature. This result is concerning, and suggests NOS needs to be expanded to include consideration of how science methods may constitute nature, and a sustained engagement with this component of NOS in science teacher preparation.

**3. Constitution of nature in traditional science teaching practices both align, and have been align to, the curriculum.**

Many of the practices described by participants have a long history and tradition in school science (Pedretti & Bellomo, 2015; Tobin & Roth, 2007). Their presence in science teaching communities can be seen largely as a result of cultural traditions, passed down to new teachers by senior teachers. These practices become embedded in knowledge about how to teach topics, what is often referred to as pedagogical content knowledge (Pedretti & Bellomo, 2015). Many participants spoke of the determinism of the curriculum on their practice, and described their jobs as “a deliver of the curriculum” (Steven, Interview 1). The data collected, however, is somewhat in conflict with this claim; traditional science activities were maintained over time, needing only minimal adaptation to meet new curricular expectations, suggesting participants were “delivering” traditions of science teacher culture, rather than something unique to the Ontario science curriculum. The curriculum and existing science teacher cultural artifacts (activities, lessons, projects) appear to have a co-constructive relationship; although participants described these artifacts as having been aligned with the curriculum, it is apparent that much of the curriculum was developed with existing science pedagogy in mind (Hodson, 2009; Pedretti & Bellomo, 2015). In other words, even with a new curriculum, there was a maintenance of existing science teaching culture, which already included teaching artifacts and practices, and NOS perspectives, inscribed with particular constitutions of nature.  Pressures of accountability and social expectations further shaped science teaching practice; what teachers keep in this culture is ‘what works’ in meeting expectations of the curriculum. A students’ value is determined based on their acquisition of the learning outlined in the curriculum. In this milieu of science cultural traditions, community expectations, and policy requirements, what appeared to be valued in the teaching communities described by participants is the maintenance of what has been shown to work to teach valued science knowledge, which is both aligned to, and aligns, the science curriculum, and can provide the required accountability data to the community

(Chudnofsky, 2010). These expectations influence the culture of schools, producing discourse containing knowledge and practices about what and how teachers should teach. This discourse enables certain practices that constitute nature in a certain way, while at the same time constraining knowledge and practice about constituting nature in other ways that is not contained in dominant discourse. Dominant discourse is schools also places limitations on what is conceivable for teachers (Chambers and Nixon, 2013), making the production of something new, such as knowledge about teaching practice that could enable production of biocentric knowledge of nature, difficult to acquire for many teachers.

**4. Constitution of nature is institutionally coordinated by the curriculum, combined with technologies of accountability, consistent with neoliberalism.**

A science teaching culture that values engaging students in anthropocentric practices would be difficult to maintain if other discursive and structural aspects of the institution did not support this education. Much of the discourse present in teacher interviews and policy documents appears to represent various institutional systems of separation, objectification, control and dominance over teachers and students (De Lissovoy & McLaren, 2003). This system of control can be seen as a form of governance in education. Such governance, claims Foucault (1980), involves guiding or shaping attitudes and behaviors of others (or oneself) through "contact between the technologies of domination (such as policy) of others and those of the self" (p. 19).

One way to look at this co-supportive system of governance is as a way to quantify the value of objects (students; teachers; schools). In every extra-local level of coordination of school science described by participants, social relations that objectify, control, manipulate and dominate the other (student/teacher/nature) were described. For example, practices oppressive to student individuality and agency are applied throughout the life of the student so that observation of objective qualities and salient features that are valued in the student by the institution (grades; performance) are quantified. De Lissovoy and McLaren (2003) have described the reduction of complex social relations (learning) into abstract statistical data (grades) as the objectification of human consciousness. Objective, quantitative constitutions of nature are of value to this system of accountability, because this represents the knowledge of nature that is obtainable and assessable in existing science teacher cultures. By imposing assessment and knowledge requirements on nature, traditional, anthropocentric constitutions are sustained.

The student quality that is valued is the acquisition of science knowledge of nature. This knowledge is outlined in official policy documents, in this case, the Ontario Science curriculum. This knowledge is valued because it is quantifiable, thus enabling educational systems to measure the value of the student to economic system of production (Apple, 2004).

Managerialism of Nature

Control over the constitution of nature appears to be enacted through a system of management, or *managerialism*. Managerialism represents an organisational arm of neoliberalism. It is a mode of governance designed to realise the neoliberal project through the institutionalising of market principles in the governance of organisations. In the public sector (and increasingly in civil society bodies) it involves the prioritisation of private (for-profit) sector values of *efficiency* and *productivity* in the regulation of public bodies. Participants frequently identified technologies of managerialism during interviews, that “bring corporate control into the classroom” (Carlson, 2005, p. 33). For example, the Markbook™ system of numerical accounting and reporting for achievement mentioned by Zoltan and Joanne can be seen as a way for school administrators to monitor the efficiency, effectiveness and performance of teachers. As Joanne said, this information is used by principals to take disciplinary measures on teachers who are not performing well. Thus broader assessment policy, ‘as discourse’ (Ball, 2000), exerts power over teachers practices related to nature. At the same time, associated locally produced texts like these not only mediate the institutional work of participants and their colleagues, they also change teachers’ working practices (Comber & Nixon, 2009). They affect both the kinds of opportunities teachers have to carve out an oppositional discourse, and also the kinds of spaces they have in which to make discretionary professional judgments. For example, as Joanne noted, in the highly managerial system at her school, she felt that she was increasingly being excluded from teaching and assessing in more inclusive ways because these were not valued, or accountable, in the current system of management.

Performance of Nature

Participants expressed feeling pressure to 'measure up' to local systems of accountability in their schools. Student (consciousness/nature) *performance* was discussed frequently by participants, particularly in relation to Growing Success. Student performance was then connected to teacher performance. Taken literally, 'performance' in everyday usage can mean: "the accomplishment of a given task measured against pre-set known standards of accuracy, completeness, cost, and speed" (performance, n.d.b.). Defined sets of practices are critical to neoliberal systems of authority and accountability.. Performance, according to Stephen Ball (2000), is:

> A technology, a culture and a mode of regulation that employs judgements, comparisons and displays as means of control, attrition and change. The performances (of individual subjects or organisations) serve as measures of productivity or output, or displays of 'quality', or 'moments' of promotion or inspection. (p. 2)

An example of how conceptions of performance work toward controlling learning in schools is high stakes testing. High states examinations, which are administered for Mathematics and English Literacy in Grade 3, 6 and 9 on Ontario, provide a public account of the performance of any particular school or district in delivering the academic product. Teacher performance linked to systems of control have been identified in the USA, where student (and teacher) performance on these tests determine how funding is distributed to schools (Apple, 2001; Black & William, 2005). Reform policies in the USA enforce a measure of performance through incorporation of disciplinary technologies that measure, evaluate, and correct the pedagogy of teachers through tools, such as value added metrics and merit pay (Dorey, 2013).

To ensure performance, participants discussed effectiveness and efficiency - terms appearing to be related to meeting the various expectations embedded in the managerial discourse, such as those from the curriculum, assessment policies, other social influences (parents) and interdepartmental expectations. Participants were required to meet these expectations quickly so that learning could be achieved in limited amounts of time. Thus, good teacher performance involves engaging students in practices in which they are acquiring knowledge of nature that is easily assessable – primarily known science facts and reproductive practices that have traditional existence in school science. These are typically lab-based activities, and teacher centered lecture, in which the outcome of these learning experiences, the knowledge students acquire, is assumed to be known (Apple, 2005). Thus, nature is performing, institutionally, when it exists in consumable, abstract, objective forms.

**5.** Mechanisms involved in the constitution of nature appear to represent neoliberal systems of control.

Much of Ontario educational policy can be seen as a form of governance intended to produce attitudes and behaviors of future citizens required in neoliberal society. Neoliberalism, although a contested ideology, typically is seen as a form of free market capitalism in which priority is given to private sector freedoms from government interference in personal and economic affairs. In this 'new' form of liberalism, the government intervenes in markets, establishing laws that enable economic actors to pursue profit-generating activities. The original architects of neoliberalism argued that through mobilisation of the state, privatizing national and public resources, and simply letting the market be, a stable yet dynamic society would emerge (Friedman, 2002; Hayek, 1994). Advocates of neoliberalism posit it as a superior and commonsense approach to organizing all aspects of society, and that, when strategically-appropriate, market forces should replace the state as the primary producer of cultural reason and value (Scott, 2013). The worldview of neoliberals prioritises perpetual entrepreneurialism (life-long learning), in which citizens, including students, are supposed to see themselves as constantly trying to increase their personal 'human capital' in order to survive in a world in which private interests are prioritized over public democracy, and the market, rather than the state, provides for social needs (McMurtry, 2013; Scott, 2013).

Neoliberal discourse increasingly re-defines domains of *validity, normativity* and *actuality* (Foucault, 1972) in educational policy (Grimaldi, 2012). Neoliberal values and attitudes appear to be embedded in educational policy, including the Ontario Grade 9 and 10 Science and Technology curriculum, and supporting documents, such as Growing Success, through knowledge and practices inscribed in texts that have specific neoliberal meanings. These meanings are then taken up by teachers, and therefore attain utility in everyday activity (Means, 2013). Indeed, the language and practices participants described were frequently characteristic of neoliberal discourse. For example, comments about how teachers are supposed to see the purposes of school science were frequently made by participants. These comments suggested pressure to see school science as a vehicle for the preparation of entrepreneurs who will attain or create jobs in science and technology related fields. Science education reforms the world over have become increasingly oriented to preparing students specifically for science and technology related jobs, seen as the basis of the future economy (Pierce, 2013). Discourse observed during participant interviews, particularly related to Growing Success (2010), imposes pressure on science teachers to prioritise particular types of knowledge and skills related to work in science related fields. This focus would appear to narrow space for other practices not directed toward these purposes. Such narrowing of space in an already overcrowded science education program may resist teacher enactment of activities that could illuminate and interrogate constitutions of nature, because knowledge produced by such experience is contraindicative to preparation for university or science and technology related jobs (Pierce, 2013).

Neoliberal discourse of accountability in schools, and anthropocentric discourse in school science, although distinct, would appear to stem from the same basic assumption, based on the separation of the self from other, and objectification and domination of the other (Cobern, 1991). Students are engaged in practices that generally constitute nature according to the objective and abstract knowledge they can obtain from investigative methods prioritised in school science. These practices themselves, although having origins in science teacher culture and understandings about NOS, appear to have been optimised through neoliberal discourse to prepare students for university and post-secondary science education. Teachers then place value on students according to their performance in demonstrating mastery of anthropocentric science knowledge. This quantitative information represents the students' value to higher education, or the science and technology job market (Chudnofsky, 2010). Thus, the commodity accounted for by neoliberal systems of control would be a specific type of knowledge of nature. Students who have acquired this knowledge in school science are positioned to attend higher status universities, and attain better science and technology related jobs (Pierce, 2013). The institutional pressure science teachers face to produce the commodity valued in a neoliberal economy (objective, abstract anthropocentric knowledge of nature) ensures its reproduction in school science.

The way institutions such as schools function is variable and complex, making this description of how nature is constituted in Ontario Grade 9 and 10 Academic Science perhaps seem overly simplistic and deterministic. There are other possibilities of practice and outcomes of school science that are not connected to numerical performance and quantification of nature. Given traditions of pedagogical content knowledge, NOS discourse, and neoliberal systems of control present in the institutional settings described by participants, however, the spaces for other possibilities and outcomes appear to be limited.

**Implications**

The results of this study have several implications related to how nature is taught in Ontario Grade 9 and 10 Academic Science, and how these practices might be changed to disrupt anthropocentric orientations. There is abundant literature on how to teach nature in schools in ways thought to develop more biocentric relationships and orientations (e.g., Hart, 2003); many of these practices involve taking students outdoors, and engaging them with nature in unstructured activities to experience interconnection, appreciation and value for nature (Orr, 2004).  Given the limitations and constraints of school in general, and school science specifically, these may not be feasible alternatives to the common science practices described by participants. Literature on teaching environmental education in schools has been extensively reviewed elsewhere (e.g., Rickinson, 2005). Much of this literature, however, does not engage with the issues raised in this thesis - that is, how to disrupt and challenge constitutions of nature that are deeply embedded, taken for granted, and invisible in school science. Indeed, presuppositional understandings of nature have likely worked to limit research on this topic. Silences around the constitution of nature in school science likely necessitates that students receive both explicit and implicit instruction to develop biocentric conceptions of nature (e.g., Bencze & Elshof, 2004; Hodson, 2009). In the proceeding sections I describe some ways anthropocentric constitutions of nature might be disrupted in school science.

Suggestions

The emphasis on NOS, Science, Technology, Society and Environments, and Environmental Education in the Ontario Science Curriculum, appear to enable shifts in science teacher practice that could alter how nature is taught. This needs to be balanced, however, with the realities of the need for students to learn established knowledge of nature that has been produced by science, and the methods by which this has been achieved (Hart, 2003; Hodson, 2009). Such learning should not be devalued, or omitted, but, rather, examined for how it constitutes nature. This knowledge is necessary so that students and teachers can be agents in the development of the relationship they have with nature (Bowers, 1997; Hart, 2003; Orr, 2004). The following are a list of suggestions for how more biocentric relationships in school science might be realised, while maintaining the validity of Western science knowledge and methods:

1. Teachers and students need to explore NOS related to the methods they enact, particularly discussion about the relationships with nature that can be created, and debate about whether such activities and practices are necessary.

2. Teachers may need education about NOS that addresses how science methods constitute nature, so that they can make informed choices about what science practices they engage students in.

3. Activities should include appreciation and respect for nature.

4. When learning involves living organisms, such as plants or animals, no practices that result in the destruction, manipulation or domination of that life should be performed.

5. Discussion of fields of science that utilise holistic, non-reductive and monist ontologies, and engagement in of some of the science practices these communities enact.

6. Develop evaluation of biocentric activities that align with current assessment policies

7. Consideration practices and knowledge of nature from various societies, such as First Nations people of Canada, and other indigenous communities, which is often derived from holistic perspectives and monist ontologies that are considered more biocentric than European worldviews (Aikenhead & Ogawa, 2007).

For these suggestions to be tenable, radical reimagining of school science may be needed, in which the purpose of school science is to learn about nature, rather than to use nature to learn science (Östman, 1994; 1996; 1998; Roberts, 1998). Such reimagining of school science may question the need for most students to learn the hard methodological approaches traditionally valued in school science, which set up human dominated power relations with nature (Dryzek, 1997). As Derek Hodson has famously claimed, contemporary students may need to learn about science, more than they need to learn how to do science (Hodson, 2006). A biocentric reimaging of school science might include knowledge for living in nature (Kawagley et al., 1998) from Canadian First Nations and other Indigenous cultures, in which the purpose of knowing nature is not to utilise or dominate it, but to live sustainably with it. Such reimaging of school science, and public education more broadly, may need to occur so that humans can continue to be a part of nature, rather than an extinct species, on Earth.

**Limitations of the Study**

This study is limited to the experiences described by participants, who were all teachers of science in Ontario. However, considering the common curriculum, assessment, and other institutional policies, the results of this study may be applicable to Ontario Grade 9 & 10 Academic Science more broadly. The results may be even more generalizable, however, as ruling relations influencing the constitution of nature can be thought of as trans-local social relations (Smith, 1999), which coordinate school practices in other provincial and even international school settings (Ball, 2008).

This study is based on the claims participants made during interviews about their practice. The validity of the findings of this research is therefore partially dependant on the veracity of what participants said during interviews. However, since subjectivity is largely constituted as a function of discourse, the goal was to gain access to institutional discourse, rather than understand individual beliefs, systems of personal meaning making, or other mental phenomenon that are typically located in the realm of psychology (Sawchuk & Stetsenko, 2008). Evidence suggesting strong correlation between psychological orientations to nature or the environment, and behaviour, is lacking (Hoeg & Barrett, in press; Rickinson, 2005). Additionally, although analysis and discussion suggests how teacher activities might orient students in relationships with nature, this is suggestive, as there is no way to know how students come to know or relate to nature, either psychologically, or behaviorally. Analysis was performed on activities that explicitly describe to students how they must interact with nature to perform the assigned tasks; whether, and how, each student performs the activity, and their responses to it, are beyond the scope of this study. Indeed, intended learning and student responses are often spuriously aligned. For example, participants spoke of students becoming emotionally attached to, for example, the

Daphnia insect, and the Mung bean plant, even though the procedures acted to separate the students from these organisms, and engage them in oppressive practices that often killed it. Investigating students' interaction with nature during science lessons would be a natural next step in this research.

Finally, my own subjectivity is inseparable from my interpretation of the data collected in this research. Experiences as a science teacher, science researcher, and critical science education scholar are pertinent to the way I evaluate participant claims, the patterns in the data I see, and the themes identified. Yet, my positionality does not mean my interpretation of themes and discourses are invalid; it simply means there may be other interpretations that were not as apparent to me, and thus were not included in this thesis.

## Conclusions

I have used theories of structure, agency and discourse, in ethnographic research conducted to understand how nature is constituted in school science. Results suggest nature is constituted as of lesser value than human-centered concerns and priorities, through discourse and practices common in Ontario Grade 9 and 10 Academic Science. These practices are representative of cultural traditions in school science teaching, that engage students in activities that separate them from nature and put them in dominant power relationships that oppress and occasionally destroy nature. That these relationships prioritize and privilege the human above the 'other', reproducing anthropocentric orientations and behaviors in school science that can have wider influence in citizen interactions with nature outside of school (Oishi & Graham, 2005). Anthropocentric practices in school science and the institution of school more broadly, also extend, and may be foundational to, neoliberal capitalist based social discourses present in school science, such as systems of management and accountability. These systems focus science teacher practice on anthropocentric classroom activities that are valued to economic systems of production, such as science knowledge of nature that prepares students for post-secondary education leading to science and technology related jobs.

While theories of social reproduction are well relatively abundant and developed, how social change and reform occurs is not as well understood (Giddens, 1979). This study suggests change must start with knowledge of those organising and subjectifying phenomenon that coordinate our everyday activity, which may be invisible to them in their everyday work. This knowledge is needed so that students, teachers, schools, and communities can see new possibilities, and work towards resisting those structures that may be oppressive, to themselves, and toward nature. This research has provided important knowledge about how the constitution of nature is part of reproductive systems in school science education that resist change. This work needs to be extended and taken into other schools, in other provinces and countries, and explored through other theoretical frameworks, to more fully understand the way nature is socially constituted, in schools, school science, and society. This knowledge may be necessary for societies to develop more biocentric relationships with nature that are needed to sustain natural ecosystems, and life, on Earth.

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# Appendices

## Appendix A - Anthropocentric Worldviews

| Worldview | Tenets |
|---|---|
| Dominant Social Paradigm (DSP)<br><br>(Catton & Dunlap, 1980) | 1) People are fundamentally different from all other creatures on Earth, over which they have dominion.<br><br>(2) People are masters of their destiny; they can choose their goals and learn to do whatever is necessary to achieve them<br><br>(3) The world is vast, and thus provides unlimited opportunities for humans.<br><br>(4) The history of humanity is one of progress; for every problem there is a solution, and thus progress never needs to cease. |
| Scientific Worldview (Cobern, 1991) | (1) the modern scientific worldview is a uniquely Western phenomenon born out of the intellectual tumult of the 16th to 18th Centuries in Europe.<br><br>(2) Scientists (humans) are seen as dominant over nature<br><br>(3) It is a reductionistic view that sees the explanation of the whole in the parts<br><br>(4) Machine-type analogies are considered appropriate for explaining natural phenomena<br><br>(6) It remains a thoroughly empirical view that stresses the importance of testable hypotheses |

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| The scientific worldview<br><br>(adapted from AAAS, 1990) | concerning natural causes<br><br>(1) the things and events in the universe occur in consistent patterns that are comprehensible through careful, systematic study. Scientists believe that through the use of the intellect, and with the aid of instruments that extend the senses, people can discover patterns in all of nature.<br><br>(2) The universe is, as its name implies, a vast single system in which the basic rules are everywhere the same. Knowledge gained from studying one part of the universe is applicable to other parts.<br><br>(3) Science is a process for producing knowledge. The process depends both on making careful observations of phenomena and on inventing theories for making sense out of those observations. Change in knowledge is inevitable because new observations may challenge prevailing theories.<br><br>(4) Although scientists reject the notion of attaining absolute truth and accept some uncertainty as part of nature, most scientific knowledge is durable. The modification of ideas, rather than their outright rejection, is the norm in science, as powerful constructs tend to survive and grow more precise and to become widely accepted.<br><br>(5) There are many matters that cAliceot usefully |

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| | be examined in a scientific way. There are, for instance, beliefs that—by their very nature—cAliceot be proved or disproved (such as the existence of supernatural powers and beings, or the true purposes of life). |
| Worldview components present in Western forms of schooling<br><br>(Bowers, 1997) | (1) A view of the individual as the basic social unit.<br><br>(2) An anthropocentric view of the world that leads to organizing knowledge and constituting values from a human perspective and need.<br><br>(3) Change is viewed as inherently progressive in nature.<br><br>(4) Traditions, except for family holidays, patterns and events, are seen as inhibiting progress.<br><br>(5) The world is understood as secular in nature, with spirituality either being limited to the experience of the individual or explained in functional terms.<br><br>(6) Social development is understood in economic and technological terms.<br><br>(7) Machines continue to serve as the analog for understanding life processes.<br><br>(8) Technologies are created using designs that can be replicated anywhere in the world to maximize profits and ensure central control over the technology.<br><br>(9) There is an increasing reliance on science as |

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| | the most powerful and legitimate source of knowledge. |

Appendix B - Bio/naturecentric worldviews

| Worldview | Tenets |
|---|---|
| New Ecological Paradigm (NEP)<br><br>(Catton & Dunlap, 1980, p.34) | (1) While humans have exceptional characteristics (culture, technology, etc.) they remain one among many species that are interdependently involved in the global ecosystem.<br><br>(2) Human affairs are not only influenced by social and cultural factors, but also by intricate linkages of cause, effect and feedback in the web of nature; thus, purposive human actions have many unintended consequences.<br><br>(3) Humans live in and are dependent upon a finite biophysical environment which imposes potent physical and biological restraints on human affairs.<br><br>(4) Although the inventiveness of humans and the powers derived there from may seem for awhile to extend carrying capacity limits, ecological laws cannot be repealed. |

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| Ecological Worldview (Marten, 2001) | (1) Nature is an interrelated system.<br>(2) Nature has a limited capacity.<br>(3) Nature has value of and for itself.<br>(4).Humankind is an integral part of nature.<br>(5) Human destruction of nature is exceeding natural limits.<br>(6) Humankind is responsible for nature.<br>i) Based on human health and development (shallow ecology).<br>ii) For the reason that all species have an intrinsic right to live (deep ecology). |
| Spiritual Model of Environmental Concern (Ignatow, 2006) | (1) Nature is highly valued, and recognized as something that needs protection<br>(2) Nature and humans should be kept apart<br>(3) The natural world is threatened by modern society<br>(4) Science and technology allow for the increased utilization of nature, and therefore need to be avoided or |

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| | used with extreme caution |

Appendix C – Nature-human relationships in an Ontario Grade 10 Academic Science textbook

| Anthropocentric | | | |
|---|---|---|---|
| **Constructs** | **Themes** | **Frequency** | **Totals** |
| **Concepts** | *Mechanistic processes of Nature* | 62% | 76% |
| | *Nature as a resource* | 8% | |
| | *Fragile Nature* | 5% | |
| **Assumptions** | *Humans separate from Nature* | 31% | 77% |
| | *Hierarchy* | 11% | |
| | *Ambivalence* | 2% | |
| | *Management* | 11% | |
| | *Nature dependency* | 10% | |
| | *Threat/fear of Nature* | 12% | |
| | | | |

| Biocentric | | | |
|---|---|---|---|
| **Constructs** | **Themes** | **Frequency** | **Totals** |
| **Concepts** | *Complexity of Nature* | 11% | 24% |
| | *Nature has intrinsic value* | 6% | |
| | *Nested systems* | 8% | |
| **Assumptions** | *Human dependency* | 15% | 23% |
| | *Cooperation* | 1% | |
| | *Caretakers* | 3% | |
| | *Interdependence* | 4% | |
| | | | |
| **Anthropocentric and Biocentric** | | | |
| **Constructs** | **Themes** | **Frequency** | **Totals** |
| **Concepts** | *all* | 0 % | 0% |
| **Assumptions** | *all (threat/fear of nature* and *human dependancy* | 11% | 11% |

Appendix D - Interview 1 – Experiences in nature, science and general teaching approaches

**Part 1 – Life experiences and teaching history**

1. How did you get into teaching? Why science teaching? What did you think about science/what was your relationship with science? As a child? Teenager? Adult?

2. What were your experiences in nature in your childhood? Growing up? Adulthood? As a student-teacher? As a teacher?

3. Can you characterise some of your experiences in science? What does science mean to you? How has it shaped your life and worldview? (In your childhood; Growing up; As a student-teacher; As a teacher)

4. When I say "Nature of science" (NOS) what does that mean to you? What do you believe the nature of science is? (Ask some more specific questions about this). NOS questionnaire or some other device? Do I really need this?

5. How do you see the relationship between science and nature? What has led you to these beliefs?

**Part 2 – Teaching practice (What influences this. Is there a common culture? What makes up the culture?**

6. Are there things about being a science teacher, things in the profession, or in the school, that highly influence, or even determine, to some degree, what you do as a teacher? What are these? (Now, using the things they identified, get them to expand….how do these determine how they teach? Is there flexibility? How do they come to be so influential? )

7. Characterize your science teaching/teaching style. Ask them for examples. What has led them to this? How does this relate to the influencing components of the profession or school system they identified in question 6?

8. What teaching methods do you use most often? How are these influenced by the components described in question 6? *If there is a particular lesson they describe, get them to talk about that lesson in detail, and how these components guide what they do.*

A) Learning knowledge? Why? Where does this come from?

B)Learning about science and technology? Why? Where does this come from?

C) Doing science and technology? Why? Where does this come from?

D)Engaging in sociopolitical activism? Why? Where does this come from?

9. How do you teach laboratory practicum? (Doing science). Are there regulations about how this needs to be done? Are there some regular methods you use? Can you describe a "typical" one? Where does your idea of what is "typical" come from?

10. What are the things (materials, entities) (such as documents, policies, people, relationships) that influence you the most in how you teach science? In what ways do these influence you?

**Part 3 - Entities/ components of the school system/ profession (Documents/Policies/beliefs (culture)**

11. Do you use these (documents) in your lessons? How do you use them? What do they tell you, or how do they influence how and what you teach?

12. Do you discuss science teaching with other teachers or professionals at school or elsewhere? What do you talk about? How do these conversations influence the way you teach?

13. What personal beliefs about science influence your practice? Do these conflict with the way you teach science?

Appendix E – Interview Two, Institutional texts and teaching nature

**Part I (10 minutes). Review of first interview and question further to substantiate dominant institutional factors (*if needed*).**

- I will summarize some themes I found in first-round interviews, focusing particularly on how these are reflective of what that particular participant said.

- I will backtrack with a couple of participants that I did not get into as much depth with about the "science teaching culture" and the "common repository of materials" (suitcase curriculum) that science teachers draw from to provide the material resources to teach.

**Part II (80-90 minutes). Teacher will be asked to bring to the interview 3 lessons/ activities/ projects that come from the participants personal teaching materials. These activities will be represented in documents that the students use to do the activity. The 3 activities will include:**

i) The one activity the teacher feels is the most representative of the way they want students to engage in science (the best thing they do in their program all year)

ii) An activity that is 'typical' of how they engage students in science inquiry

iii) An activity in which the goal is to teach about nature

**I will ask the following question for each activity before moving on to the next question.**

A) Divergent questions

1. How does this activity fit into the general practices of the school? (*Do other teachers do it?; Where does this activity come from?; Why do you use it?*)

2. How do you use this activity? (*What is the pedagogy, the physical things students do…tell me what you are doing with this activity?*)

3. What are you trying to achieve with this activity? What are you trying to teach students about science in this activity? (*trying to draw out relationships to nature*)

4. Is this derived more from curricular expectations, or science disciplinary expectations, or from what you have observed as what is effective and engaging to the kids in front of you?

Potential focusing questions if needed:

i) How do the science methods students use in this activity *cause* students to *"see" the materials they are using or studying in a certain way??*

ii) Are there assumptions about the materials students are studying? What are they?

iii) Does the purpose of the inquiry/activity *cause* students to *"see"the materials they are using or studying in a certain way?*

iv) Do the procedures *cause* students to *"see"the materials they are using or studying in a certain way?*

iv) Do the likely results of the inquiry/activity *cause* students to *"see"the materials they are using or studying in a certain way?*

5. What sorts of "qualities" or "characteristics" of science does this activity inculcate in students? (*again, leading toward relationships with nature*)

6. How satisfied are you with what the kids do with this? (Explain)

*What are you trying to teach them, what are your intentions in using this activity?*

7. If you had a blank palette, how would you do this differently, if at all? (*removing any institutional restrictions*)

B) Convergent questions

8. How does what the kids are doing relate to what scientists are actually doing? (*getting at emotions and psychology in relation to nature*)

9. In these activities, what do you see the role to be of emotion or psychological attachment to the actual processes, procedures and materials students engage with? (*In the sense that it is representing life as it occurs outside of school*)

10. Here are some key words. *Thinking about what students are being asked to do*, how are these words related to this activity?

- responsibility

-rules

-parameters

-principles

-hidden messages (give a couple of examples)

- control

- dominance

11. Ok, in this activity there are several things that determine what students will do. There are the instructions, the written procedures, the materials, you the teacher, your backgrounds and experiences (teacher education; involvement in a professional science teacher culture); the student themselves? Textbook; Administrators. What are the relationships between these? What are the "big" influencers? What do these "big influencers" do to inform what the students will do?

*Why did this activity "make it" into your personal repository of teaching materials?*

C) Convergent questions to use at the end of the interview (getting right to the heart of the issue I am interested in)

12. What are the institutional/school components that influence your selection of this activity? (*draw them to one or two, such as science teacher culture*). How does this inform you about to what should be achieved with this activity. (*drawing out their understanding of the "rules" in these institutional factors inform the teacher about how human relationships with nature are to be demonstrated in school science*)

13. Last question –spill it out. Here is a way of looking at school science. People have claimed, there is this view of humans as being separated from nature, and it might play out in the way students are asked to practice science, for example doing labs (*explain this to them*). Tell me about how you feel about this statement, and is it relevant to these activities?

14. How do you relate to nature and how do you work it into science activities and/or inquiry?

15. How would you define nature?

# Copyright Acknowledgements (if any)