Teaching Towards Deep Ecological Understanding: Sociocultural Influences and Epistemic Navigation in Outdoor Science Education

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Abstract

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This dissertation begins with a description of the territory that lies between sociocultural theory, education, and the natural world. It consists of three separate studies that all focus on moments of science teaching and learning that are intentionally situated outdoors. The second, third and fourth chapters are written as somewhat independent manuscripts, but they all revolve around the central concept of teaching and learning with and within complex ecological systems as influenced by nature-culture relations. The second chapter focuses on school gardens and is a case study of one garden educator working within a series of systems that influence her teaching. Culture and power are not often discussed in this context and human dominance is often taken as a given, reifying human exceptionalism. An analysis of the ethnographic data shows that normative and power-laden structures actually prevent her from sharing her expertise with students while she is teaching. I outline how those structures manifest in the garden lessons and the teacher's

moves of resistance. The third chapter investigates the role of teachers in science learning in the outdoors, positioning the natural world as an active agent in student learning. The researchers designed and implemented a curriculum that used Indigenous teaching methodologies. By adopting instructional practices that promote a relational standpoint to the natural world, instructors position children to draw upon the strengths of knowledge-in-context rather than asking them to integrate discordant epistemologies. Results suggest that instructional moves that draw attention to relationships and ascribe agency to the natural world facilitate a deeper understanding of complex systems reasoning. In the fourth chapter, the study examines the educational implications for Indigenous youth when stories are used as an epistemological tool to theorize about more-than-human beings. Youth were encouraged to observe and engage in the perspective of different rocks during a field-based Indigenous learning seminar. Using chronotopic analysis, the results showed that youth reasoned across a range of timeframes and ecological scales. This onto-epistemic flexibility may ultimately prove to be a key to encouraging agentic reasoning when teaching and learning about complex ecological systems.

Keywords: Environmental education, Science education, Epistemic navigation, Indigenous pedagogies

DEDICATION

In memory of David Lee McGinty
January 18, 1944 – March 26, 2017

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CHAPTER ONE: SOCIOCULTURAL THEORY, THE LEARNING ENVIRONMENT, AND THE MORE-THAN-HUMAN

Sociocultural Theory

We are currently witnessing the most profound biogeophysical changes to occur in modern human history, and responding to these changes will require a widespread re-imagining of how humans regard and interact with natural systems. In short, it will require a reorientation of our epistemological, ontological, and axiological perspectives concerning the human-nature relationship and ultimately, an acknowledgement of both the intense dependence of humans upon the planet Earth and the tenuous nature of that dependency. This dissertation focuses on cultivating transformative teaching methods for understanding ecological systems.

Our surroundings have a strong influence on what we learn. The application of sociocultural theory and human development has contributed a great amount to understanding the influence of different factors on learning and meaning-making. Situated theory in particular has been useful in making the case that environments have an impact on knowledge development. However, for the most part, educational research has focused on those parts of the educational environmental that are human-mediated, and/or operated under the assumption that humans can control every aspect of the educational environment. Science education, environmental education, ecological education, and other educational fields concerned with the non-human, or more–than-human (MTH)—rocks, plants, water, the land that surrounds us, and other aspects of the natural world— have all tended to reinforce the human-nature divide, which in turn allows us to disregard the MTH. During the rest of this chapter I will outline the role that education, as an extension of culture, plays in understanding the ecological world and the MTH.

Culture and Learning

Psychologist Lev Vygotsky and early proponents of his work developed ideas concerning the influence of culture on learning (Nasir & Hand, 2006). Activity theory, or cultural-historical activity theory, is a central tenet of Vygotsky's theories. Cole outlines the three foundational concepts of activity theory by saying "[T]he structure and development of human psychological processes emerge through culturally mediated, historically developing, practical activity" (Cole, 1998, p.108). Cultural practices, family members, community norms, linguistic patterns, and numerous other elements are all participating factors in creating knowledge that surrounds and influences an individual organism from its inception (Rogoff, 2003). Although we speak of an individual organism, it is important to remember that the individual is a member of many communities. The knowledge that a community holds is shaped by all of its members, which in turn are shaped by the community (Gutiérrez & Rogoff, 2003), forming a reflexive series of influences that prevent a body of knowledge from being static. In other words, despite its profound influence, culture is not a fixed, deterministic predictor of people's actions, needs, desires, etc., nor does it reside in any one fixed location.

Situated Activity

Situative activity theory focuses upon learning environments as key factors in learning and human development. There are many facets to situative activity theory, with situated cognition, situated leaning, ecological psychology, and distributed cognition being the most prominent (Durning & Artino, 2011). James Greeno writes of situative research: "Analyses that use the situative perspective consider learning environments as activity systems in which learners interact with each other and with material, informational, and conceptual resources in their environment" (Greeno, 2006, p.92). Emphasis is placed upon human activity within a system, the

learning environment, with activity constantly being negotiated and constructed by the participants as they interact with the learning environment and each other.

Specific research topics on learning environments have included argumentation (Bricker & Bell, 2008; Manz, 2014), power (Cornelius & Herrenkohl, 2004), student motivation (Azevedo, 2013), identity (Nasir, 2002), subject domain (Stevens, Wineburg, Herrenkohl, & Bell, 2005), culture and diversity (Nasir, Roseberry, Warren, & Lee, 2006), among other factors. Some inquiries specifically investigate the influence of physical space— for example, classroom design (Brooks, 2011) or the social implications of different school settings (Barton & Tan, 2009; Bell, Bricker, Reeve, Zimmerman, & Tzou, 2013; Nasir & Hand, 2008). The seminal report on the science of human learning, "How People Learn" (Bransford, Brown, & Cocking, 2000) has an entire chapter devoted to the design of learning environments; its four main points are concerned with the importance of "[T]he degree to which [learning environments] are student centered, knowledge centered, assessment centered, and community centered" (p.153).

The fact that these are all ideas dealing with nonphysical phenomena, or processes considered to be located within the human mind, rather than with the concrete surroundings, is notable. A 2014 literature review of educational learning environments by Cleveland and Fisher, who note that "The term 'learning environment' is regularly used to refer to the social, psychological or conceptual environment rather than to the physical learning environment or space" supports this observation. The review then goes on to define educational spaces as the buildings in which teaching and learning occur, bringing the focus of the research back into human-created parameters.

The literature makes a powerful case for considering the influences of factors both visible, current, and prominent, as well those that are invisible, historic, and intrinsic, as

profound shapers of human development and learning. However, throughout all of these studies there is no consideration of the world beyond the bodies or minds of the learners and teachers. There is reference to community (Bransford et al., 2000) and culture (Rogoff, 2003), but these are references to human, and only human, communities. In fact, culture becomes a problematic construct when studying human/ nature interactions, in that it necessitates the exclusion of the nonhuman. According to sociocultural theory, cultural mediation refers to the human modification or manipulation of physical surroundings (aka tool use), in order to interact with each other and the world. Cultural mediation also includes conceptual mediators, especially language, thus begging the question of what happens to those that do not share 'language', whether it be idiom, ability to speak, or communicating by human standards (i.e. speech).

Ecological Education and Human Exceptionalism

Educational research that explicitly addresses human-nature interactions is often classified as ecological education, which in turn is usually within either or both the domains of science education and environmental education. There is a substantial body of work, crossing many disciplines, addressing the more-than-human— science education, environmental education, outdoor education, ecological education, and place-based education are only a few of the myriad fields devoted to investigating human / more-than-human interaction in educational settings. For the purposes of this dissertation, I will use the term ecological education to refer to educational content that includes the interaction of biotic, abiotic, geophysical and /or human factors. There are some scholars that consider ecological education a subset of environmental education, but to do so is to ignore the many lessons concerning Earth systems, biology, and/or human decision-making that take place in science education classrooms. Variations in ontology, epistemology, pedagogy and policy between environmental and science education (Dillon &

Scott, 2002; Gough, 2002) have led to widely different social and political stories for the two fields, necessitating that each field receive further treatment here.

Science Education

Western science narratives from the recent past hold humans as either separate from the laws that govern the natural world and/or able to control nature, hinting at a doctrine of human exceptionalism (Catton & Dunlap, 1978). Human exceptionalism (also known as human exemptionalism) is "the premise that humanity alone is not a spatial and temporal web of interspecies dependencies" (Haraway, 2008, p.11), that is, humans are separate from Nature and it is their destiny to continue to reify and mark that separation. The current mainstream practices in science education support this view by narrowing scientific study into specific disciplines and modeling ecological processes out of context. Research and curricula that take up ecology as science content have to contend with a highly-developed system of disciplinary specialization with much attention given to crossing disciplinary boundaries within the sciences (Buhr, 2011; Venville, Rennie, & Wallace, 2012).

For the most part, ecological education that occurs under the purview of science education entails activities that are partly or wholly conducted in classrooms, closed systems in which the more-than-human has become decontextualized from agent-in-ecosystem to object of study. In Hogan's 2000 study, students created ecosystem models by combining aquariums and terrariums and then introducing pollutant into the models. Student learning was then assessed by a card tasks and a food web analysis. Lauer (2005) presents a quantitative analysis exercise (eating Hershey's kisses within a time limit) as a method of demonstrating predator-prey relationships. For further examples see: Covitt, Gunckel, and Anderson 2009; Gunckel, Covitt, Salinas, and Anderson, 2010; Jin and Anderson, 2010; Joyner, Majerich & Goel, 2013; and

Mohan, Chen, and Anderson, 2009. These efforts still adhere the discourse and practice patterns of mainstream science education: lesson content is presented indoors via models or materials; there is a focus towards summative content assessment; and human exceptionalism is implicit (and often explicit).

Environmental Education

The ontological and epistemological treatment of the natural world has been problematic for some Environmental Education (EE) researchers and practitioners. Some scholars charge that a significant portion of Environmental Education research is conducted under the same positivistic traditions enacted in science classrooms (Gough, 1999; McKenzie, 2005). Recent critical research in Environmental Education questions the dominant discourses of human supremacy (McKenzie, 2005) and the position of land (Whitehouse, Watkin Lui, Sellwood, Barrett, & Chigeza, 2014) that are taken for granted in formal science education. For many critical Environmental Education scholars, the tension is great enough to warrant a distinct separation from science education. Gough (1999) writes:

> Thus, for me at this time, rethinking the subject in/of environmental education research involves a continuing alertness to the need to resist the particular forms of subjectivity and 'objectivism' that many Environmental Education researchers have appropriated from science education research. (Conclusion)

Smith & Williams (1999) state that ecological education "connotes an emphasis on the inescapable embeddedness of human beings in natural systems." (p.3) and they work to distinguish ecological education from environmental education, asserting that Environmental Education has failed to address the status quo of Western progress and thus the cultural change necessary for spanning the human nature-divide. By “tracing the dualisms of environmental

education" (p.12) Adsit-Morris (2015) adroitly lays out how, despite support from a broad base of interests, Environmental Education remains unable to free itself from a nature/culture binary and thus is susceptible to manipulation by neoliberal interests. These concerns are bolstered by the recent global move towards sustainability education, or education for sustainable development (ESD). The UNESCO Global Action Programme on Education for Sustainable Development defines ESD as education that "[E]mpowers learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society, for present and future generations, while respecting cultural diversity" (UNESCO, 2016). Kopina (2012)and other scholars voice concern that the inclusion of economic viability frames ESD as a re-anthropocentrization of Environmental Education. By and large, science and environmental education practices confirm (rather than trouble) any assumptions of human exceptionalism (Gough, 1999) by reinforcing binaries of objectivity-subjectivity, human-nonhuman, nature-culture.

Cognitive Barriers

A central challenge to ecological education is the fact that ecological systems are very complex, with multiple nested sub-systems within larger systems. Educators often resort to over-simplified models for the sake of assessment (Hmelo-Silver & Azevedo, 2006, p.54), Additionally, there is increasing evidence that in technologically-oriented cultures, a lack of familiarity with ecological phenomena impedes systems understanding (Atran & Medin, 2008; Levy & Wilensky; 2008; Louv, 2005).

The current model of science and environmental education, with their emphases upon separation, actually works against students' abilities to develop ecological reasoning (Gonzalez-Gaudiano, 2001). Hmelo, Holton and Kolodner (2000, p.293) point out that the typical science

classroom practices of a) researching extensively before "doing" and b) ending in a single final product, can inhibit approaches that rely on iterative experimentation to develop concepts. Pagan (2010) argues that focusing only on the quantitative water–quality data gathered when studying a river presents a reductionist view of the river and inhibits students' abilities to form relationships with the river as a complex biological system. Educational literature tends to be single-level and "… schools find themselves perpetuating… science curricula that are organized around decontextualized factoids, outdated models, and analytic arguments that are of limited use in a complex world" (Davis & Sumara, 2006, p.133). In a similar vein, Colucci-Gray, Camino, Barbiero and Gray (2006) question the positivistic assumptions of mainstream science education, particularly that

> …knowledge of the whole can be achieved through the knowledge of the component parts; most issues and events may be regarded as discrete quantities; partition and segregation can ensure objectivity, by elimination of interferences and unknown disturbances; and that we can predict future outcomes by making a linear extrapolation from the past history and present conditions of the system… (p.236).

Up until this point, I have focused on the difficulties that science and environmental education present to a broad audience. When we turn to populations that do not adhere to Western science narratives, different issues arise.

Culture, Complex Systems, and Ecological Cognition

Cultural perspectives of the natural world have a distinct effect upon abilities to comprehend ecological systems. Assaraf and Orion (2005, 2010) and Assaraf, Esach, Orion, and Alamour (2012) have conducted a series of studies investigating cognitive influences on student conceptions of ecological systems. At the same time, Atran and Medin (2008); Atran, Medin,

and Ross (2005); Bang, Medin, and Atran, (2007); Bang and Medin (2010); ojaleto, Waxman, and Medin (2013); and ojaleto, Medin, Horton, Garcia, and Kays (2015) have all investigated the influence of culture on human perspectives of the natural world, particularly in correspondence to the relational epistemologies of specific Indigenous groups. The combined findings of these researchers suggest that there is a connection between outdoor experience, relational epistemologies and deep ecological understanding.

Medin and Bang (2014b) used both Indigenous and standard science epistemologies with a group of students in a summer program and reported significant increases in students' complex-systems reasoning skills. They argue that "…there are substantial cultural differences in framework theories or epistemological orientations toward the natural world and [that] these differences affect science-related practices…" (p.100). More specifically, the researchers employed construal-level theory and psychological distance to explain the differences between Native American and European American orientations to ecological science. Native American participants were more likely to foreground nature in their outdoor practices, include humans in the natural world, and produce children's literature with close perspectives of the natural world.

Bang, Medin, and Atran (2007) found a stronger ecological orientation and understanding in Menominee fisherman and children than their majority culture counterparts; Assaraf et al. (2012) found that Bedouin students had richer mental models of the water cycle and were much more likely to place water in the context of seasons and their own habitat, in effect relating it to other systems. Finally, in a study of working- and middle-class participants in Brazil, Olsen (2015) found that "complex systems thinking outcomes are affected by both cultural epistemologies and practices" (p.2). Each of these studies points to the influence of culture on epistemologies, which in turn, has an influence on students' ability to understand complex

ecological systems. When we consider this in light of current ecological education practices, we begin to see that the perpetuation of the human / more-than-human divide and other binaries impede our ability to understand the more-than-human. In recognition of this, some scholars have attempted to move beyond these binaries by looking to post-structural critiques and turning to theories that focus on the power of material (or more-than-human) objects.

More-Than-Human Agency

Several branches of scholarship have been attempting to draw attention to the role that the MTH plays in influencing human lives; what sets them apart is their treatment of the MTH as entities, with desires, intentions, and capacities to those of humans. In the next section, I will focus on two approaches that come from different philosophical traditions, science and technology studies and Indigenous knowledge systems. Both approaches focus on the relationships between entities, both human and non-human, to draw out the influence that MTH entities bring to social life.

Actor-network Theory

A relatively recent area of study focuses on the abilities of 'things' to influence human lives (Bennett, 2009; Deluze & Guttari, 1988; Latour 1991 & 2005). A foundational branch of this field, actor-network theory (ANT), is concerned with meaning-making and the more-than-human (referred to in this case as material-semiotics). It is often used in sociotechnical analysis and "treats entities and materialities as enacted and relational effects, and explores the configuration and reconfiguration of these relations. Its relationality means that major ontological categories are … are treated as effects or outcomes, rather than explanatory resources." (Law, 2004, p.157). Agency is thus ascribed to objects not so much by the actual powers they possess but by the role they play in a network of interactions, or their relationships

to other things. Bruno Latour, one of the primary developers of ANT (along with Law and Michael Callow) describes ANT's main tenet as "that actors themselves make everything, including their own frames, their own theories, their own contexts, their own metaphysics, even their own ontologies" (2005, p.147). ANT specifically seeks to emphasize that "any course of action will rarely consist of human-to-human connections (for which the basic social skills would be enough anyway) or of object-object connections, but will probably zigzag from one to the other" (Roehl, 2012, p.75). Additionally, ANT "is co-constructionist. It seeks to identify how relations and entities come into being together" (Murdoch, 2001, p.111). These features make ANT well-suited to exploring knowledge-building relationships between humans and the more-than-human.

Several scholars have explored ANT's implications for science education. Using Deleuze & Guattari's "migrations of rhizomatic and nomadic thought" (p.625), environmental education scholar Neil Gough (2006) traces the trajectory of mosquitoes through various texts, articles, studies, science fiction novels, to reveal the social, historical, and political nature of malaria. He highlights science education's inability to convey the complexity of current sociotechnical issues by drawing attention to the fact that a state-endorsed biology textbook discusses malaria in isolation of political, epidemiological, or other "cultural determinants" (p.637). Pierce (2015a) points out that "there has been almost no work done on developing a model of scientific literacy that is capable of dealing with the imploding human/nonhuman boundary that has occurred after the human genomic code was deciphered 10 years ago" (p. 85). He uses ANT as a pedagogical method, giving agency to salmon, which allows students to develop a scientific literacy appropriate to the intertwined social and ethical issues that characterize current science topics in education. Roehl (2012) focuses on the educational environment, using ANT to highlight the

relationships between human actors and material objects in the science classroom, declaring that epistemic objects are entangled, thus co-creating and shaping knowledge with the students. The fact that material objects, indeed environments themselves, play a role in making knowledge means that in order to conduct effective ecological education, we must surround students with those ecologies we are trying to teach them about. But it is not just the objects themselves that matter, it is the relationship between the objects involved in the meaning-making that is important.

Relational Epistemologies

Indigenous scholars Marin and Bang, drawing on other Indigenous scholars (Burkhart, 2004; Cajete, 2000; Kawagley, 1995), define relational epistemologies as "The ways in which knowledge, its source, scope, and validity, knowledge organization, knowledge construction, and knowledge dissemination are rooted in the premise that everything is related, that is, connected in dynamic, interactive, and mutually reciprocal relationships" (Marin & Bang, 2015). Bird-David (1999) defines relational epistemology as a way of knowing based on interaction between the actor-perceiver and things-in-situations. Beeman and Blenkinsop (2008) refer to “the ontological enactment of attentive receptivity", wherein

> The significance of this state of being … is that it not only offers these conditions of ontological difference whereby what self is changes, but it also is a state in which the borders of the self relax, and become permeable with the more-than-human world. (p.98)

Medin et al. (2014) go so far as to describe four markers for relational epistemologies “(1) perspective-taking, including taking the perspective of nonhuman entities, (2) sensitivity to ecological relations, (3) nontaxonomic conceptual organization, and (4) attention to context and relations linked to it” (p.179). Like posthumanist approaches, relational epistemologies

emphasize interdependencies, permeable and indistinct borders, and the importance of the more-than-human. However, relational epistemologies extend greater commitment to the "nondifferentiation between humans and animals" (Vieveros de Castro, 2004, p.464) by recognizing the agency and personhood of the more-than-human and providing "frameworks for reasoning and problem solving in terms of ecological, reciprocal, and correlational relations" (Bang, 2015, p. 9). Contrary to the Western-influenced narratives of post-structuralism, post-modernism, and post-humanism, Vieveros de Castro (2004) asserts that for Amerindian peoples the great divide is not humans leaving nature, but "nature distancing itself from culture" (p.464). Taken a step further, this implies that being a human is not a step up in the world of being(s), nor is it a morally ascendant position. Regarding humanity in this light unseats a whole host of humanist theories, including some of their variants, such as environmental stewardship, racial differentiation, dominion over the earth, manifest destiny, and so forth.

There is a connection between relational epistemologies and deep ecological understanding; given that a human nature-divide has characterized mainstream science education (Bang, et al., 2014; Brayboy & Maughan, 2009; Ingold, 2000), we are given pause in considering future efforts in ecological education for all peoples. "[T]he severance of people from lands…is a critical issue facing human species, as it has led to destructive social and economic systems—in short, axiological innovation in nature–culture relations is necessary for all peoples and communities" (Bang, Faber, Gurneau, Marin, & Soto, 2015, p.7).

Indigenous Relationships to Land

For the indigene, Land is their birthplace, the place of their ancestral origin, tied into their very being, physically, emotionally, spiritually (or ontologically, epistemologically, and axiologically). They are the Land and the Land is them (Cajete, 2000; Deloria & Wildcat, 2001;

Kawagley, 1996; Meyer, 2008; Burkhart, 2004). Meyer (2008) articulates a (Native) Hawaiian epistemology as a relationship with Land: "Land/ocean shapes my thinking, my way of being, and my priorities of what is of value" (p.219). Bang et al. (2014) summarized a Land-based ontology as "Land is, therefore we are" (p.44).

This description was taken up by Tuck and McKenzie (2014), who pull in the works of other scholars to reiterate that Land is not just a material phenomenon, but holds cultural, spiritual, emotional, intellectual, historical, and genealogical aspects. Styres, Haig-Brown and Blimkie (2013) state that Land is sentient and has an existence beyond the range of human memory. This relationship is vital to humans ("Land is life—or, at least, land is necessary for life. Thus contests for land can be— indeed, often are—contests for life"{Wolfe, 2006, p. 387}), to the point where separation from land causes physical and mental harm for generations to come (Walters, Beltran, Huh, & Evans-Campbell, 2011). Elliot-Groves (2018) traces Land separation via settler permanency and documents how the extended trauma impedes tribal-nation futurities and contributes to suicidal behavior. Indeed, it is in the relationships to Land where the damage of settler-colonialism is done most effectively.

Carter (2004) notes that "one of the most durable aspects of colonization has been the imposition of binary thinking" (p.827) and that simply adopting an oppositional stance is not sufficient, and in fact can even serve to further reify hegemonic structures via "double moves of translation and appropriation" (p.829). An important factor in Indigenous relationships to Land is an open acknowledgement of the importance of values and ethics in establishing and maintaining relationships. This is in direct opposition to the Enlightenment ideal of an acultural scientific objectivity into which most ecological educators and researchers have been inculcated (Aikenhead, 2008).

Land Education

The field of Land education takes these long-standing ontological commitments into account and thus honors a dimension Science, Environmental, Outdoor, Place-based and many other forms of ecological education ignore— the dimension of time, on a scale both beyond the modern and the human. Attention to temporality (in this case, futurity) is what differentiates settler-colonialism (in which colonialism is an ongoing structure) from post-colonialism (where colonialism is something that happened once, in the past, and is thus now inert). Settlers turn Land into capital, a commodity with no ties to ways of being and knowing and hence "[e]pistemological, ontological, and cosmological relationships to land are interred" (Tuck & Wang, 2012, p.5). In order to turn the Land into capital, the settler must disconnect the indigene from the Land, and the very act of severance itself is one of violence.

Notions of temporality are a key distinction between Indigenous philosophies and epistemologies and Western science philosophies and epistemologies. The past carries forward, continues to be a factor, but the future it projects is not a given. "You came from a place. You grew in a place…*This is an epistemological idea"* (Meyer, 2008, p.219, italics the author's). In developing her own framework of desire, Tuck (2009) says it "…is involved with the *not yet* and, at times, the *not anymore*" (p.417, italics the author's). Riggs (2004) speaks to the importance of situating geological education within a physical and cultural context, pointing out that the Indigenous knowledge utilized in tribal management decision-making is premised on a timescale that is far more appropriate for making land-based decisions than the timescales utilized by mainstream agencies.

The importance of a Land-based temporality in ecological education becomes clearer as we turn to the current (and pressing) concerns presented by climate change education. If we

ignore the history of Land, both in the humans that preceded us and in the history of the land itself, we insist on positioning Land as static, fixed in a certain time and state. As anyone who lives near an ocean, glacier, volcano, fault zone, or any other large-scale geologic phenomena, Land is anything but static and stable. Even on a human-temporal scale, the changing states of water, winds, and weather, and their secondary and tertiary effects (shifts in sea level and habitat, species migration, crop abundance or failure, conflict over water rights, etc.) are best suited to the ecological dynamism and complexity recognized by relational epistemologies. This same dynamism is present in Western science as well-- our understanding of Earth science is very different than it was thirty years ago, and most scientists will readily admit that many scientific 'facts' will change over the next thirty years (McGinty & Bang, 2015). Science education needs to more accurately reflect the actual practice of science by acknowledging this land dynamism in classrooms.

Positionality

Two chapters of this dissertation are based on work conducted with the urban Native communities in Seattle and Chicago. I do not consider myself indigenous to the Americas; to the best of my knowledge, my ancestors are predominantly indigenous to Ireland, Scotland, Germany, the Netherlands, and other unknown lands before they arrived in the Americas as settlers. There is one maternal ancestor several generations removed that came from people indigenous to present-day Southeastern Canada, but her ancestral and cultural background has been lost and/or erased.

My motivating educational passion and primary scholarly interest has been in the connection between humans and the Earth, or the Land. I have come to believe that our best hope of continued existence is to make a much deeper relationship with the Land, and to learn from it.

This belief led me to the work of Native scholars and communities, as it is they who have best maintained the relationship that comes from speaking with and learning from the land. I have had the privilege of being mentored by and working alongside many members of the Native community, and have learned much from the experience.

I have also become familiar with the troubled history between settlers and Natives, a large part of which is the appropriation of Native culture, and kept this in mind while learning alongside Native scholars, and it is in my mind even as I seek to bring relational ways of knowing to mainstream science education. To do so is to risk yet again repeating the cycle of appropriation. At the same time, I am driven by the belief that all people have a fundamental need to connect to Land and that we all carry within us the seeds of forgotten indigeneities.

Putting Theory into Practice

In this dissertation, I will focus on the influence of underlying assumptions and premises on the pedagogical options and sense-making of teachers and students who are participating in field-based ecological education. An important part of this investigation is the role of the MTH in creating knowledge. We need to begin giving serious consideration to the MTH aspects of the educational environment. Investigating these entities in a manner that acknowledges their presence, power, and potential requires addressing matters of morality, ethics, and equity in science education and questioning how current epistemological, ontological, and axiological orientations are represented (or neglected) in science and ecological education.

While ecological education is important for everyone, it is even more important that we teach kids to understand and work with the MTH because they are the ones who will be dealing with the imminent changes in our rapidly shifting socio-ecological systems. The Next Generation Science Standards, with their emphasis on understanding intertwined human-natural systems, are

a significant move to address this need at a policy level. On an applied level, two educational theories that have attempted to break the human-MTH binary are actor-network theory and relational epistemologies. Finally, curricula that privilege the MTH by locating learning activities outside of the classroom, within non-human-modified environments, create significant opportunities for ecological meaning-making. To date, there is not a widely used framework that incorporates these ideas into science education.

In the following chapters, I will further develop the ideas in this chapter through a series of studies. There is some overlap in the writing, as the chapters were written to stand alone as drafts for journal articles. In the first, I will examine the double-bind of garden educators as they work within school gardens. In the second, I will present an example of educators putting relational epistemologies into practice, comparing an Indigenous educator and a non-Indigenous educator. The third study is an examination of the ontological and epistemological effects of different conceptions of time and place.

CHAPTER 2: "SO TEACHING KIDS HOW TO GROW FOOD IS PRETTY RADICAL": THE ECOLOGICAL POTENTIAL OF GARDEN EDUCATION

Introduction

School gardens hold great potential as venues for ecological education. A deliberate mixture of human and more-than-human entities, they exist squarely in the intersection of the social and natural worlds. To use gardens to their fullest educational potential, we need to consider the wider social contexts around them; geographic, political, historic and other factors all affect the activity that takes place within a garden. When teachers engage in school garden education, we bring with us a host of filters and assumptions that affect the teaching and learning that takes place in the garden. Some of these assumptions are seated in the teacher's own epistemology, but a significant portion of them comes from the greater social environment surrounding the teacher, students, and garden. These factors are rarely noted or accounted for in in garden education research literature.

In this case study, I focus on an experienced garden educator and outline her ecological knowledge of and her pedagogical practice within a teaching garden. I then examine the differences between the two and work with the educator to understand reasons for the differences. There were several significant social factors that influenced the teaching and learning activity in the garden, to the point of influencing the educators' pedagogical practice. I conclude by examining ways in which we could create conditions that would allow gardens and garden educators to live up to their full potential as places for exploring and understanding ecological systems.

Nature-Culture Relations

Considerable attention has been devoted to the relationship between humans and the natural world. In the anthropological, sociological, and philosophical literature, postmodern environmental scholars have recognized the schism created by rationalist theory and have developed a variety of terms in an attempt to address it. Donna Haraway (2008) used *natureculture*, while Dickinson (2016) uses *humanature*. Following Bang and Marin (2015) I use the term *nature-culture relations* in support of the assertion that human activity is inseparable from the natural world and that nature-culture relations influence the core ontological, epistemological, and axiological conceptions upon which we build knowledge and engage in activity.

Our surroundings have a strong influence on what we learn. The application of sociocultural theory and human development has contributed a great amount to understanding the influence of different factors on learning and meaning-making (Cole, 1998; Rogoff, 2003). Situated cognition has been useful in making the case that environments have an impact on knowledge development (Brown, Collins, & Duguid, 1989), especially in regard to communities of practice (Lave, 1991; Lave & Wenger, 1991). However, for the most part, educational research has focused on those parts of the educational environmental that are human-mediated, and/or operated under the assumption that humans can control every aspect of the educational environment (Catton & Dunlap, 1978). Science education, environmental education, ecological education, and other educational fields concerned with the non-human, or more–than-human (MTH)—rocks, plants, water, the land that surrounds us, and other aspects of the natural world—have all tended to reinforce the human-nature divide, which in turn allows us to disregard the

MTH (Dickinson, 2011; Gough, 1999; Kopina, 2012, 2014; McKenzie, 2005; Smith & Williams, 1999; Whitehouse, Watkin Lui, Sellwood, Barrett, & Chigeza, 2014).

Culture plays an important role in how we learn (Cole, 1998; Gutiérrez & Rogoff, 2003; Nasir & Hand, 2006; Rogoff, 2003; Wertsch, 1988), and this is especially true in regards to the natural world (Assaraf & Orion, 2005, 2010; Assaraf, Esach, Orion, & Alamour, 2012; Atran & Medin, 2008; Atran, Medin, & Ross, 2005; Bang, Medin, & Atran, 2007; Bang & Medin, 2010; Medin & Bang, 2014a & 2014b; ojaleto, Waxman, & Medin, 2013; ojaleto, Medin, Horton, Garcia, & Kays, 2015). Inherent in these cultural influences are impediments and affordances to the ability to form robust mental models of complex ecological systems (Henrich, Heine, & Norenzayan, 2010). The human/nature divide is evident in typical science classroom practices, where messages about the separation of humans and the MTH are presented and reified (Colucci-Gray, Camino, Barbiero, & Gray, 2006; Davis & Sumara, 2006; Gonzalez-Gaudiano, 2001; Hmelo, Holton, & Kolodner, 2000; Pagan, 2010). Ironically, this same division is also presented in many environmental education efforts (Dickinson, 2011; Gough, 1999; McKenzie, 2005; Smith & Williams, 1999; Whitehouse et al., 2014), including school gardens.

Humans, Culture, and Ecosystems

Humans have had a relationship to plants ever since they appeared on the Earth. The first harvesting methods consisted of knowing where useful plants grew and when they were ready to be collected. By observing the plants and experimenting, people began to figure out how to influence their growth. Whole families and communities worked together to develop more careful and elaborate ways to cultivate plants for human use. Over the years, humans designated specific areas for the express purpose of growing fruits, vegetables, grains, herbs, building

materials and anything else we needed. Children were included in the work, learning to sow, tend, and collect in the fields and forests. These were our first learning gardens.

The connection between humans and their immediate surroundings is very clear. A substantial body of research documents the connection ecosystem health and human well-being (i.e. Diamond, 2005; Montgomery, 2012). For a significant period of human existence, people have been aware of their presence as a part of the ecosystems they are in. Recognizing this role, as *a part of* a complicated, dynamic series of cycles and systems, requires the presence of other aspects of these systems. While these different entities may not be fully understood (or even known), their roles as co-actors and influencers of the system is acknowledged and respected.

Carolyn Merchant (1996) illustrates how the movement of settler-colonialists across the US brought a specific public discourse that portrayed uncolonized land (and peoples) as being in a state of chaos, neglected, and in need of repair. According to this narrative, it was the moral duty of the European settler to develop the land by planting and harvesting crops, many of which were foodstuffs. In this version, it is through the industriousness of these early colonialists that the US grew to a productive and powerful producer of manifold goods. More importantly, this narrative positions humans as being *apart from* nature; rather, they are agents of industry, recovering and redeeming the land as they tame the wilderness. This story has become the mainstream narrative of US history— many accounts of the history of US garden education begin after westward expansion, often crediting European educators for the initial impetus to incorporate gardens into schools (i.e. Desmond, Grieshop, & Subramaniam, 2002; Gaylie, 2011; Kohlstedt, 2008; Lawson, 2005; Subramaniam, 2002; Walter, 2013). By failing to examine the deeper history of humans and land, many school garden programs thus reinforce the human-nature divide.

Garden Education

School gardening has become an educational movement in the past few decades and a robust body of literature has grown around gardens, food, children, and education. The locations and circumstances surrounding this phenomenon are diverse enough that the terms garden-based education (Williams & Dixon, 2013) or garden-based learning (Desmond et al., 2004) has been adopted to designate organized educational efforts that occur in gardens, whether they are community gardens or gardens specifically associated with a school or other youth-oriented educational organization. In this manuscript, the focus is on formal educational opportunities for children and I will use the term garden-based education (GBE).

There are numerous articles attesting to the physical, mental, and academic benefits of GBE programs. The wide range of research topics represented include: students' performance in science education, literacy, art, and math; childhood obesity; food preferences; social development; and, prominently, nutrition. (c.f. Berezowitz, Bontrager Yoder, & Schoeller, 2015; Blair, 2009; Bowker & Tearle, 2005; Glover, Shinew, & Parry, 2005; Graham, Beall, Lussier, McLaughlin, & Zidenberg-Cherr, 2005; Heim, Stang, & Ireland, 2009; Hermann et al., 2006; Klemmer, Waliczek, Zajiczek, 2005; Krasny & Tidball, 2009; McAleese & Rankin, 2007; Morgan, Warren, Lubans, Saunders, Quick, & Collins, 2010; Morris & Zidenberg-Cherr, 2002; Ozer, 2007; Parmer, Salisbury-Glennon, Shannon, & Sreumpler, 2009; Skelly & Bradley, 2007; Smith & Motsenbocker, 2005; also see Williams & Dixon, 2013). By and large, the results have been in favor of GBE for children in school and community gardens, with a myriad and widespread array of claims to their benefits.

Critique and culture in garden education. Desmond et al. (2002) noted that a first challenge to garden-based education research is identifying and defining the field. Williams and

Dixon's (2013) investigation of the academic impact of garden-based learning concluded that "…the body of research on garden-based education lacked focus and clarity" (p. 224). Guitart, Pickering and Byrne (2012) conducted a review of community garden research literature and found a similar lack of coherence, noting in particular the lack of depth regarding what was grown in the garden and gardening practices, pointing out that these are key factors for assessing the sustainability and environmental impact of gardens. In their research synthesis, Williams and Dixon (2013) rejected two-thirds of the initial article pool because articles were not empirically based, did not measure outcomes, and /or were of insufficient research caliber; they noted that the rigor of the research literature had not kept pace with the enthusiasm and growth of school garden programming and practices. Concordantly, the subfield of *critical* garden-based education research literature has been slower to develop. There are some notable exceptions: Guthman (2008a, 2008b, 2008c), Guitart et al. (2012), Hayes-Conroy (2014), Ostertag (2015), Pierce (2015a & 2015b), Walter (2013), and Williams and Dixon (2013), have all challenged the assumption that school gardens are a universal good. Slocum (2007) points out that a significant portion of the alternative food movement is informed by upper-middle class white neoliberal values, a finding echoed by Alkon and McCullen (2012) and Allen and Guthman (2006). None of these critiques investigate the connection between ecosystem knowledge and the historic use of gardens per se, but they do examine the larger systems and factors at play in garden education.

The social history of garden education. In general, this period of community gardens for urban reform, assimilation of immigrants, and socialization of citizens to 'hygienic' and 'productive' norms of behavior might be seen as a form of 'hegemonic' public pedagogy reinforcing assimilation to dominate cultural mores, ideologies and social class. (p. 525, Walter, 2013)

The above quote was written to describe community gardens during the 1890's to 1910's; if we substitute 'local' and 'sustainable' in lieu of 'hygienic' and 'productive', the passage could be a future historian looking back on 2017. Histories of school gardening often begin in the Victorian period and fail to examine the narratives that had been set in motion beforehand, foreclosing any acknowledgement of pre-colonial peoples and their activity on the land. In the following section, I will discuss the history of school gardens in North America (with an emphasis on the US) and highlight the social importance of that history.

School gardening advocates point to WWII Victory gardens (Gaylie, 2011) as an example of the civic, health, and physical benefits of gardening. However, a deeper and more critical look at the historic roles of gardens and agriculture in education reveals the ways in which gardens have been used to serve several larger socio-political agendas. In the Victorian era, gardening was an active metaphor for taming the uncivilized, bringing order and moral rectitude (cf. Firminger & Firminger, 1904). North American school gardens have been used in various forms to promote various ideologies, ranging from cultural assimilation (Lawson, 2005, p.82), Christianity, gender roles, work ethos, and nationalism (Ostertag, 2015, p.52). During WWI, the United States School Garden Army "… felt and operated like a military unit" (Carter, 2017, n.p.), and gardening was considered "as real and patriotic an effort as the building of ships or the firing of cannon." (Findlay as cited in Carter, 2017; see also Hayden-Smith, 2014).

In the US and Canada, a campaign of extermination through assimilation was executed via a system of Indian residential schools. Children were removed from their families and homelands and placed into boarding schools where they were prevented from having any contact with their families and aggressively indoctrinated. Gardens were originally adopted into the curriculum as nature study (Kohlstedt, 2008) but quickly became vocational training appropriate

to a people of low status and possibilities (Lawson, 2005; Ostertag, 2015). There is significant irony in the fact that many students suffered from malnutrition and insufficient food even as they were performing difficult physical labor in the school fields, growing crops for sale at market.

In the beginning of the 20th century, gardening programs were valued in Germany for reconnecting the German youth to the land and addressing food shortages amid the economic, physical and social destruction the country experienced (Pine, 2010). With the rise of the National Socialist party, the virtues of physical activity in the outdoors, a work ethic, health, and a romantic sense of connection to the land were developed and promoted through school garden programs (Ostertag, 2015). These values were incorporated into an ideology of "blood and soil", a phrase popularized by Richard Walther Darré, a prominent figure in the Nazi party (Kiernan, 2008), and then extended into race education and Hitler Youth programs (Blackburn, 2012; Kiernan, 2008). Both the residential schools and Nazi Germany used humans' relationship with land as key foundational ideologies for campaigns of extermination.

It would be impossible to undertake any educational effort and have it be independent of social values, and gardens are no exception. However, it behooves us to be aware of the precedents and trends associated with food production and land-based education, especially as they are still active today. The intergenerational trauma of migrant work plays out in the Skagit Valley as Triqui and other Indigenous Mexicans endure severe physical and mental stress in order to harvest food (Holmes, 2013). In August, 2017 "Blood and soil" was chanted by white nationalists at a rally in Charlottesville, Virginia (Wagner, 2017). Neither of these events is directly connected to gardens, but the power of the human-land connection is apparent in these and other diverse outcomes.

The debate over culture and neoliberalism in school gardens. Following the sociocultural turn in education, garden scholars have begun to examine the role of culture in garden activity and education. Programs leverage cultural practices such as harvesting, growing food, and cooking to provide students the chance to learn language, form stronger bonds with their communities, and reclaim cultures (Bang, Curley, Kessel, Marin, Suzukovich III, & Strack, 2014; Cutter-Mackenzie, 2009). Williams and Brown (2012) illustrate the use of school gardens to highlight biocultural diversity. Pierce (2015b) notes that school gardens can be used to help students develop a critical ecoliteracy in opposition to the homogenization that occurs through biocapitalization.

Neoliberalism is a "theory of political economic practices that proposes that human well-being can best be advanced by liberating individual entrepreneurial freedoms and skills within an institutional framework characterized by strong private property rights, free markets, and free trade" (Harvey, 2005, p.2) that has gained prominence in global practice. It is also the subject of much theorizing in the academic world (Larner, 2003); many scholars argue that neoliberal forces affect much of daily life (c.f. Bradley & Luxton, 2010). In this manuscript I will explain how the neoliberal forces of curriculum standardization and accountability testing in education influence the lives of garden educators and make the transmission of ecological knowledge difficult.

Neoliberal theory and alternative food programs. Guitart et al. (2012) note that "…community gardens literature is geographically limited. There is detailed academic literature on community gardens in English language journals, but it is mostly about gardens in low-income earning areas with different cultural backgrounds in industrial cities in the USA" (p. 368). This observation corresponds with Guthman's (2008a) concern that a prevalence of

alternative food network projects in African American communities reflect the desires of garden advocates subscribing to Whitened cultural histories, rather than the histories of the communities in which the projects are situated. In other words, there is a concern that gardens are once again being used to inculcate othered populations into following dominant cultural mores, as well as an overarching concern that alternative food networks' discourse of self-reliance reinforces the neoliberal tenets of unfettered private markets with an unequal distribution of resources.

Guthman (2008c) argues that alternative food programs' emphasis upon individual purchasing decisions (as evidenced in many 'buy local' campaigns) ends up supporting neoliberal agendas. Weissman (2015) came to a similar conclusion while studying an urban agriculture program for youth in Brooklyn. Pudup (2007) goes so far as to charge that California's Edible Schoolyard Project is designed to create a populace "who share a common interest in…a well-heeled sustainable lifestyle produced…through alternative consumption practices" by a "countercultural elite with designs on securing and widening its ambit of power" (p. 1238). Other scholars argue that the question of neoliberal agendas in garden movements are not as clear-cut. Alkon (2012) presents a complex analysis of farmers' gardens in California, examining the intersections of race and class present in the intertwined environmentalism, social justice, and green economic principles underlying the markets' respective histories.

Conversely, Hayes-Conroy (2012) acknowledges that while school gardens might reinforce neoliberal ideals, they also undermine the same ideals via contradictions of the social norms surrounding food. Taylor and Lovell (2014) view gardens as sites of and catalysts for resistance to a variety of dominant paradigms, including those around neighborhood disinvestment, food systems, and urban land use. Moore, Wilson, Kelly-Richards, and Marston (2015) even argue that "for some children in 'struggling schools,' school gardens become spaces

where the alienating aspects of neoliberal school reform in the United States can be overcome by forging connections with classmates, university students, plants, and animals" (p.407).

The arguments attesting to the influence of the neoliberal agenda in science education (Bazzul, 2012; Shihza, 2010; Tobin, 2011) and environmental education (Fletcher, 2016; Hursh, Henderson, & Greenwood, 2015; Little, 2015; Weissman, 2015) are somewhat stronger, but we do not always see how the policies are played out in students' and teachers' lives. It takes a critical reframing of what counts as knowledge and an analysis of structures to bring the moments to light as they appear in daily activity. This study will show how issues of power and normativity inhibit the practices of an archetypical garden educator.

Gardens and boundary-crossing. A garden ecology is the result of intertwining human and biogeological systems. One cannot talk about the garden without implicating both people and the MTH— the plants, soil, water, insects, animals, and other entities within the garden borders. The learning environment becomes greater than the physical classroom structure, with garden borders that are themselves permeable to both material agents —animals (pests), plants (weeds), water-borne agents (Hammond, 2016), and social influences — garden space (land availability), teaching practices (school policies), and educational content (curriculum requirements). Many advocates support GBE because it provides alternatives to traditional classroom settings and practices (i.e. Blair, 2009; Thorp, 2006; Krasny & Tidball, 2009; Parmer et al., 2009; Williams & Brown, 2012). A significant number of scholars and practitioners consider experiential education, with its emphasis on direct experience and intentional reflection, to be a definitional feature of garden-based education (Desmond et al., 2004; Ozer, 2007; Parmer et al., 2009; Williams & Dixon, 2013), citing it as one of garden-based education's primary strengths. Advocates also value the fact that GBE brings students outdoors in direct contact with

nature (Power, 2005; Skelly & Bradley, 2007; Thorp, 2006) and the greater community (Cutter-Mackenzie, 2009; Ozer, 2007; Saldivar-Tanaka & Krasny, 2004). However, many GBE scholars neglect the wider social and historical contexts surrounding education, land, culture, and gardens (Cairns, 2017, p.311). As Ostertag (2015) warns,

> [T]he notion of gardens-as-teachers only works materially and discursively if gardens are not conflated with Nature… Although gardens are enclosures, we cannot know all their boundaries. In this way, humans are folded within the materials and discourses of a garden. If a garden is a teacher, much of what is human is also implicated in this teaching. (p. 177-8).

If nature is a social construct (Cronon, 1995), then learning gardens are that social construct put into educational practice. While there a significant body of literature illustrating in myriad ways that the division between humans and the MTH is a constructed separation (Latour, 1991), a garden is a place where human systems and biogeographical systems are combined by human intent.

Power (2005) and Pierce (2015b) argue that gardens are a co-constructed space, where the social and the MTH hybridize across borders, each shaping the other. Pierce suggests that ecological educators must resist the "neoliberal construction of education in the US" (2015b, p.460) that controls lives (both humans and the MTH) to yield optimal free market competition. This enterprise is jointly conducted by the food industry and education policies. He advocates for the use of actor-network theory (ANT) to allow students to trace the power differentials upheld by the food industry and educational policy. ANT places students, communities, schools, garden vegetables, food, and scientists in horizontal (versus hierarchical) relationship, and subsequently de-centers "biotech knowledge regimes" as the holders of knowledge. This, in turn, creates room

for previously subaltern forms of knowledge, such as community-based, traditional, and oral knowledges. For this reason, other researchers have also turned to ANT in order to analyze power structures in gardens, specifically Hayes-Conroy, 2012; Hitchings, 2003; Power, 2005; and Taylor and Lovell, 2014; among others. The blurring of boundaries and the examination of power that ANT allows is an important influence on this study— by tracing these connections we can begin to see the full spectrum of factors brought into play in a lesson in the garden.

Educator expertise and knowledge is not always reflected in practice (Beyer & Davis, 2008; McNeill & Krajcik, 2008; Sebasto-Smith & Smith, 1997), but this study allowed me to investigate in depth the barriers to an educator's practice in a situation specific to garden education. The informant shared insight into the larger social, political, physical, and natural worlds surrounding the garden lessons. Although it is a case study of one individual, Maya, there are many characteristics of her particular case that are common to garden educators, making it a strong representation of the norm for garden-based education in the US. Returning to the research questions in the opening chapter, I asked:

1) What practices did Maya use in the field to introduce complex ecological relationships? Specifically, how did she foster and reinforce the development of ecological understanding?

2) What structures supported Maya's facilitation of students' ecological reasoning in outdoor learning environments? Specifically, how did she negotiate agency and power in her teaching?

Methods

In its broadest iteration, this is an interpretive case study, (Erikson, 1986) or a "basic qualitative study" (Merriam, 2009). After discussions with a number of garden educators and

visits to ten different school gardens, I decided to focus on the interactions that occurred outdoors, in the actual garden itself, as this is what differentiates garden-based education from other science lessons. I wanted to select an experienced *outdoor* garden educator in order to ensure that the data was focused on pedagogical practices that incorporated the garden environment rather than simply replicating classroom practices outdoors (Beames, Higgins, & Nicol, 2012). I made the decision to select Maya as a candidate for intensive study because she represented a broad range of the characteristics of the garden educators as a whole—female, college-educated, in her mid-twenties. This is not to say that Maya represents every garden educator but that she represented the majority demographic characteristics of the garden educators I met when the group was taken as a whole.

Data

To approach the question of teaching methods and content in the field, I began with ethnographic methods in order to allow trends and patterns to reveal themselves (Hammersley & Atkinson, 2007). I made an initial visit to the organization that Maya worked for, Green Kids, to make arrangements for working with Maya in the field and to begin collecting data about her workplace during that visit.

Setting. *Green Kids.* Green Kids is a non-profit organization in Fairville, a city in western Washington state. During the school year, Green Kids oversees the school garden program in the local school district, providing planning expertise, curriculum, garden educators, and garden maintenance for every elementary school in the district. During school breaks and in the summer the organization runs day camp programs. Their stated mission on their website is to "…grow good people, healthy food and strong communities through hands-on, seed-to-table educational experiences."

Fairville School District. A town of roughly 120,000 people, Fairville is a garden-friendly community, with several farmer's markets, a victory garden program (private gardens grow produce for the food bank), and several public and privately-owned community gardens. There are several indicators that garden-based education is valued in the Fairville school district: 1) Green Kids works in partnership with the school district and has office space on district grounds 2) There are educator positions solely dedicated to garden-based learning. 3) Every elementary school in Fairville has a garden on its grounds. Advocates include principals, teachers, parents, restauranteurs, and community members, all actively working to promote local garden-based education.

Maya. Rather than create a case study character compiled from the many garden educators that I met, I selected Maya in part because of her demographics. Like many garden educators, she is in her mid-twenties, college-educated, and is comfortable navigating middle-class mores. I did not inquire about her ethnic background, but she easily passes for White. Maya has been teaching children for nearly ten years. Four years ago, her teaching focus shifted to gardens and food systems. During the past two years Maya has been an AmeriCorps volunteer with Green Kids. Before working with Green Kids she had been involved in sustainable local food systems and food justice work in another part of the country, working with youth in urban gardens and food deserts. She characterized herself as "a liberal arts student who saw a problem and is trying to help facilitate a solution".

My position. As this research is an investigation into the effects of power, I wanted to be consistent and acknowledge the mutual positioning between myself and Maya— I am older than her and know her supervisor Susan from a previous era. At the same time, I related to Maya as a peer due to the fact that we were both engaged in garden-based education and then-currently

teaching school-age children in urban outdoor programs. Throughout the field work and the interviews, I deferred to Maya when appropriate and encouraged her to ask me questions.

Interviews. The data analyzed in this paper consists of two types: interviews and field observations. I conducted two semi-structured interviews with Maya five months apart, lasting 92 minutes and 46 minutes respectively. The first interview was designed to elicit Maya's epistemological and pedagogical views about garden ecology and teaching in the garden. I wanted to learn how she described the systems and actors in gardens and then compare her interview responses to her pedagogical discourse and activity. After conducting a preliminary analysis of the field data and the first interview, I interviewed her supervisor, Susan, the Executive Director of Green Kids, regarding themes and practices that I had noticed in both Maya's interview and in the field data. I then conducted a second interview with Maya to further confirm and clarify data.

The objective of the second interview was to member check (Cresswell & Miller, 2000) the prominent themes and questions that arose in my research. I explained to Maya the work I had been doing and some the contradictions that I had noticed. Following the cautionary advice of Carlson (2010), I chose to give her a summative version of the research rather than presenting the raw data. I framed the conversation by sharing some of the results of the literature I had been reviewing and explaining how it pertained to the teaching that both she and I were undertaking.

Field data. The field observations occurred over four days, approximately three hours each. Maya wore an audio recorder the entire time and I video-recorded much of the day. Although there were 12 hours of instruction, using multiple instruments yielded 20 hours and 34 minutes of data. There were often two and sometimes three recording devices running at once, as the group often split into smaller groups and multiple instances of teaching and learning occurred

simultaneously. It was important to track as much of this activity as possible since the desired grain size of data was interactions between students, teachers, and plants. I also kept a field journal to track interactions and possible topics of interest. The field data was logged on a spreadsheet to facilitate organization and to allow systemic review of notes.

I cataloged the time spent in various activities throughout the day into five areas: Games, Stories, Crafts, & Songs; Garden Exploration; Food Preparation and Eating; Structured Garden Learning; and Other. The Games, Stories, Crafts, & Songs were all garden-themed and occurred daily, as did Food Preparation and Eating. Structured Garden Learning were lessons where the entire group participated in as structured format, often accompanied by some lecture. They consisted of weeding, harvesting, and a lesson on beekeeping. Garden Exploration designated those times when students had semi-structured opportunities to explore plants, chickens, and worms in situ. All other activities were in Other, including travel time from one area to another, going to the bathroom, filling out surveys, water breaks, etc. Of the total time, 35% was devoted to Food Preparation and Eating; 23% into Games, Stories, Crafts, & Songs; 17% to Garden Exploration; 15% to Other; and 10% to Structured Garden Learning (see Figure 1).

While teaching and learning undoubtedly occurred throughout all of these activities, I focused on moments that had both Maya and one or more children interacting with a plant, bug, or some other MTH entity. Most of these moments occurred during Garden Exploration (65%), but a portion (23%) occurred during Structured Garden Learning, with 5% during both Food Preparation and Eating and Other and 3% during Games, Stories, Crafts, & Songs. Previous research shows that attentional focus plays a key role in the semiotic ecologies that teachers and students co-create (Goodwin, 2000). By selecting clips where MTH entities are actively present, I hoped to examine the role that they played in the pedagogical and learning activity.

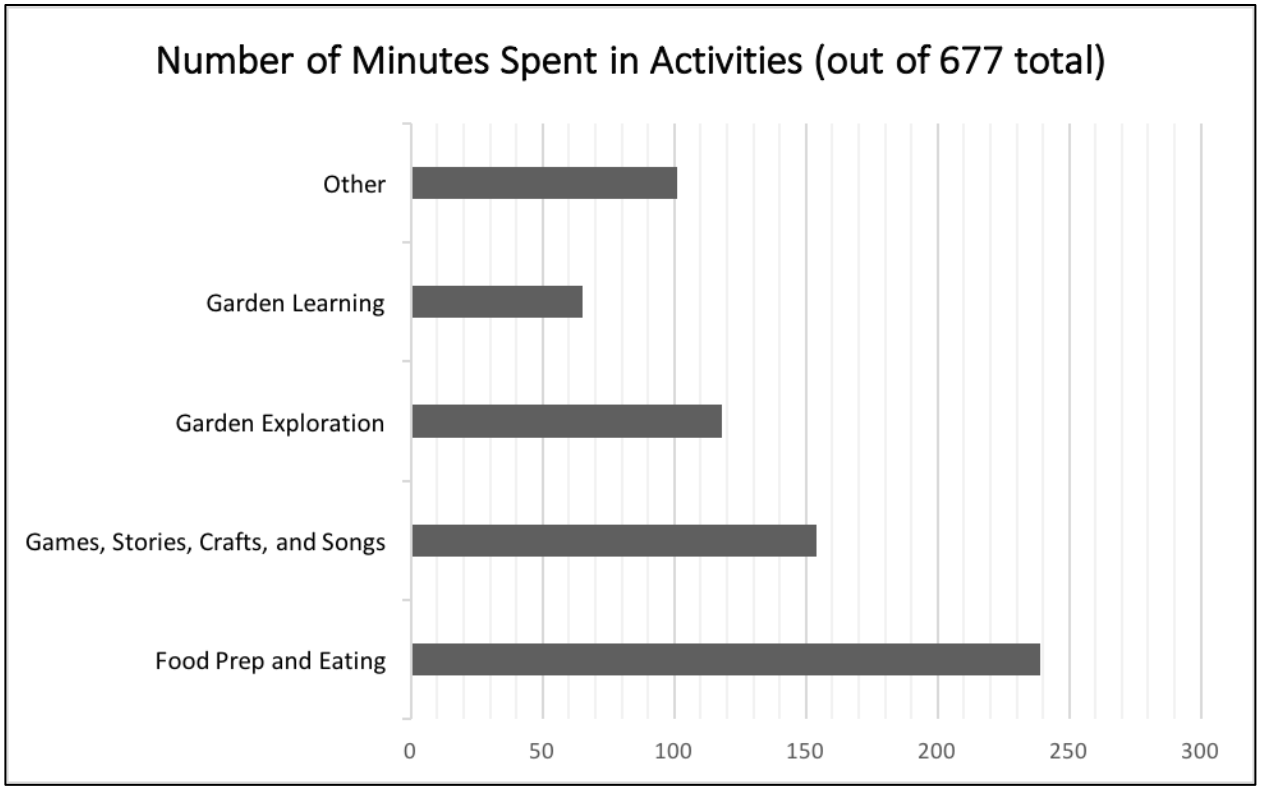

Figure 1: Time spent in activities

The field data corpus was 62 interactions. To determine if ecosystems were being discussed, I further coded data into two categories— Category 1 included the interactions involving references to relationships *between* MTH entities, and Category 2 included interactions that involved references to life cycles. Other MTH entities and relationships were referenced in 42% of the interactions and cycles were mentioned in 45% of the interactions.

Analysis

Preliminary analysis began during data collection while I logged the recorded data and highlighted recurring or prominent themes and ideas, using an open coding methodology as the first stage of a grounded theory analysis (Merriam, 2009). I logged the data by breaking each recording into 15-minute segments and writing a description of the activity while I listened to and/ or watched the data, highlighting activity that I wanted to return to and examine more carefully.

The primary unit of analysis was Maya's references to complex systems. In particular, I wanted to look at which systems she referred to, the active agents within those systems, and the distribution of power within those systems. As the analysis progressed, I selected quotes referencing complex systems from Maya's interviews and grouped them into categories. As themes developed, I also scanned Susan's interview for quotes pertaining to these themes. Using these data I was able to compare Maya's teaching with her interviews and compile a picture of the influences surrounding her position.

Findings

Maya's practice during the field data and her interview data provided very different versions of complex systems. While this is not unusual in and of itself, this particular case provided an opportunity to compare interview responses to pedagogical practice. In both interviews, Maya made it clear that she has a strong grasp on the workings of ecosystems within the garden. Several times she extemporaneously theorized aloud the possible ramifications of changes to the garden ecosystems, like the disappearance of a specific aggressive plant species, or the role of slugs. She also had an appreciation of the potential that gardens can have as places to learn about ecological cycles. This is in contrast with the field instruction, where features of the garden were dichotomized into 'good' and 'bad' and plants were classified in narrow categories. In the following sections, I will go through each of the two data sets, providing examples for the claims I make. I will then give an explanation for the disparate ecologies Maya lays out.

Maya: *Interview.* In the first interview, Maya displayed an appreciation of the educational importance of complex ecological systems: "I think it's great for young ones to learn about the life cycle, start thinking about the garden as a habitat, like an ecosystem where lots of

things can work together to create this space." (Interview, October 2, 2015) She also understood the boundary-crossing that happens in plant ecosystems:

> I don't think it would be very honest if we were to just talk about the vegetables because the vegetables wouldn't be possible without healthy soil. Soil is the root of life in so many ways, and kids are exposed to the water cycle and not quite the nitrogen cycle yet, but compost is such a hands-on tangible way to see how you can cycle these nutrients. You can take this old leaf mulch or this banana peel and you can break it down with intention and then return it to the soil. (Interview, October 2, 2015)

Maya is emphasizing that vegetables cannot be held in isolation from healthy soil, which in turn includes understanding that what is 'waste' to humans is 'food' for decomposers, who play important roles in the nutrient cycling and soil chemistry.

In terms of 'garden foes', Maya was very clear about the relative positionality of organisms within nested systems:

> Slugs are foes in the context of these vegetables when we're looking at it from this scale, but if we were to zoom in or zoom out, they play a really important role in the food web. What would all of this look like this the slug were removed? ... We need that slug. (Interview, March 15, 2016)

In a classic gardening sense, slugs are unwanted because they eat the plants that humans are growing. In an ecosystemic view, slugs are an important part of the decomposition process that turns plants into soil. She displayed a similar grasp of the human relationship to plants, and how definitional terms varied according to perspective and circumstance:

> It's an invasive [weed], in that conventional definition for it, but now it's serving a really crucial function. If we're eradicating this 'invasive weed' what are we replacing it with,

> and what is the food source in which our local native pollinators are going to depend upon? (Interview, March 15, 2016)

Here Maya troubles the use of the term 'weed' and points out the role that any given plant (whether deemed useful by gardeners or not) plays a role in a garden ecosystem.

Instruction in the field. When compared to the interviews, Maya's instructional discourse in the learning garden portrayed a very different perspective. The discourse was anthropocentric and followed mainstream narratives of human exceptionalism; plants and animals' needs or desires were not mentioned in 57 (92%) of the interactions. Plants and animals were positioned exclusively within the wider framework of the garden, usually in service to the end goal of human sustenance. In the following excerpt, Maya is showing the students how to weed a row of peas. She opens the lesson with "There is a thief in our garden. This thief is stealing water and nutrients, or healthy food, from our plants":

> *Maya:* Why is having weeds in our garden next to our peas bad for our peas?
>
> *Xiao:* Because it can choke them.
>
> *Maya:* Maybe it can choke them. What else could it do?
>
> *Xiao:* It could ... I don't know.
>
> *Maya:* When I pull the grass out what do you notice is at the very bottom?
>
> *Xiao:* Roots.
>
> *Maya:* The roots. Do you think our peas have similar roots growing underground? This pea plant doesn't look very healthy. Let's pull it up and then see. Oh, look! They both have roots. Do you think our peas are going to grow as well if these roots are growing right through it and on top of it? If these plants are growing on top of each other like this, do you think that's good for our pea plant?

Xiao: No.

Maya: Why not? Do you know that roots have a very important job for our plants?

Xiao: No.

Maya: Roots are so important for our plants. Do you know what they do? They collect water. Their job is to carry water up to the rest of the plant. If we have two different root systems growing right on top of each other, they're going to be competing. They're going to fighting against each other for water. Do you think our pea plant will get enough water if this root system is taking up all of our water?

Xiao: No.

Maya: Do plants need water?

Xiao: Yeah.

Maya: So do we want to get our weeds out of our garden?

Xiao: Yeah.

Maya: Why?

Xiao: Because the roots will take the water from the big plants?

Maya: You're right. High five!

Within this garden frame, plants' reason for existing is to grow and produce. Various garden entities were labeled to reinforce this positioning— plants were referred to almost exclusively as "vegetables", "produce", or "weeds". Flowers were valued because they were aesthetically pleasing, but also a key site for pollination, a necessary step in the production of fruits, vegetables, and honey, all of which are harvested. Throughout the instructional discourse, humans were the actors and plants were acted upon, being harvested, sown, planted or weeded. For example, one of the craft activities was planting flower seeds for honeybees. The seeds came

from a national distributor and were disbursed to school programs across the country. The preferred habitats of the flowers being planted and their potential roles in a Pacific Northwest ecosystem were not addressed.

All of this phrasing depicts plants and animals as passive subjects that are subordinated, albeit benevolently, towards supporting human needs and desires. Human attention to the garden occupants' needs and well-being is focused towards that which will ultimately encourage production of food. Plants that act outside of the human-dictated paradigm by growing too vigorously, at the wrong time, or in the wrong place, become "weeds" and are removed by being "weeded".

Pedagogical discourse around plants and animals tended toward a polar scale, with one end being productive and therefore desirable, and the other being unwanted. This was exemplified by the use of the terms "garden friends" and "garden foes".

Maya: Why do you think we have a big gate right here?

Xiao: So no one can get in.

Maya: Oh you're so smart. So no *animals* can get in.

Leah (another teacher): What kind of animals do we want to keep out?

Xiao: Deer?

Maya: Deer. Do you think a deer is a garden friend or garden foe?

Xiao: A garden foe.

Maya: You're right! What does foe mean? (2s) So I'm going to let all my friends in through the gate. Let's make sure we hold the door open for our friends, and let's make sure we latch it afterwards. 'Cause what do we want to keep out?

Collin: Deer!

Maya: Deer and other garden foes! You're right!

Garden friends were things that helped garden vegetables grow and achieve high yields. Bees and hummingbirds were pollinators, worms helped to cycle nutrients and aerate soil, and ladybugs ate vegetable-eating aphids. Garden foes ate valued plants (rabbits, deer, slugs, and aphids), prevented the growth of other plants (buttercup and other vigorous plants), and were to be removed from and/or kept out of the garden. Weeding was a common and frequent garden activity. As plants that "choke and poison other plants" and "thieves that steal water and nutrients from our plants", weeds were a garden foe that demanded particular attention and treatment. Weeding was taught as a skill with specific techniques and protocol:

Maya: Friends, I want you to watch carefully as I find a weed. Skylar, you observed that we've got some weeds with some blue flowers. When I weed, do I want to just pull off the top like this?

Skylar: No.

Maya: What do I want to do?

Skylar: Pull it by the stem so you pull it out by the root.

Maya: The top of the stem or the bottom of the stem?

Skylar: Bottom.

Maya: The bottom, you're right. I pull at the bottom. And pull, and pull. Perfect. Thanks. *What* did you notice that I got?

Skylar: The roots.

Maya: You're right, I pulled up the roots. Once I've pulled up the weed, and I've made sure that I've got all the roots, you know what I'm going to do with it? I'm going to make

a nice little pile right at the end of the bed. Let's find as many weeds as we can, and put them at the end of our bed, okay?

What was striking in this instance was Maya's pedagogical portrayal of the garden ecosystem as overly simple and flat. When I asked Maya point blank about why the use of the terms 'garden friends and garden foes' she replied "Probably because we're not giving the kids enough credit…[W]hen we dichotomize in that regard, friends versus foes, it's making assumptions about what kids are able to handle, or how to introduce a topic in a larger scale."

Ruptures. In five of the sixty-two interactions, plants and animals were described as having needs, desires, or feelings. This aspect of being-hood is an important part of ecosystem perception, in that it is an acknowledgement of motives outside the realm of the human, a necessary move away from anthropocentrism and towards acknowledgement that natural entities have powers of their own (Ingold, 2000; Medin & Bang, 2014b). We could infer from these instances that Maya and other instructors see plants and animals as acting and existing on their own volition, while at the same time often defaulting towards a human-dominant perspective.

Influences on Maya. Having established that Maya does indeed have a sense of the roles that plants and animals play, and of the fluidity of their position within a system, I now turn to the systems in which Maya finds herself imbricated as she takes on the role of a teacher in the garden. The entities that form these systems were all explicitly named by Maya during her interviews. I organized the entities into three different categories roughly corresponding to their magnitude— "Social Forces and Systems", "Agencies", and "Local Actors" (Table 1). Social Forces and Systems are all broadly-acting influences that don't have a proper noun name or a specific acting entity (i.e. "corporate interests"). Agencies are institutions or organizations that tend to act on a regional level. These institutions may not have one particular face, but there are

usually specific contact people. They also tend to have some sort of regulatory influence on the local educational process. Examples in this category are the local school board or the health department. The third category, Local Actors, are specific individuals or smaller organizations with whom Maya has direct contact in the course of her work. These are the teachers whose classes Maya works with, the students themselves, or their parents. Within the two interviews, Maya references eighteen different entities as influencing her practice of garden pedagogy (see Table 1):

Table 1

Social Forces & Systems	Agencies	Local Actors
Corporate Interests	Local School District	Principals
Federal agencies (USDA)	State Education Standards	Teachers
Salmon lobby	AmeriCorps	Parents
Fast Food Lobbies	School board	Students
Dairy Lobby	Health Department	A given School
High-stakes school achievement		Green Kids
		Green Kids ED Susan
		School staff

There are hierarchical trees both within and across these categories. For example, ‘students’, ‘teachers’, and ‘principals’, are all within Local Actors, but they comprise a hierarchy among themselves (see Figure 2).

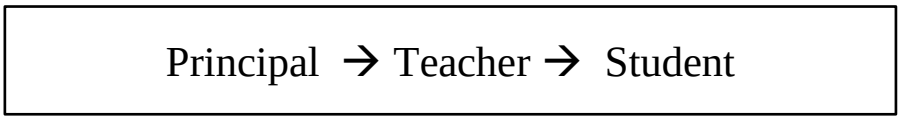

Figure 2: Hierarchies within a category

At the same time, the entities 'High-stakes school achievement', 'State education standards', and 'Teachers' represent the three different categories and also form a hierarchal tree (see Figure 3).

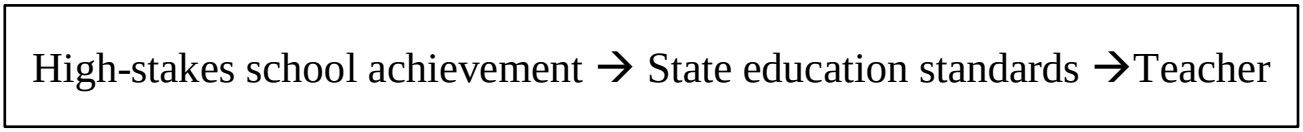

Figure 3: Hierarchies across categories

form trees, webs, and loops. From these eighteen entities we can begin to draw conclusions about some of the systems that Maya is involved in when she teaches in a school garden. Maya is only one person, but she is located at the nexus of nature-culture relations, and many the non-material political, regulatory, and social networks all have an influential role in the activity that Maya and her students pursue in the garden.

The disparity between the flat garden ecologies described in the field observations and the dynamic, complex systems Maya described in her interviews can be attributed to the different positions she occupied when the respective data were collected. Each time she steps into a school garden, Maya has a number of social factors that she must take into account. If we imagine each factors as a filter (Figure 3), Maya named 18 different filters in her interviews: Corporate Interests, The USDA, Salmon Lobby, Fast Food Lobby, Dairy Lobby, Test Scores, State Standards, Health Department, Americorps, School Board, School District, Green Kids, Susan (her supervisor at Green Kids), School Principals, Teachers, School Staff, Parents (see Table 1).

These filters all have some influence on her teaching. Any given filter might exert its own influence, or the felt influence might be the result of an aggregated system (see Figure 4). It is

small wonder if at times Maya feels like she is forced into conceptual gymnastics in meeting all of these demands.

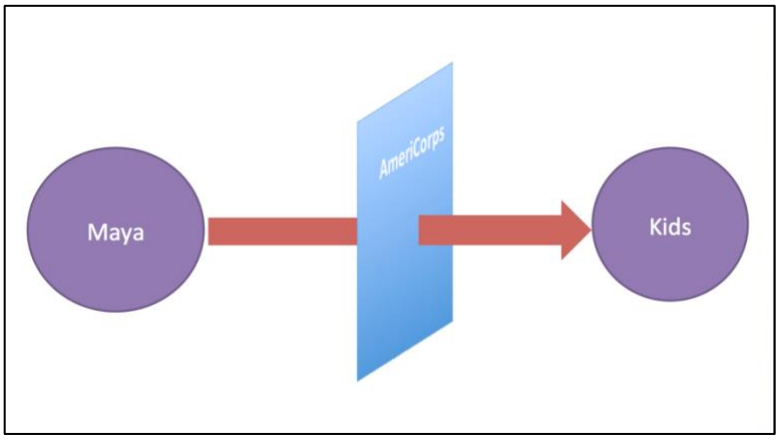

Figure 4: A factor as a filter

Figure 5: The many filters of Maya's teaching

Susan's interview. I initially interviewed Susan to triangulate the data from Maya's first interview, especially that regarding Green Kids' pedagogical theory, curriculum, and procedures. After identifying sources of influence and power in Maya's first and second interviews, I revisited Susan's interview. She named or referred to twelve of the same influences as Maya and added both Specific Donors and Community Perceptions as factors. This data reinforced the presence of social and economic pressures that Maya both named and alluded to. Susan also referred to deficit models of children in garden lessons, stating that she often felt that they were

being pandered to: “I guess I'd like to give kids credit for being a little more sophisticated than the words yuck and yum.”

Interestingly, nearly all of the influences Susan named were in the Agency or Local Actor categories, although this may be a result of the interview questions. The influences that Maya and Susan bring up are not unique; many educators may point to some of these same elements—school boards, districts, parents, etc.— as influencing their practice. In this case these influences combined in such a way that it was difficult for a knowledgeable expert to share their expertise. As discussed earlier, a significant number of the conditions Maya contends with are a direct or secondary result of neoliberal educational policies and /or hierarchical structures. For example, she is often asked to fit garden lesson to the teachers’ curricula rather than the garden being incorporated into the classroom activity. As she says, “…how am I supposed to cater to the needs of thirty different teachers?” (Interview, October 2, 2015). These imposed frameworks appeared prominently in the data collected during this study in several ways, as demonstrated below.

Discussion

Competing Discourses

> In her first interview, Maya outlined some of the difficulties of her position:
>
> [O]ne of the ‘perks’… of my program, is that I am a food stamp recipient, I get SNAP benefits…[E]xplaining my position becomes really challenging because from the AmeriCorps side they keep stressing it's not a job, you're not getting an income. It is a living stipend, you are a volunteer. All of my trainings, all of my paperwork, everything that I've signed stresses that I communicate that. When it comes to filling out paperwork for my taxes, or for food stamps, then it's like ‘Well, you're receiving an income, so you

> have a job.' There are little idiosyncrasies that I don't fully understand, but I know I am legally required to say that I do not have a job…Meanwhile I'm sitting in department of family and health services like 'but I don't have a job!' (Interview, March 15, 2016)

On the one hand, she is expected to closely follow the policies that forbid her from expressing opinions that depart from the conservative political mainstream (i.e. abortion, the power of lobbying organizations); on the other, she is encouraged to manipulate conflicting policies in the revenue, public assistance and health care systems in order to access basic services. These conflicting messages are characteristic of the position that Maya holds in the gardens, and she is quite accustomed to navigating the breach.

It is worth noting that the entities in the first category, Social Forces and Systems, are all tied in some way to a neoliberal discourse of globalization that promotes free-market economics and corporate interests over social equity or environmental protection (Davies & Bansel, 2007; Lakes & Carter, 2011; Tuck & McKenzie, 2013). For example, the mission statement of the USDA states that it "provides leadership on food, agriculture, natural resources, rural development, nutrition and related issues based on sound public policy, the best available science, and efficient management". Any reference to MTH elements positions them as things for human use, often within an economic discourse – food, agriculture, and natural resources. Fast Food (and other) Lobbies refers to the act of applying social and monetary capital towards political influence for special interest groups. This practice is a uniquely human process with a documented history of manipulation by interests that prioritize monetary profit over human and environmental health (Oreskes & Conway, 2010).

On a regional level, the entities that Maya mentions are all organizations that concern themselves exclusively with human or social issues and are tied into the same neoliberal

discourse. If MTH aspects are addressed in any way, it is only in respect to human health or economic benefit. For example, the Washington State Department of Health, the organization that requires the careful separation of food and dirt via hand-washing, also monitors shellfish for toxins. The webpage states "Our state is the leading producer of farmed shellfish in the nation, and commercial product is shipped around the world…Washington coastal beaches attract hundreds of thousands of recreational harvesters each year" (Washington State Department of Health, 2017). The reason for monitoring shellfish health is not to maintain ecosystem health, or for the benefit of the shellfish themselves, but to protect Washington's economic stake in shellfish export and in the tourism dollars from recreation.

Many of the Local Actors that Maya and Susan refer to are themselves part of larger regulatory systems (principals, teachers, and school staff are part of the district, state, and national educational systems). Green Kids must adhere to the standards of the health department, and order to receive support from AmeriCorps and other granting organizations, they must collect specific data on student outcomes as requested by the funder even when it conflicts with Green Kids' learning objectives (Susan, Interview, December 7, 2015).

When asked to explain further about how she felt social systems influenced garden pedagogies, Maya was explicit in the entanglement of political interests with garden concerns:

> I find it hard to discuss the food system in some ways while removing [politics]. I am not allowed to talk about it…There's really specific language in our training...I'm not allowed to lobby, I'm not allowed to discuss any political candidate, I'm not allowed to tell anyone where they can get abortion services. Things like this. (Interview, March 15, 2016)

In this passage, Maya is speaking specifically of AmeriCorps, the umbrella organization through which her volunteer position with Green Kids is facilitated. In her view, there are direct edicts concerning what she can and cannot say without violating the terms of her position.

She is also well-informed about the complexities of the US food system and the role that various institutions play in influencing it:

> Politics are unfortunately deeply embedded in our food system. No talking about that. Or the complications of what is organic and what is not organic. There's over a hundred chemicals that are listed as acceptable under the USDA organic. Don't even get me started on what the USDA nutritional requirements are...milk, what? This I'm not allowed to talk about. (Interview, March 15, 2016)

Maya names specific agencies (USDA) and policies (organic certification, nutritional requirements) that influence the discussions she has with students and identifies factors (acceptable chemicals, milk production) that she sees as counter to healthy food systems. In doing so, Maya is employing her own version of network theory to identify and challenges the "unsustainable and exploitative" (Pierce, 2015b, p. 469) networks that she sees being reinforced by learning gardens.

Power and Hierarchy

Manifestations of power and hierarchy were common throughout the study. Maya's position as a putative volunteer, the optional nature of the garden curriculum, and the myriad contingencies that determined whether a given lesson occurred were only a few of the ways in which hierarchies were established and reinforced. Two areas in particular, time and curricular content, presented examples of the power structures that affected the school garden program.

Time as resource. In the crowded school day, time is a precious and contested commodity. Maya had a limited amount of time with her students. She saw a given class for 30 minutes every two weeks. Class sizes are usually around 28 students. During this time, Maya had to attend to the logistical nature of her field, help the students adjust to a different learning environment, and fulfill the requirements stipulated by her funder.

> I have to put things in the ground, because we just haven't gotten to it, because we had to do surveys and we had to go over expectations. That's thirty minutes, and now I have ten minutes left [to teach]. (Interview, October 2, 2015)

Not only did Maya feel forced to forego the experiential potential of garden learning when a student put a plant in the ground, she had to use some of her allotted time to prime students on how to behave in a new learning environment, and also ensure that her session aligned with the conditions for program sustainability.

Curriculum content. Some teachers utilized the garden and Maya's expertise by making content-specific lesson requests to correspond with the curriculum they are following. The pace and timing of the curriculum is set to a myriad of factors (length of the school year, student grade level, etc.), but virtually none of these factors is the seasonal cycle of plant growth. As a result, Maya was often in a double-bind, balancing her professional capital against her ecological expertise. On the one hand, she could be seen as valuable curricular support, providing empirical, experiential opportunities for student learning by growing corn in December, a very difficult proposition in the Fairville climate at that time of year. The danger here is in reinforcing the normative on-demand mentality of out-of-season food consumption that contributes to significant environmental impact (Stoessel, Juraske, Pfister, & Hellweg, 2012), and violating one of the central tenets of sustainable food systems in the process. On the other hand, she could

stick to the values and principles of garden-based education and adhere to seasonal and ecological cycles, thus missing an opportunity to demonstrate the value of garden programming to a classroom teacher (who holds the power to make curriculum decisions) as well as risking the chance of being seen as an uncooperative partner.

A given teachers' understanding of what counts as science becomes important here. One of the widely acknowledged benefits of garden-based education is the fact that teaching and learning takes place outdoors, in an environment open to the flows of multiple human and MTH agents. Removing the opportunity to study science in this way reinforces notions of science as a series of mechanistic processes with predetermined outcomes, all of which are manipulable by humans. The current mainstream practices in science education support this view by narrowing scientific study into specific disciplines and modeling ecological processes out of context. Research and curricula that take up ecology as science content have to contend with a highly-developed system of disciplinary specialization with much attention given to crossing disciplinary boundaries within the sciences (Buhr, 2011; Venville, Rennie, & Wallace, 2012).

Maya and Green Kids also had to contend with different teachers' notions of what was worthwhile learning in general. Some explicitly said that they did not see the garden lessons as meeting their curriculum goals. Susan describes the challenge of including weeding in the garden curriculum:

> [S]ome teachers go, "Heck yeah." Because that's teaching [the students] about stewardship of the earth, it's teaching them about self-sufficiency. It's teaching them so many different things, and other teachers are like, "Well, I got a lot of standards I need to be clicking through. We've already learned how to weed." (Susan, Interview, December 7, 2015)

The value of garden lessons and their content is thus determined by someone who not only may lack expertise in garden-based education, but holds a greater position of power due to the fact that they themselves are held accountable to state- and district-imposed standards. This is how adherence to universal standards becomes prioritized over content- and place-based local expertise.

Separation of humans and nature. The structural constraints placed on Maya's teaching actually forced her to teach that humans and nature are separate by emphasizing a rationale for the separation and insisting upon anthropocentric chronologies.

Contamination. Plants that are "contaminated" by contact with other (not human) organisms are not appropriate sources of nutrition for humans. For instance, if a school has livestock on the grounds and the garden is nearby, "…then it would have to be really intentional that we can't grow things here for consumption" (Maya, Interview, October 2, 2015) due to regulations that mandate separation of animals from plants being grown for food.

MTH cycles. There is another aspect of time that is often not addressed when designing for garden education, the time of the more-than-human. Time is a funny tool, because on the one hand it is quantifiably measured and meted (Maya plans her lessons down to the minute) and thus held to be an objective construct. On the other hand, time is a contextual measure. The average lifespans of a mayfly, a kale plant, a chicken, an apple tree, and a quartz crystal differ by orders of magnitude.

Rather than say timescales are not addressed in garden education, it is more accurate to say that the importance and value of phenomena are determined in large part by how well they fit into the industrialized timeframe of the school day. Phenomena that cannot be observed in half-hour periods, or that take place during the summer (when school is not in session), or require

moving outside of a hundred-meter radius around the school building are not likely to be included in the curriculum, severely constraining learners' access to the learning opportunities in gardens and other lands. Maya often finds herself at odds with the school schedule, whether by planting a summer crop in winter, or by contriving to only grow plants that complete their cycle within a three-month time span.

> I do emphasize that certain things can grow here certain times of the year, but I think it would beneficial for the students if we tried these things and they just never grew. But it's like I've told you, I see them twice a month, and then I only see them four times. (Interview, October 2, 2015)

Disrupting and "Subversive teaching". An educator's resources for resistance will be contingent upon the immediate circumstances they are enmeshed in. Despite the many barriers that Maya had to contend with, she still managed to disrupt the dictates of the broader neoliberal discourse surrounding the schools. Maya commented on the oversimplification of garden ecosystems, by labeling it as "…a failure of the education system, in its own way. In that regard, we're not giving the kids enough credit." Even as she works within the system, Maya maintains a critical eye on the greater educational system and her position within it.

One of the greatest success she described involved collaborating with another teacher, Mr. M, who didn't want to divide his class according to math performativity, yet had to provide additional instruction for students underperforming in math.

> I asked him what kind of math are you doing right now? He said 'A lot of multiplication.' I said 'Perfect, because that can tie into figuring out cover crops.' And this was a conversation we had in the staff room twenty minutes before his class came out. (Interview, October 2, 2015)

Cover crops are planted to maintain soil health and reduce weed growth over the winter. Deciding how much seed to sow requires measuring the garden and calculating area and ratios. By working together and adjusting the garden curriculum, Maya and Mr. M were able to meet the math instruction requirements and provide a garden experience for the entire class.

At other times, Maya incorporated teaching moves that challenged the binary classification of plants. In the dialogue below, she and a student are pulling out weeds.

Maya: Do you know what this weed is called? Have you seen this weed before?

Jasmine: It's horsetail.

Maya: Horsetail, you're right. Did you know that some people have found uses for horsetail? You know how we talked about weeds being garden foes?

Jasmine: Yeah.

Maya: Some weeds have uses. I was actually reading my shampoo bottle the other day, and one of the ingredients in my shampoo is horsetail! Can you believe that? Something growing in my yard can be used in my hair-washing stuff. Pretty wild, huh?

With this exchange, Maya both challenges the classification of weeds as useless and detrimental and opens the possibility of plant uses. Normative garden discourse often places plants that grow voluntarily into the blanket category of 'weeds'. When Maya notes that "something growing in my yard" can be useful, she is not only troubling the designation of weeds as bad, but the garden as the only place where helpful plants grow. Additionally, this particular plant, horsetail or *Equisetum*, is a plant family native to the Pacific Northwest for which there are numerous modern and traditional uses.

Implications and Conclusion

In this case study we have looked at a situation where there is an established garden location, with a supportive organizational structure and open support from the school community. The educator in this study was an experienced educator who demonstrated her ecological knowledge during interviews. Yet there were still significant challenges in teaching socio-ecological concepts in the garden, and there are solutions to each of these challenges.

Children and Ecological Reasoning

Both Maya and Susan noted the presence of deficit models of children in garden education, yet very young children are able to use ecological reasoning (Bang, Medin, & Atran 2007; Unsworth, Levin, Bang, Washinawatok, Waxman, & Medin, 2012) and children raised in contact with nature are more likely to engage in reasoning from a non-anthropocentric viewpoint (Atran, Medin, & Ross, 2005; Medin, Waxman, Woodring, & Washinawatok, 2010; Taverna, Medin & Waxman, 2016). Encouraging and expecting children, even young ones, to take up sophisticated ecological reasoning in the garden is an important step. Additionally, pointing out the influence of human activity in the garden helps students develop an understanding of the systems that are formed by the relationships between humans and nature. Ecological knowledge requires the ability to make connections across degrees of scale; discern between agent and aggregate levels; account for branching and chained causes and effects; and understand thresholds and feedback loops (Davis & Sumara, 2006; Levy & Wilensky, 2008; White, 2008). Traditional science education has emphasized specialization and separation, inhibiting students' progress in understanding systems behavior (Colucci-Gray, Camino, Barbiero & Gray, 2006; Eberbach & Crowley, 2009; Gonzalez-Gaudiano, 2001; Hmelo, Holton & Kolodner, 2000; Hmelo-Silver & Azevedo, 2006; Pagan, 2010; Venville, Rennie, & Wallace, 2012). The school

garden presents rich opportunities for interdisciplinary science and engineering lessons that are premised on understanding socio-ecological systems. This in turn supports science education efforts such as the NGSS.

Incorporating the Classroom

Ecology is inherently a cross-disciplinary topic, and ecological thinking is as much a habit of mind as it is a content area (Davis & Sumara, 2006; Orr, 1992; Smith & Williams, 1999; Walker & Salt, 2006). Maya specifically mentioned an instance when she worked with a teacher to modify the day's garden curriculum to accommodate a math lesson within the course of 15 minutes. There are many, many ways the garden can be incorporated into the curriculum. Predicting carrying capacity and resource distribution requires the ability to use mathematical concepts and tools. Further researching and communicating those predictions requires the ability to read, organize information, and write.

There are some distinct advantages to incorporating traditional curriculum into the garden, especially with regard to ecological education. Reflection in class discussions or written essays can help students to engage in inferential reasoning, an important skill in ecological thinking. Students can easily see the importance of fundamental literacy and math skills when they are applied in an experiential lesson.

Prioritizing Ecological Education

Some of the biggest challenges Maya wrestled with were directly related to the lack of importance ascribed to ecological education. This is changing in many ways, from the inclusion of garden education to specific standards within NGSS, but there is still much work to be done. The fact that garden education is considered an adjunct curriculum is evident in many ways—Maya is paid considerably less than other teachers and has much less access to professional

training and development; the garden education program exists in large part due to the efforts of a non-profit organization; and the accountability for teachers who do not use the garden program is low or nonexistent.

Maya's expertise as an ecological educator was overridden by teachers via curriculum content, allocation of time, and perceptions of educational value. Susan, the Director of Green Kids, has been incorporating NGSS into her programming, but support for ecological education must come from multiple levels. Expert ecological educators need the opportunity to translate between their conceptual understandings and their ability to enact that complexity in practice with children. Teachers in general need support in understanding and teaching ecological concepts (Cotton, 2006). School administrators must provide structure and leadership to facilitate this growth.

We cannot study gardens as separate, idyllic, enclosed spaces. Just as we pay attention to the physical factors like pesticides or heavy metals when they come into the garden, we must also pay attention to the social and economic factors that cross the garden borders. Sharma and Buxton (2015) write that it is important for science teachers to understand how texts "position the environment, climate, and a range of actors through particular linguistic practices with critical sociocultural implications" (p. 278). This same thought applies to pedagogy- as educators, even with conscious work towards awareness of our language and our actions with students, we are still affected by and conveyors of the deep underlying social, political, economic- in short, cultural- forces that we have experienced and that shape the moment in which we are teaching.

The greater social context of a garden has a profound influence on the educational content inside. Learning gardens are located in a physical space, within bounded temporalities,

and amidst a host of social structures. In this case, the structures in power drive decidedly anthropocentric decision-making, where the perspective of the MTH is neither considered nor even imagined. This anthropocentricism manifests as value-laden educational messages regarding the positionality and agency of humans in the natural world, which play out in Maya's teaching. The fact that she is still able to find ways to communicate her beliefs and understanding of garden ecosystems is a testament to her conviction that teaching people about food is an important and revolutionary act.

CHAPTER 3: TALKING TO CEDAR: ADDRESSIVITY AND PLANT AGENCY IN MAKING KNOWLEDGE

Introduction

Understanding and living within the limits of Earth's systems has always been a prerequisite of human existence. As industrialized societies have risen, we have lost sight of our dependence on Earth systems and replaced it with a doctrine of human exceptionalism that sets humans apart from the natural world. At the same time, data from recent technological advances combined with the insight of deep historical perspective is re-emphasizing in greater and more nuanced detail the importance of managing human activity within ecosystems. Developing pedagogies that can counter human exceptionalism is the challenge for 21st century science education. A first step for those pedagogies is to help students realize the agency of non-human actors in complex socio-ecological systems.

This study explores the pedagogical moves used to develop and support *addressivity* — the engagement of an entity in reciprocal communication (Bakhtin, 1981)— in a forest environment by focusing on the practices employed when adult teacher-mentors were involved in students' meaning-making relationships with plants. Specifically, I examined the discursive practices teaching adults used to facilitate, support, or resist addressivity in moments of teaching and learning about plants outdoors.

Framework

Culture and Ecological Cognition

Cultural perspectives on the nature of science also influence ecological cognition (Medin & Bang, 2014; ojalehto, Medin, Horton, Garcia, & Kays, 2015; ojalehto, Waxman, & Medin, 2013). A tendency to separate and specialize into scientific fields can inhibit understanding of

larger-scale scientific processes (Assaraf, Dodick, & Tripto, 2013; Atran & Medin, 2008; Colucci-Gray, Camino, Barbiero & Gray, 2006; Davis & Sumara, 2006; Weart, 2008). This tendency to specialize supports mainstream forms of science, environmental, and ecological education can lead to or bolster ideas of human exceptionalism (Dickinson, 2011; Gough, 1999; Kopina, 2012, 2014; McKenzie, 2005; Smith & Williams, 1999; Watts, 2013; Whitehouse, Watkin Lui, Sellwood, Barrett, & Chigeza, 2014), bringing into debate the role of the more-than-human (MTH) and the power and agency, or lack thereof, ascribed to it.

There is a general perception that understanding ecological systems is difficult because large and diverse amounts of information are organized across different scales and levels (Hmelo-Silver & Pfeffer, 2003; Perkins & Grotzer, 2000). Many of these claims are based in computer-science dominated views of complex systems (see Allesina & Bondavalli, 2004; Mitchell, 2009), focusing on causal influence, structural forms, and the behavior of individual entities (Azevedo, Guthrie, & Siebert, 2004; Eliam & Poyas, 2010; Hmelo, Holton, & Kolodner, 2000; Hmelo-Silver & Azevedo, 2006; Hmelo-Silver, Marathe, & Liu, 2007; Jacobsen & Wilensky, 2006; Lagnado, Waldman, Hagmayer, & Sloman, 2007; Plate, 2008, 2010; Rye & Rubba, 1998, 2002; Sterman, 1994; Sterman & Sweeney, 2007; Sweeney & Sterman, 2000; Ulanowicz, 2011; Walker & Cooper, 2011; Wilensky & Resnick, 1999; White, 1997, 2008).

The primary (and salient) difference between models of complex systems and complex systems in the "wild", is that models being insufficient to adequately predict emergent phenomena (Mustin, Sutherland, & Gill, 2007; Watt, 1966; Wu & David, 2002). The computational view of complexity identifies the mechanisms of complex systems (feedback loops, exponential growth, emergent properties), but it is only useful in predicting behavior in models. That is, it does not enhance our understanding of the nature of the relationships between

different entities and their behavior when unforeseen or unimagined factors come into play. The difficulty weather forecasters have in accurately predicting the weather is an example of this- meteorological models allow us to make predictions about the weather, but do not guarantee the forecast will be the outcome.

While ecological systems are certainly complex systems, they also consist of many agentic entities, both human and the more-than-human (MTH). Hence the study of complex ecological systems is also the study of the relationship of humans to nature (Bang, Marin, Medin, & Washinawatok, 2015), an onto-epistemological dimension not always acknowledged in science education literature. Following Bang and Marin (2015), I use the term *nature-culture relations* in support of the assertion that human activity is inseparable from the natural world and that nature-culture relations influence the core ontological, epistemological, and axiological conceptions upon which we build knowledge.

Addressivity

Addressivity is a concept introduced by Bahktin to indicate the engagement of two entities in an act of communication (1986, p.95). Addressivity is what turns language into the act of communication. Without addressivity, words and sentences are merely units of language. When there is a speaker and an addressee, they become 'utterances' — "links in the chain of speech communication" (*ibid,* p.93). Further, the speaker is constructing the utterance for a very important other, who are "active participants in the in speech communication" (*ibid.* p.94). Without this other to receive and interpret the utterance, the speech is only noise.

Kubli (2005) writes that "Addressivity is only possible between socially connected persons" (p.509), bringing into question the quality of personhood. Ingold (2000) draws on the ontologies of Cree and other indigenous hunter-gatherers to discuss the topic. From this view,

personhood is not the thing that sets humans apart from the MTH; rather "the human is one of many outward forms of personhood" (p.50). In having personhood, or in being ontologically equal persons, plants and animals have capacities to act and perceive, and are "endowed with powers of feeling and autonomous action" (p.52). This perspective is by no means unique to the Cree. It has been documented and written about by numerous scholars, both Indigenous and non-Native (i.e. Bang, Curley, Kessel, Marin, Suzukovich, & Strack, 2014; Brayboy & Maughan, 2009; Cajete, 1999, 2000; Deloria & Wildcat, 2001; Engle-Di Mauro & Carroll, 2014; Kawagley, 1996; Kincheloe & Steinberg, 2008; Kohn, 2013; Whyte, Brewer, & Johnson, 2016).

Taking Others' Perspectives

Perspective-taking performs important connective work. As a development skill in humans, it strengthens social bonds and facilitates social coordination (Galinsky, Ku, & Wang, 2005). Studies link perspective-taking to environmental concern (Schultz, 2001) and a sense of connectedness with the natural world (Mayer & Frantz, 2004). Davis, Conklin, Smith, and Luce (1996) found that perspective-taking behavior led observers to attribute self-definitional traits to unknown others. The extension of perspective-taking to MTH others is a key element of addressivity.

In order to take the perspective of another, it must be acknowledged that the other has both a perspective to adopt, and a state of mind from which to have that perspective. Seeking the perspectives of the MTH means bringing them into the social sphere of beinghood and relations, and thus making them a potential addressee. Extending perspective-taking to plants and bugs reduces the psychological distance between the student and nature (Medin & Bang, 2014a). Perspective-taking has also been linked to power differentials, with a negative relationship between measures of power and the ability to take another's perspective (Galinsky, Magee,

Inesei, & Gruenfeld, 2006). In short, perspective-taking is central to the disruption of powered hierarchies between humans and the MTH. Taking this a step further, addressivity is essential to dismantling the power inequities that permeate the relationship between Western science and Native science.

The social connection between humans and the MTH lies at the root of Indigenous ontologies, epistemologies, and axiologies. It is inherent to every aspect of knowing and being in the world, including science and education. This same feature is what causes many to differentiate between Native and western sciences and ecological knowledge (Bang et al., 2014; Ingold, 2000; Kimmerer, 2013; Kincheloe & Steinberg, 2008) and is often the pivot for discussions of power between the different versions of science. Framing an MTH entity as something that "does" things is a categorical shift away from the paradigms in mainstream science classrooms (Brayboy & Maughan, 2009). This *interagency* (Ingold, 2000) is different from intersubjectivity in that it demands recognition of the MTH as fellow *beings* that act, not merely as objects that affect the world. This then brings both the ethical treatment of other beings, and the many hierarchies played out in mainstream science classrooms, into question.

Indigenous Knowledge and Addressivity

Two particular aspects of Indigenous knowledge and science, or Indigenous Knowledge Systems (IKS), that I wish to address are science and pedagogy. Indigenous science involves observation, attention to the seasons and temporal cycles of the Earth, an acknowledgement of the knowledge held by more-than-humans, and a focus on the connections or possibilities offered (Battiste, 2010; Brayboy & Castagno, 2009; Cajete, 2005; Medin & Bang, 2014b). As an example, Brayboy and Maughan (2009) highlight a teacher's explanation for why a mainstream science lesson on planting seeds would be inappropriate for Indigenous students. The lesson

decontextualized the knowledge that resides in and around the seed — what it will become, when and where it is best planted, how to tend the plant that the seed will become. From an indigenist perspective, by removing the relationships that the seed was embedded in, the lesson stripped the seed of its relevance and knowledge. This same emphasis on contextuality and interconnection is what allows Indigenous perspectives to be so useful in studying ecological systems.

Indigenous Pedagogies

Indigenous pedagogies are premised on the same values as IKS and Native science (Merculieff & Roderick, 2013), with context, relationality, collective membership, centrality of land, and moral content as key tenets. Lessons are contextual to both place and time, to the point where the lesson often comes from the place itself, the surroundings and their history having significant bearing on the lesson (Bang et al., 2014). Many lessons call for a story, and some are best learned via experience. The two often intertwine, with a story setting the stage for discovering a phenomenon, or providing an opportunity to reflect upon empirical observations (Marin & Bang, 2015).

Learning is a collective enterprise, encompassing teacher, student, community, and land, often blurring the boundaries between them. Elders are the decision makers, but the community itself, including students and MTH entities (such as water or a deer) holds important knowledge. Much of this knowledge is indirect, and requires reflection and contemplation to be fully realized. At the same time, knowledge is built and reified by the community as members share and develop ideas. Visual and non-verbal ways of knowing are recognized and honored, and the use of the full range of senses is important. Western Science Education

One feature of Native science / ways of knowing that is very distinct from Western science is the direct acknowledgement of the power and responsibility of knowledge (Archibald,

2008; Brayboy & Maughan, 2009; Cajete, 2005; Deloria & Wildcat, 2001; Kawagley, 1995; Kawagley & Barnhardt, 1999). This helps determine what should be taught, to and by whom, and when it is appropriate. This is a point where Native (Indigenous) and Western (mainstream) science education diverge. While both views acknowledge the connection between knowledge and power, Western science education is premised on the ideal of an objective standpoint from which universal truths can be discovered (Aikenhead, 1996; 2008; Malcolm, 2007). These truths are separate and distinct from moral concerns and many science teachers are often distinctly uncomfortable with science topics that are affected by philosophical or ethical beliefs, such as climate change, evolution, or population growth. Indigenous pedagogies hold that ethics and moral considerations should accompany knowledge, indeed are intertwined with it, to the point where some knowledges are deemed sacred and/or very powerful and must be shared with great care (Archibald, 2008).

Another important difference is the emphasis of Indigenous education on physical place. In environmental, outdoor, and place-based education this is often interpreted as the physical site as it is encountered and remembered within modern human memory (c.f. Bunting, 2006; Lieberman & Hoody, 1998; Place-based Education Evaluation Collaborative, 2008; Woodhouse & Knapp, 2002). In Indigenous education, the geographic location of a teaching and learning site, with all its attendant social and ecological history as well as its potential futures, is central to the teaching, particularly in matters of natural history. (Deloria & Wildcat, 2001). Environmental education is often presented as an alternative to standard science education, but if it persists in presenting lessons that occur indoors or away from the ecosystem at hand, it is committing the same errors of abstraction and disassociation.

Relational Epistemologies in Situ

Relational epistemologies hold the world as a collection of interconnected entities, with permeable borders and a focus on the constitutive nature of relationships— without knowing the context around something, we cannot know the thing itself (Bird-David, 1999; Burkhart, 2004; Cajete, 2000; Kawagley, 1995; Marin & Bang, 2015). They extend greater commitment to the "nondifferentiation between humans and animals" (Viveiros de Castro, 2004, p.464) by recognizing the agency and personhood of the more-than-human and providing "frameworks for reasoning and problem solving in terms of ecological, reciprocal, and correlational relations" (Bang, 2015, p. 9) than posthumanism and other Western-dominated fields of thought.

Relational epistemologies are a foundational premise of Indigenous ways of knowing, and as such, one we attempted to broach and foster during the study. In Indigenous pedagogies, the teacher is one of many community members influencing the students' learning. That same learning community also includes the outdoor environment and all the MTH actors that become physically and epistemologically present when students are in outside learning spaces. This is concordant with Roehl's (2012) assertion that the classroom itself plays a foundational epistemological role in science education.

Assaraf and Orion (2005, 2010) and Assaraf, Esach, Orion, and Alamour (2012) have conducted a series of studies investigating cognitive influences on student conceptions of ecological systems. At the same time, education scholars have been investigating the influence of culture on human perspectives of the natural world, particularly in correspondence to the relational epistemologies of specific Indigenous groups (see Bang & Medin, 2010; Bang, Medin, & Atran, 2007; Medin & Bang, 2014; Medin, ojalehto, Marin, & Bang, 2014; ojalehto et al., 2015; Taverna, Medin, & Waxman, 2016). The combined findings of these researchers suggest

that there is a connection between outdoor experience, relational epistemologies and deep ecological understanding. Given that a human nature-divide has characterized mainstream science education (Bang, et al., 2014; Brayboy & Maughan, 2009; Ingold, 2000), future efforts in ecological education for all peoples may do well to consider including Indigenous theories in education for all audiences.

Indigenous pedagogies were central to this project for two reasons— equity and sustainability. Native children have had to navigate across different ontological, axiological, and epistemological versions of the natural world (Bang & Medin, 2010; Bang, Warren, Rosebery & Medin, 2012; Brayboy, 2006; Brayboy & Castagno, 2008; Brayboy & Maughan, 2009; Whitehouse, Lui, Sellwood, Barrett, & Chigeza, 2014). The understanding and importance that Native communities and families give to the relationships between humans, water, animals, plants, and other natural elements can differ greatly from the models presented by the western science-oriented classroom (Bang, 2017; Cajete, 2000; Kawagley & Barnhart, 1999). The difference in these two versions is important, with western science holding more power (Bang et al., 2014; Warren & Rosebery, 2011). This imbalance plays out in the form of low representation of Native Americans in the sciences and engineering (National Research Council, 2007), a fact that carries additional weight when we consider that many land management positions require a degree in the sciences, including those on tribal lands.

Addressivity, Teachers, and Science

In the current mainstream US educational systems, nature-culture relations are not identified as a specific field of study. Instead, they fall under the purview of science, environmental, outdoor, place-based, and other educational disciplines. Teachers facilitate nature-culture relations by guiding student attention and pointing out relationships within the

natural world. In education at the nexus of nature-culture, teachers' individual attitudes and knowledge are particularly important (Chawla & Cushing, 2007; Cotton; 2006; Hart, 2003; Mosely, Reinke, & Bookout, 2002).

Science teachers play an influential role in shaping students' epistemologies of the natural world; for some students this may be the greatest contact they have with nature. The moves that instructors in outdoor learning use to scaffold student knowledge and understanding can help or hinder student understanding of ecological processes. An instructor's pedagogy can exacerbate or reduce the divides that Indigenous students navigate between power, science, community knowledge, and mainstream knowledge when sense-making in the eco-social world. While there is research and curricula that addresses teaching and learning alongside Indigenous students, there is not yet a well-developed body of literature regarding the impact of addressivity on teaching and learning science curricula. The central research questions here are:

What are the discursive practices used by teaching adults to introduce or support addressivity in moments of teaching and learning about plants?

What specific practices do teachers use to direct student attention in ways that support addressivity?

Design and Methods

This project was created to help Native students and their families in creating just, sustainable, and culturally healthy communities as they prepare for and act on the socio-scientific challenges of the 21st century, and to do so without ceding the deep knowledge and traditional practices of their communities. The project design enabled participants to integrate both forms of scientific understanding, a practice that has been shown to lead to richer mental models of ecosystems (Medin & Bang, 2014a).

This work is an ongoing extension of work begun in Chicago by the Native community (Bang, et al., 2014; Bang, Faber, Gurneau, Marin, & Soto, 2015; Bang, Medin, Washinawatok, & Chapman, 2010; Marin, 2013; Marin & Bang, 2015; Medin & Bang, 2014a). Previous iterations focused on desettling science content (Bang, Warren, Rosebery, & Medin, 2013) and building place-based curriculum with Native youth. This project was one aspect of a larger design-based research project (Collins, Joseph, & Bielaczyc, 2004) using art and science in tandem to increase the participation of youth underrepresented in the STEM fields while fostering deep learning in a complex socio-ecological issue. Our team worked with the urban Native community in a large western city and focused on climate change. The greater project centered around developing a repertoire of four key practices – cultivating attention, making, critique, & exhibition. These key practices connect with the eight practices identified in the NGSS and we wished to determine whether they can support the deep ecological and scientific learning of Native youth. This paper focuses on the practice of cultivating attention, while also holding that the activity was very dynamic and could easily flow from one practice to another and back again.

Researchers / Instructors

The instructors for the camp activities were a combination of members of the research group and community members. The instructional team covered a range of experience and characteristics among its members. For the purposes of this study we will focus on two aspects; Indigenous identity and ecological expertise. Every instructor fell somewhere within a continuum for each characteristic— some instructors were well-established in their Indigenous identity, while others identified as non-Native. Some instructors have spent extensive time teaching in outdoor settings and were familiar with the local ecology while others were spending

their first year in the area. They had varying degrees of science specialty, ranging from general interest to an advanced degree in restoration ecology. All of the instructors had been educated in mainstream schools and were successful in the current educational systems, having earned four-year college degrees and pursuing advanced degrees. Additionally, all of the instructors had some combination of experience in working with children and educational expertise. This particular aspect of the project demanded required specific pedagogical expertise; the work of navigating and facilitating transitions between relational ways of knowing the world and Western science is not documented nor commonly practiced in mainstream science education. In a later section I will discuss the difference between novice and expert teachers using Indigenous pedagogies.

This study focuses on two instructors within the project. Sonya, of mixed European American and Eastern Indian descent, is an experienced educator, with 12 years teaching experience, 8 of those years teaching ecological science in the field. She holds an advanced degree in education and is pursuing further study. A teacher-researcher with the project, this was her first year working with Indigenous pedagogies and methodologies. Luis, is Ashinaabe and Diné, a teacher, a father, and an experienced educator with 6 years teaching youth programs using Indigenous pedagogies, currently pursuing an advanced degree in ecology. He is Native American, raised in Ashinaabeg and Navajo traditions. Two other teacher-researchers' actions were also analyzed in the data. Elena is a member of the Cowichan Tribe, while Maria is Ashinaabeg. I, the author, must address my own positionality here. I too am a teacher-researcher in the project, with predominantly European-American settler colonial ancestry. Like Sonya, I have extensive teaching experience in the local natural history and am very comfortable teaching

outdoors, and am pursuing a doctoral degree in education. This was also my first year working with Indigenous methods and pedagogies.

Design Process

In in order to combine STEM learning, the arts, and Indigenous pedagogies, the research team decided to design a learning environment centered on field-based STEAM (science, technology, engineering, arts, and math) education for Indigenous youth, or I-STEAM. As a first step in beginning the process, the project's Principal Investigator, Megan Bang, acknowledged and followed community protocol by approaching the leaders of the Duwamish and Muckleshoot tribes and asking for permission to conduct the project on their ancestral lands.

Designing for addressivity. Fostering onto-epistemic heterogeneity (Bang et al., 2013; Bang & Marin, 2015; Roseberry, Ogonowski, DiSchino, & Warren, 2010) and facilitating onto-epistemic navigation between and among the varied forms of science are an important part of designing for addressivity. Due to the powered relationship between western science and Indigenous knowledges, this required drawing from decolonizing methodologies (Smith, 1999) and Land Education theory (Tuck, McCoy, & McKenzie, 2014), for if we failed to address the historicity of Native science education then we ran the risk of perpetuating the actions that we were trying to counter, namely the erasure of Indigenous science.

Indigenous methodologies were implemented from the very beginning of the project, by including youth, elders, researchers, scientists, educators, and community members in the first design meetings. These design meetings contained foundational structures that were carried throughout the design process into implementation at the camp, including ceremony; community inclusion and participation; honoring the land and waters; and representing both western and Native science. Each of these aspects served important purposes in undertaking a group endeavor

of this nature, especially one that crossed cultural boundaries (academia to community, Native and Western sciences). In the first design meeting we established a space for Indigenous ways of knowing by opening with a ceremony that acknowledged the presence of ancestors, established communal intent, and requested guidance. Young people, scientists, elders, educational administrators, and other community members were expressly invited, making it clear that all roles were recognized and valued.

An important part of the project design was seeking guidance from Indigenous community members. We met with urban Native caregivers to understand the needs of the foster children attending the camp, and specifically invited key elders, leaders, families, and caregivers to attend the camp. One member of the design team was a storyteller. As we discussed the scientific and artistic processes that we would explore during the camp, he gifted the team with a series of appropriate stories. For example, making cedar cordage was an opening activity, so the story of Grandmother Cedar was selected. The researchers who would be serving as camp staff were expected to learn the stories, and to acknowledge the storytelling lineage while telling them.

The design team repeatedly walked the land where the camp would take place. The location had specific historical importance— in 1970 Native American activists reclaimed the ground on which the community center now stands (Allen, 2006). We consulted with local community members about the local phenomena and the best places to see them, while also learning the trails; familiarizing ourselves with the plants and specific growing zones; and studying the waterways and shorelines. These walks informed our design decisions—For example, a series of ponds prompted a ‘water walk’, following stormwater drainage from a

marsh down through a series of ponds. Walking on the ocean beach with a Western-trained marine ecologist prompted a sea star lesson to gather data about sea star-wasting syndrome.

During this phase of the design, the team began to develop and document specific practices, especially observation and perspective-taking. We wanted to document the component practices of onto-epistemic navigation and these two practices are important for several reasons. Observation is a key skill in both Western and Indigenous sciences. As discussed earlier, perspective-taking is an important aspect of developing addressivity. As a design practice, perspective-taking was emphasized as a means of directing instructors' intellectual resources and expertise towards cultivating addressivity with the MTH. As a further move to close the distance between humans and the MTH, the design team made the decision to implement the practices of referring to plants and animals as our plant relatives or animal relatives.

Program design. These elements all carried into the program structure. The camp opened each day with a ceremony, with the entire group seated in a circle sharing songs and setting the intent for the day. We called these events and others like them "Launches". Launch activities set the tone and established the framework wherein themes and ideas were emphasized. Activities conducted in a deliberate sequence. Launches could be nested within each other, and might be a story, song, or an activity. For example, the first launch of the day is the opening circle ceremony in which we introduced overarching themes— in this case, reciprocity. A second launch is the storytelling activity, with a plot that reinforces and elaborate on those themes, telling a story of reciprocity between a young cedar sapling and an old growth grandmother cedar. In the next activity, the launch introduces the activity, plant study, and the mediating tool has specific questions to cue the students to think about types of reciprocity and their chosen plant.

One of these launch activities was the introduction of students to plants. Throughout the lesson, plants were referred to as "our relatives", and human-plant interactions were highlighted. After an initial orientation to the native plant garden where students and instructors met some plants and offered tobacco, each student was asked to select a plant species to become familiar with. They were asked to notice and record details about the plant's features, its location, surrounding plants, as well as take the plant's perspective, with particular attention given to relationships between the plant, humans, other plants, animals, water, sunlight, etc. The lesson framing was supported by the distribution of a template tool that mediated different modes of interaction with the plant. The front side of the tool had a picture of the plant in the center, with the name in English and Lushootseed, the regional language. The image of the plant was surrounded by prompts for the different relationships the plant was involved in, i.e. neighboring plants, water, the sun, soil, animals, establishing the web of interrelationality that it existed in. The prompts were specifically phrased from the plant's point of view ("Who eats me?"), to encourage perspective-taking on the part of the plant and its neighbors. The back side of the tool (Figure 3) was designed to encourage more focused attention to parts or aspects of the plant— cone, bark, leaf, flower, plant shape— in the manner similar to a Western-science influenced botanical study.

Data

Data Collection

Data consisted of audio and video recordings of the field-based instruction, audio recordings of the design meetings, field notes collected by researchers, and interviews. Throughout the week of the camp, instructors wore audio recorders as they worked and researchers filmed the teaching interventions, yielding a total of 20 hours and 21 minutes of

field-based video and 28 hours and 24 minutes of field-based audio data. In the course of reviewing and analyzing the data, I returned to several project teachers who worked with Jim during the first day and interviewed them as a form of triangulating and member-checking.

The Plant Relatives activity occurred in the morning on the first day of the camp. As the first outdoor lesson, it was the first encounter with nature *in place* and thus a foundational event in establishing the role of plants and animals within the onto-epistemological landscape of the camp. I wanted to focus on the teachers' pedagogical moves towards (or away from) addressivity of the MTH. I collated all the data collected during the plant launch, 4 hours and 14 minutes, on the first day of the camp and reviewed the corpus. To create a framework of addressivity, I selected segments where adult teacher-mentors and students interacted with a plant (or a bug on a plant). Parts of the dialogue were coded according to recurrent themes and pedagogical moves supporting addressivity were identified and grouped together in categories (See Table 1). After identifying pedagogical moves, I returned to the design data to trace the development and implementation of the structures that fostered or reinforced addressive speech and practices. In a second round of analysis, a story emerged, one that illustrated the different semiotic landscapes that the instructors and students were both navigating. To tell this story, we follow Jim, an 11-year-old boy of Yakima descent, as he travels through the garden, meeting plants, listening to instructors, observing and discussing MTH entities with other students and adults, and negotiates the various onto-epistemological frames as they appear. In the next section I will present the discourse moves the instructors used.

Instructor Moves in the Moment

There were a wide variety of discourse moves by the adults, but five specific moves appeared repeatedly throughout the interactions among all of the instructors. They were:

Noticing Detail; Directly Speaking to Plants and Animals; Attention to States of Mind; Perspective Taking on the Part of the Plant or Bug; and Protocols. Each of these moves were consistent with Indigenous pedagogies, reinforced relational ways of perceiving and understanding the world, and finally, were steps towards addressivity. In the following section, I explain each move more thoroughly. In the following transcripts, "S" is used for student and "T" is used for a teaching adult.

Attention to states of mind. In this excerpt, a teaching adult reminds students to pay attention to the plant they are harvesting, both physically and mentally, while another student reminds the group that the plant needs to be respected.

T1: Zora, you're stepping on them.

S1: Oh I don't mean to.

T1: I know this name, wood sorrel, but the other name, what name in my language I forget.

T2: The path is right here.

T1: We're gonna go out this way guys. We're gonna take the easy way out this time, we're not going through the… Remember, don't take too much.

S2: I'm definitely going to eat…

S3: Don't take too much or... uh... it's just not respecting the plant.

T1: Exactly.

Children's attention to the internal states of others is considered a developmental milestone (Bretherton & Beeghly, 1982). It is important to note, however, that this development research has been exclusively focused on the internal states of humans, thus restricting our understanding of children's sense-making. Relational epistemologies and the Indigenous

knowledge systems based upon them have often been dismissed for attending to the internal states of plants and animals. Recent research in now beginning to challenge this dismissal; for example, Kohn (2013) applies anthropological methods to assert the ability of non-human beings, including plants and animals, to think. Additionally, botanists have been studying the mechanisms behind plant communication (Heil & Karaban, 2010).

Directly speaking to the more-than-human. The ability (or lack thereof) to use a specific language or human speech, has served as a robust gate-keeper in maintaining the human / non-human divide. In the exchange below, a student and an adult notice a crane fly. The student speaks directly to the fly and the teaching adult joins in the conversation.

S: Did you see the mosquito-eater?

T: I seen some in my lifetime, but I didn't see the one you were showing me. Did it look full, or just look hungry?

S: Full (whispers) It was flying!

T: I bet looking for mosquitoes. (2s.) I don't see—

S: Hey you skee—mosquito–eater, can you come to my house tonight and eat my skee—mosquitoes.

T: (Laughing) That's cool. Yeah, me too after you're done with Yasmin's, wherever you went. (1s) Hey, where is this… vine maple at? I know we saw it, but now I don't remember where it went, or where we saw it.

Plants and bugs were regarded as being able to understand states of mind and thus were acknowledged, thanked, and accorded respect. Furthermore, addressing the bug indicates a social connection, which is in concordance with relational epistemologies. The connection between

plants and humans is reciprocal, with each having roles and responsibilities. The social connection extends to a whole network, of which the plant and child are part.

Observing detail. The teaching adult pointed out or encouraged the student to notice details about the plant and/or its surroundings. This practice is supported by Eberbach and Crowley's (2009) steps for helping children to become expert observers and develop the abilities of trained scientists. In the segment below, a teaching adult coaches a student through paying attention to the features that distinguish one plant from another.

T: What, what else grows around it? This is yellow dock, and I can tell because look at the leaves. What do you notice about the leaves?

S: There's dots.

T: There is dots, look at there—

S: [There's] some yellow dots that I see.

T: Mm hm, that's what I see too. And what else do you see?

S: Seeds…

T: Seeds

S: …and a stem…

T: and a stem. What do you notice that's [growing around?]

By paying attention to the different details on the plant with an informed adult, children begin to develop an expertise about the plants. This expertise becomes a systematic knowledge of what is common and what is uncommon, or a noticing of patterns and disruptions. It is important to note here that the manner of noticing matters as well. Students were encouraged to notice plants in relationship to other entities, forming an ecosystemic expertise. This manner of

observation is in contrast to the common (Western) scientific practice of introducing people to plants via taxonomic classification, or a narrowing of which details to notice.

Protocols. Specific practices, such as offering tobacco, or how to harvest a plant, were demonstrated and modeled by the teaching adults. In the following segment a teacher shows students the steps involved in eating wood sorrel. First, tobacco is offered as a show of gratitude and respect to the plant. Then the leaves are harvested, but the sorrel is delicate and easy to uproot. It is also growing in a patch among several other kinds of plants, so the adult emphasizes the importance of picking and eating the correct plant.

T: Look at this. Here we have our tobacco already down. Take a leaf. Pinch it with your fingernails… instead of pulling it out from the root. Oh, that's cool.

S1: I don't think I pulled enough of the root, but…

S2: What you're eating it?

S1: Well it's safe to eat.

T: But you— has to be this one. This one only. What's it taste like?

S3: Can I bite this one?

T: Yes. That one. But you really have to remember what it looks like.

S1: Why?

T: Because, you don't want to bite one that isn't something you know.

Protocols establish the guidelines for proper relationships with plants and animals. They attend to the mental states of plants (such as when an offering is made) but they also serve practical purposes, such as saving plant populations from overharvesting, or preventing humans from ingesting something poisonous. Ultimately, protocols foster responsible behavior by

encouraging people to consider the ramifications of actions before they are taken (Archibald, 2008; Brayboy & Maughan, 2009).

Perspective-taking. In Indigenous pedagogies, the ability to adopt different points of view is often developed through telling and reflecting upon stories (Archibald, 2008). Teaching adults adopted plant and bug perspectives and encouraged students to take them on as well. During the following excerpt, a group of students and teaching adults are walking through a dense patch of bushes laced with tough, prickly, blackberry vines. The students are moving quickly and are somewhat nervous about the blackberry vines, with some students using sticks to push the vines aside.

T1: Wow. Don't, D— What would happen if you grabbed at it?

S1: It would hurt.

T1: Yeah. Why do you think he has- why do think this plant relative has thorns?

S1: To protect itself.

T1: Yeah.

T2: Why do you think it has thorns?

S2: Because thorns protecting.

T2: Yeah. (1s) So the plants are defending themselves.

S3: Yes.

Perspective-taking is considered an important social development skill in humans, strengthening social bonds and facilitating social coordination (Galinsky Wu, & Wang, 2005). In Indigenous pedagogies, the ability to adopt different points of view is often developed through telling and reflecting upon stories (Archibald, 2008). Extending perspective-taking to plants and bugs reduces the psychological distance between the student and nature (Medin & Bang, 2014).

In order to take the perspective of another, they must have a perspective to adopt, and a state of mind from which to have that perspective. Perspective-taking has been linked to power differentials, with a negative relationship between measures of power and the ability to take another's perspective (Galinsky, Magee, Inesei, & Gruenfeld, 2006). It is possible to infer from this that taking the perspective of a MTH being reduces notions of human exceptionalism.

Following Jim

The first segment of video (0:00 - 2:43) showed Jim and the other children and instructors seated in a large circle in a classroom. Maria, the instructor presenting the activity, set the intention— "What we're going to start doing this afternoon is getting to know some plant relatives." Students were reminded of the plants that they had already come to know during the camp in the opening activities, including cedar, sage, and *asema*, or tobacco. Maria discussed her relationship with plants, saying, "I go visit with them and I see how they're doing. And they help me think about how I'm doing. And so that's what we're going to start to do today." She then initiated the transition from indoors to outdoors by reminding the group of *asema's* role in establishing relational protocols, and everyone was invited to take some *asema* out to the garden as they went to introduce themselves to the plants. This portion of the lesson is a deliberately Indigenous framing, with emphasis on traditional knowledge, human-plant relationships, interconnection, intent, and protocols.

In the next video segment (6:15 - 7:44), Sonya is walking towards the garden with the students, including Jim. They are all holding *asema*; when one complains that he doesn't "want to hold this medicine forever", Sonya tells them him "You can say a little prayer, offer it to a plant of your choice". She turns away from him and we see her silently place the *asema* in her own hand. Turning back towards the students, who are asking about putting *asema* down, she

responds “Sure, you can say a little something.” She spends the next few minutes gathering Jim and the other the students into a circle. Once everyone is together, she orients then to the space by pointing out an interpretive sign with a map on it. (11:48) She describes the upcoming activity; “We’re going to meet a lot of new relatives today, and you are all going to become really close with one relative in particular…We’re going to explore the garden and… to see who’s around and to see where your relatives are.” Pointing out the boundaries of the garden, she directs them to explore for a bit and then return to collect sheets for plant study (12:46). Within a minute of beginning to explore, she points out an interpretive sign (13:22) and asks if they notice anything special about the sign. Jim identifies the Latin wording on the sign as the “scientific name”. There several science classroom cues in this section, from the Latin plant name, the work sheets, the interpretive signs. At the same time, an Indigenous frame is in play with the use of *asema* and involving the relationality of “our garden relatives”.

At this point (13:37) another adult, Luis, steps in. Gathering the groups’ attention, he explains that they are not making new relatives so much as getting re-acquainted. He demonstrates the protocol for politely introducing oneself to a plant with asema. He then asks the students if it possible to speak without using one’s mouth, explaining that “I try to use my emotions next to a plant and give the good energy off. So if I’m happy I want to give the good energy, or receive some energy from plants…. I think they can give off some emotion too… These guys are like our cousins. Everyone ready to say hello to our relatives?” In contrast to Sonya’s instruction about placing the asema earlier, Luis is clear about how to use the asema and he makes a point of modeling it. He uses human relationships to illustrate the connections to plants and explains communication beyond human parameters. The asema, a plant product itself,

anchors the connection between human and plants, formalizing the reciprocal nature of the relationship and placing it within an Indigenous frame.

Sonya, Jim, and Lisa, another student, move to a nearby plant, using the sign to identify it as trailing blackberry. They note the Lushootseed (a language native to the area) writing on the sign, and Lisa asks if she can take a berry. Sonya responds "Before we do that let's say 'hello', and I might offer a little asema. So before we take anything, let's just go around and say 'hi'. And introduce ourselves first." They then discuss what the plant has to offer humans as food, materials for clothing, and as medicine. When they move to another plant, Sonya says, "Let's see what other plant relatives have to tell us." The group moves on through the garden and finds a salmonberry bush. Upon Sonya's remark that the stalks have tiny thorns, Jim remarks "That's how berries usually protect themselves. Most berry plants have thorns." Like Luis in the paragraph before, Sonya is focusing on reciprocity and communication with the plants, using asema to mark the exchange. However, she uses the interpretive signs as an intermediary for this information.

Working on the study sheets and individual observation. After the group explored the garden, Sonya collected the group (28:55) to work on their plant study sheets. The students each selected a plant relative with which to form an "extra-special" relationship on an individual level. Jim chooses Western Red Cedar. Sonya introduced the study sheets, pointing out the sections for detailed plant part observations on the back — leaf , bark, flower, seed or cone. Soon the group is seated around two plants, observing and sketching the plants. The longer the group looks at the plants, the more detail they notice. The students discuss what they are observing and different plant facts. As they are drawing and discussing, Jim shares information about the natural world throughout the conversation, noting that "If you ever find a stinging nettle, make sure you have

ferns… You have to break off the needles." (36:56, referring to the use of sword fern spores to soothe nettle stings); pointing out a ladybug on the plant (39:40); explaining that daddy long-leg spiders' mouths are different from other spiders and that they can't bite humans (41:26); and counting the number of spiders on the plants (43:50). At 45:17 he explains that spiders keep down the insect population, and that "Mosquitoes do have a purpose. They do a tiny bit of pollination, but not a lot." At one point, (46:04) he says "Actually, I'm not too fond of bugs". Later Jim, Sonya, and Mikey, a younger student, are drawing and discussing the plant. Mikey says "This is so hard!…There's so much stuff!" (46:14) referring to the detail he is observing. Jim responds "If you ever do a drawing of plant life, it's always going to have to be scientific, so…", finishing the phrase by rolling his eyes and sighing, addressing Sonya. She replies "Well, this doesn't have to be scientific. It can just be… a sketch. You can draw it however you want." From the previous activity, we know that Jim is interested in plants and animals, is knowledgeable about natural processes, is a quick and keen observer, and enjoys sharing knowledge. Yet there is a burdened air about doing something 'scientific'. Throughout this section of the activity, they have been given a plant study tool and are doing botanical illustration using pen and paper— both of these acts are reminiscent of classroom science, with its predominantly Western view. Further, the side of the sheet the students are using is segmented, with different plant parts framed in isolation of each other.

At 52:50, Sonya rounds the group up and has them go find their individual plant relatives and focus on learning what the leaf and seed of the plant looks like, using the back side of the sheet. At 55:02 Jim, walking with Sonya, identifies Western red cedar, the plant that he has chosen. Sonya says:

> So get to know your plant— say hi, you can introduce yourself. [to tree] 'Hi Western red cedar, I'm Sonya.' …So after you've introduced yourself and taken some time to spend with Western red cedar, really focus on, today, the leaf shape, and the seed, and the cone, and the flower. So actually this one is kind of interesting…it looks like this would be considered the leaf, even though it's very different from say this leaf right here. So take a good look...how does it smell, how does it feel? And you can draw it, you can take notes, you can use more than one sheet of paper, okay? I'll be back. (Transcript)

Sonya has encouraged Jim to get to know the tree using a range of senses— touch, smell, sight— but for the most part the introduction has been on human terms, using speech and focusing on the paper study sheet.

Onto-epistemic navigation and addressivity. There is a two and a half minute gap where we do not see or hear Jim. When Luis joins him, Jim is standing by the tree. From the following dialogue, we realize he is wrestling with different ontological and epistemological frames, trying to reconcile the onto-epistemic heterogeneity he is experiencing with Sonya and Luis. At 58:45 Luis walks by Jim and says "Ohhh yeah. Know what, in my language this is what we call *giishik*." Jim responds "Yep. Western red cedar. This is all new to me, so it feels a little awkward sometimes." Rather than responding directly, Luis begins to point out details of the tree to Jim. Jim continues:

> *Jim:* It's just a little awkward to start talking to trees because I've never done this before…This feels different for me.
>
> *Luis*: Different is good. I like it. So.(.) Do you ever feel awkward with other people? (Weird) that someone you didn't – you're not quite sure?
>
> *Jim:* Like…awkward talking to them? Yeah.

Luis: It happens sometimes when you're not sure how to communicate. Say…someone has a different language and only speaks that language.

Jim: Right.

Luis: Remember in the beginning when I said that there are different ways of talking—

Jim: (Mm-hmm)

Luis: —other than your mouth?

Jim: Yeah , I mean, earlier I had no problem speaking in my mind, but now talking out loud it's…

Luis: Yeah.

Jim: —harder.

Luis: That's cool. You know one of the best things about plants? Maybe you have plants in your house? By the windows? Turn it, turn the whole pot the other way around, and in just a short time, the plant will move and move its leaf towards the sun. And it happens really fast. Not like, not immediately, but like—

Jim: Some subtle movement. Twelve hour fast.

Luis: When you think about it the plants are smart. They have… they have a way of moving so that, it's good for them. The sunlight's good for them.

Jim: Bamboo doesn't move that much, so…

Luis: When you have big broad leaves like this, there's a reason why it's showing this way. 'Cause if the sun was that direction—

Jim: They would be bending the other way

Luis: —they would be bent. That way. Like this.

Jim: Yeah.

Luis: Same with these guys, you know? See how it's flat?—

Jim: Yeah.

Luis: —They're getting all the energy from the sun, from this direction.

Jim: Yes. If it was turned the other way you'd (unintelligible).

Luis: If for some weird reason the sun was that direction, these branches would be faced like that.

Jim: Yeah.

Luis: Which is the amazing thing, because these guys know exactly where the light is and they face the direction of the light. That's part of talking with your body, body language.

Jim: (unintelligible)

Luis: But these guys have their own, their own characteristics and their own… jobs to do. Not every one has the same job. So these (rules). You know how we had tobacco and we offered it down?

Jim: Yeah.

Luis: This has a different job. You wouldn't necessarily crumple this up and use it the same as, as tobacco would. Because that's like… that's like our food is medicine. And using the apple to eat it, and feeling all the energy from the apple, you wouldn't do that with a… a sponge, right?

Jim: No.

Luis: They got two different jobs to do. One is to nourish you and the sponge, you got so many different reasons for sponges but, you wouldn't stick it in your mouth to eat it. Maybe you might wash dishes, maybe you might pick up a spill… It's the same thing with plants, they all have different jobs to do.

Luis begins the conversation by sharing the Ojibway name for cedar, establishing an Indigenous space. When Jim asserts that he is having difficulty reconciling the idea of 'studying' trees with 'talking to them', Luis uses ontological frames (The plants move in a way that's good for them; They know and face the light) and axiological frames (Everything, including plants, has a job; food is medicine; tobacco is for offering) to establish the plants' personhood, illustrate the social connection, and show their perspective. In short, Luis is explaining and performing addressivity to help Jim both navigate and integrate the different frames of plant science.

Discussion

As we watch both the instructors and Jim move from the classroom to the garden, we see them move between several different framings of the human-MTH relationship. Each framing can be traced by attitudes, actions, language, and other semiotic markers (Goodwin, 2007). The tension between relational ways of knowing the world and Western science is apparent in instructor and student discourse patterns and actions.

The discourse of classroom science, often abbreviated as 'science' comes easily to many of the instructors and to Jim. Cued by Latin names on an interpretive sign or a sketching activity, classroom science does not consider feeling, intuition, or spirituality. Aikenhead notes (1996), this axiological stance is one that differs most dramatically between Western classroom science and Indigenous knowledge systems, requiring Indigenous students to engage in epistemic border crossing every time they are in a science classroom. Pedagogical facilitation of students' navigation of this border requires experience and practice. By comparing Sonya and Luis, we get a sense of what is required to become both an experienced teacher in Indigenous methods and to move among different semiotic, ontological, and epistemological environments with students.

Sonya

Sonya greeted the plant on human terms, gently shaking the branches like one would shake another persons' hand. She also used human tools, such as the study sheet and interpretive signs, to facilitate the learning. Further, the study sheet and pencil combination linked the activity to classroom science and its associated epistemologies, ontologies, and axiologies. From her previous conversations and activities with Jim (reading Latin names on the interpretive sign, botanical sketching) it is easy to see how Jim would associate her instruction with that of a classroom science teacher.

During the interview, she watched the video of the interactions with Jim and noted that during the activity she was consistently worried about being on schedule and feeling time constraints. Additionally, Sonya is distinctly aware of the fact that she is working with students from a different cultural environment and admits she is not comfortable talking about spiritual aspects of relating to plants, or at least as an Indigenous representative. In the interview she says, "[T]hat's not my practice. I don't feel comfortable." She recognizes Jim's inclination towards science and comments that while she can use epistemic levers, ontological navigation "is a different ballpark". While many teachers are concerned about overstepping cultural boundaries, as a researcher Sonya is acutely aware of the importance of relationships with the natural world for Indigenous students, and more importantly, the epistemic violence that so many Native students are subjected to in science education.

Luis

As an experienced Indigenous scientist educated in mainstream US science methods, Luis is accustomed to negotiating epistemic heterogeneity and reconciling the potentially conflicting worldviews of enlightenment-influenced science and Indigenous knowledge systems. Further, he

is accustomed to recognizing the plants' 'personhood' on an ethical plane. He established the space as Indigenous by using *asema* and speaking in Ojibway, both for the benefit of the students and the plants. He reiterated the principles of collective membership (everything has a place and a role), taking the plants' perspectives ('they would be bent this way'), addressing the plants directly, acknowledging their knowledge and capacities ("because these guys know exactly where the light is and they face the direction of the light"), all tenets central to Indigenous pedagogies and philosophies.

Jim's Identity

Watching Luis model these moves is incredibly important to Jim. These questions of different ways of knowing pertain directly to his identity. The fact that by the end of the conversation he is comfortable relating to the plants, and wants to reinforce the relationship by offering asema is pivotal. Later in the week, the full impact of the encounter became clearer when Jim's mother shared a story with Maria. Jim often fought with his sister at home, due in part to his struggles with anxiety. A few days after the cedar tree encounter with Luis, Jim and his sister were fighting when he suddenly stopped and told his mother "I'm going to go outside and talk to cedar." When he returned, he was centered and calm. Jim's dramatic personal growth was important, but the fact he was doing so by establishing a connection with a culturally significant plant was especially meaningful. Like many urban Native parents, Jim's mother has had to fight to provide opportunities for her children to follow ancestral ways that have been suppressed or lost among changing social and physical landscapes.

Conclusion

When we watch Sonya with Jim, we are watching her in a double-bind. One the one hand, she is an experienced educator, working with familiar content (science, plants, water,

animals) in familiar contexts (the Pacific Northwest forest, youth between 6-16, outdoors). On the other she is teaching Indigenous students, using Indigenous methods and philosophy, all for the first time. Not only must she use new techniques, she must re-examine the patterns and responses she has developed over years of pedagogical practice, often in the moment of teaching.

As Sonya explained, and Medin and Bang (2014) illustrate, it very difficult to draw boundaries between onto-epistemic moves and cultural practices. However, trying to develop and support onto-epistemic moves towards forming relationships with the MTH is something that all teachers can do. The five pedagogical moves outlined earlier—Noticing Detail; Directly Speaking to Plants and Animals; Attention to States of Mind; Perspective Taking on the Part of the Plant or Bug; and Protocols— are actions that all instructors, both Indigenous and non-Native, engaged in throughout the course of the camp. They are actions that are easily modeled and present in many cultures, ones that can be engaged in without participating in cultural appropriation. More importantly, these moves are steps towards ethical treatment of the MTH. Seeking the knowledge and power that a plant possesses without acknowledging the personhood of the plant is an exploitative act. These pedagogical moves allow instructors to create spaces for students to interact with the MTH on relational levels. Finally, it allows us to move away from the anthropocentricism that insists upon human supremacy.

Such efforts have multiple implications. Firstly, there is the implication that there is one way to think about the natural world, and this way has a prescribed set of rules about what counts as knowledge. Further, that knowledge must be recorded and transmitted in particular formats in order to be considered valid, and must be distinctly separated from spirituality and ethics. For students that do not identify with what has been cast as the dominant form of knowing

ecosystems, the implication is that there no place in science-based fields for hybrid, adaptive, and/or outside the norm ideas, and therefore for them.

It is this difference— whether the plant is accorded that fundamental level of respect that is given to an agentic actor— that is the fulcrum of managing environmental issues. If natural elements are regarded as powerful entities with capacities and abilities outside the scope of human control, we make plans that include possibilities other than those we imagine or wish. We create buffers around sensitive areas, make contingencies for unplanned eventualities, and pay careful attention to those indicators that give us feedback about the ecosystem. If on the other hand, we assume that we are able to control every aspect of ecosystems, with technology that is either current or near enough in the future, we repeat the same mistakes that leave us with catastrophic floods from failing levees, homes inundated by sea level rise, massive wildfires that overtake cities, and crops decimated by invasive species.

To continue to develop pedagogical methods for teaching climate change, we need further studies that link teaching methods to ecological cognition, and on a large enough scale for statistical analysis. Additionally, studies like those of Medin and Bang (2014) that investigate the cultural and cognitive factors that contribute to understanding ecological processes in the wild help narrow down the specific teaching and learning factors that we can develop and improve. Finally, continuing work on science education and ethics, specifically as it relates to cognition and practice, will allow us to develop more effective pedagogies.

CHAPTER 4: DEEP TIME AND ROCK STORIES

Introduction

As the geophysical world changes around us, we must develop forms of education that inform and foster the human capacity to interact with the natural world. A significant amount of time and energy has been devoted to developing climate change curricula to prepare youth and their families for anticipated dramatic changes in the world's climate systems. While we understand that future communities will need to have a working grasp of complex ecological systems in order to ensure that humans will survive, how to go about preparing people to interact within these systems is still a large challenge. In Western industrial nations, we still struggle to recognize the role that power and agency plays in articulating a comprehensive and effective theory of education and human-nature interactions. The issue is especially pressing for peoples that rely on connections to the land for their livelihood, identity, and culture. They are the first to notice and suffer the effects of a changing ecosystem, while at the same time their voices and values are not included in the decisions that dictate human action writ large.

Complex Ecological Systems

It has been well-documented that understanding complex systems are a challenge in our educational system (Davis & Sumara, 2006). There is an established body of literature that attests to and details students' difficulties in understanding complex systems (Assaraf, Dodick, & Tripto, 2013; Covitt et al., 2009; Gunkel et al., 2010; Herbert, 2005; Hmelo-Silver & Azevedo, 2006; Jacobsen & Wilensky, 2006; Jin & Anderson, 2010; Matkins & Bell, 2007; Plate, 2010; Sterman, 1994; and Sterman & Booth-Sweeney, 2007, among others). However, there is also a growing body of literature that suggests that systems thinking difficulties may be related to epistemic views (Medin & Bang, 2014; Olsen, 2015; Spiro, Coulson, & Fentovich 1996; Spiro,

Coulson, Fentovich, & Anderson, 1988). Levy and Wilensky (2008) observed that students do have the ability to understand and analyze complex systems when there is contextual familiarity. The link between familiarity and ecological systems understanding is particularly salient when one considers Atran and Medin's (2008) findings that in technologically-oriented cultures both knowledge of the natural world and cultural support for interest in biological kinds is eroding (see also Louv, 2005).

Wilensky and Resnick (1999) wrote about complex systems as consisting of different levels, with each level representing a scale of detail within a system, and postulated that misconceptions about complex systems were due to students' confusion of, and 'slippage' between, different levels. Levy and Wilensky (2008) extended this work to describe agent-aggregate reasoning, where reasoning about a given system's overall behavior would be based on the behavior of individual units within the system or upon the system's behavior as a whole. Following other scholars (i.e. Wilensky & Stroup, 2003) they claim that it is a coordination of the two, a perspective known as "Agent-Aggregate Complementarity" that allows experts to understand emergent phenomena, and therefore the workings of complex systems.

Reading the Land

This paper is an argument for education that develops student understanding of complex ecological systems in situ— outside, in the field, in the locations where ecological processes happen. In order to truly understand ecological systems, and the entities that comprise them, especially the more-then-human (MTH), we need to do so on their own terms, and in their own timeframes. Scholars have identified the Western tendencies of separation and specialization in the sciences as an impediment to understanding natural phenomena on a grander scale, especially climate change (Weart, 2008). Simply put, Western science provides us with a way of knowing

the natural world, but it does not provide a complete picture, and in fact, is sorely lacking in some areas of knowledge.

Geologic Time, Deep Time, or Rock Time?

The timescale of rock formation and development is several orders of magnitude beyond the range of a human's lifespan, even the range of human existence. "Deep time" is a term popularized by John McPhee (1981) to refer to the concept of geologic time. The magnitude of geologic time is so great (over billions of years) that it is considered to be beyond human comprehension, but doing so implies that we only conceive of time in a linear fashion. Indeed, to arrange something chronologically means to string events along a time*line*.

Geology is an area of science that poses an ontological challenge for conventional science classrooms. Many research studies focus on subjects' conceptions of the magnitude of geologic time and their relative positioning of geologic events (Libarkin, Kurdziel, & Anderson, 2007). Libarkin & Anderson (2005) maintained that college students had a poor understanding of geologic time across three measures— scale, occurrence of events, and "…the specifics of absolute age dating" (p.400), or accurate placement of events along a timeline. In a summary of geoscience conceptions research, Cheek (2010) points out that there is a focus on what students don't know, and that, in a field where visual-spatial reasoning is acknowledged to be very important, 73% of the studies did not use drawings or visualizations to collect data. When architectural students were asked to design an outdoor exhibit that implemented "deep time", the designs that abstracted time were more successful than those that tried to adhere to a linear representation of time, due primarily to the magnitude of the geological timescale (Clary, Bruzek, & Wandersee, 2009). Similarly, Cheek (2013) theorizes that spatial reasoning plays a

big role in understanding geologic time, given students' tendency to equate spatial distance with temporal period.

The apparent enormity of the geological timescale holds particular relevance when people are trying to grasp the processes involved in Earth systems. In the early 19th century, in the course of developing the then-nascent discipline of Earth sciences, Charles Lyell extrapolated James Hutton's ideas into two big concepts that define modern geology: the observable geological processes of today extend into the past to make rock (i.e. the sand and clay we see accumulating on the bottom of a lake is the same process that made sedimentary rocks); and small changes over time can lead to great shifts (i.e. ocean waves hitting a cliff will eventually erode an entire headland) (Cervato & Frodeman, 2012; Gould, 1987). These two concepts can be also rephrased as principles of understanding complex systems: extrapolating the geological process of today into the past is a form of level-jumping (Wilensky & Resnick, 1999) and moving from small changes to large shifts is a form of agent-aggregate reasoning (Levy & Wilensky, 2008).

This shifting of timeframes to take the perspective of the more-than-human world is an important step. When we consider different ways of measuring time from the perspective of different organisms, ideas that we regard as fixed and immutable become relative. For example, a 'lifespan' can be less than a day if you are an adult mayfly, a year if you are a salmon, 200 years if you are a tree, and millions of years if you are a rock. The relative difference across different scales of time influences our ontological and epistemological notions. As Lemke states, "A process that produces change only very slowly seems to us not to be a process at all, but a constant fact of life" (p.279, 2000). Moser (2010) identifies temporal distance as one of the key traits that prevents people from engaging with and fully comprehending climate change.

Deep time also poses an ontological challenge to empiricists—to insist on strictly directly witnessed evidence of geological phenomena from a human perspective only allows us to theorize about a few recent volcanoes, extant glaciers, and a handful earthquakes, and yet we are confronted with data such as fossils, fault lines, and meteor impact craters that indicate the work of additional processes. Ironically, there are records of empirical observation of glacial shifts, floods, and other geologic phenomena, but because these accounts were maintained orally, until very recently they had not been taken seriously by the academy (see Cruikshank, 2010; Cunsolo Willox, Harper, & Edge, 2013). Early Western geologists wrestled with proof and empiricism, and when geologic time was 'discovered' by Hutton and Lyell, it shifted modern thinking (Cervato & Frodeman, 2012; Gould, 1987). Rocks, and land itself, went from being permanent, immutable, structures to things that were created and destroyed through cycles. A rock face became a snapshot, a text that spans millions of years, and human timescales became very short, even insignificant on some levels, posing an existential crisis for modern man (Cervato & Frodeman, 2012).

Indigenous Cosmologies and Space-Time

The abstraction of time is a key point here, in that it indicates an ontological flexibility, or an ability to conceive of time in a manner other than linear. Gould (1987) points out that Western ways of thinking about time have favored linear progression, leading to a focus on short-term yield, as opposed to thinking about time as a cycle. The seven-generations concept (Wildcat, 2009) is an example of applying cyclical thinking to account for deep time on a social dimension, which is specifically neglected in capitalist ideologies (Cervato & Frodeman, 2012).

It is this sequential, linear temporal orientation of Western philosophy that Deloria (1979) credits for ideas such as 'manifest destiny', and the myth of progress that is so central to the

mainstream American identity and psyche (Lasch, 1991). Deloria juxtaposes Indigenous, place-based philosophies alongside these Western ideologies, pointing out the importance of place and context, where a sacred place is the point of reference from which events are viewed and evaluated, even as the world shifts around it. This view is not to be conflated with the modern Western myth of land permanence, a perspective that is quickly undone when we shift to a geological perspective (McGinty & Bang, 2015). Rather, as Deloria states, "[R]evelation was seen as a continuous process of adjustment to the natural surroundings and not as a specific message valid for all times and places" (p.66). In Deloria's view, place supersedes time.

Anderson (2011) points out that many efforts to revitalize Indigenous knowledge are compromised because "…renewal efforts typically reduce culture or language to a standardized object in which multiple views are often eschewed for a single, abstracted one" (p.94). Here 'abstracted' refers to an idea disconnected from context, and in the process, significance, resulting in the loss of the ontological breadth of the original land-based language. For example, snow can be an unconsolidated fine powder that one can drown in, but it can also be a hard-packed, weight-bearing icy surface. Collapsing both ideas into the single word 'snow' renders the term useless for describing travel conditions in the arctic.

In this vein, Linda Smith (1999) notes that *time* and *space* are key ontological terms for some indigenous languages because there is no significant distinction between the two (the word is the same in Maori). Western ideas have been concerned with affixing the space and time in absolute, quantifiable categories. By disconnecting space from time, the world is rendered static, unchanging and without politics. This aids in a Cartesian mapping of the world, which allows for a reapportioning of land in colonially designated terms (Battiste, 2004; Rocheleau, 2005; Sparke,

1998). In social activity, the link between time and ‘work’ was important to the systematic development of colonialism.

Temporal Designations: Educational Timescales and Chronotopes

In an article exploring the effect of temporal constructs on education, Duncheon and Tierney (2013) identified several time paradigms, one of which is "clock time". In clock time, the predominant time construct in education, time is segmented into quantifiable, linear units. This has the effect of reinforcing the dominance of Western industrial values, and plays into a scarcity discourse, where time becomes commodified and competed for by different educational interests. More importantly, it is a settler-colonial tool. Clock time was (and is still) used to inculcate Native Americans into the American labor force (Pickering, 2004).

Duncheon and Tierney's analysis does not go deep enough for the purposes of this paper; it refers to clock time as a temporal theory and a paradigm, but there are a host of other factors that come into play with the use of clock time. Russian philosopher Mikhail Bakhtin created the term ‘chronotope’ to indicate a specific semiotic space where certain world views and assumptions are enlisted by a speaker. Chronotope is a very useful construct in that “…it expresses the inseparability of space and time” (1981, p. 84). Bakhtin describes three chronotopes present in ancient Greek novels, explaining that the importance is not the actual chronotopes themselves, but the representation they achieve via narrative. An example of this is the use of the phrase “Once upon a time” in European fairy tales, indicating to the audience certain conventions will be called into play (a class hierarchy of royalty; the use of magic; a pre-industrial society). Chronotopes can help us to anchor meaning in otherwise fluid circumstances, serving much like Deloria’s sacred places (1979) and have been a useful means of exploring psycho-social dynamics as they unfold within a dialogue.

Describing discourse, Bakhtin says "What is realized in the novel is the process of coming to know one's own language as it is perceived in someone else's language, coming to know one's own belief system in someone else's system" (1984, p.365). This is the perspective-taking that the presence of multiple chronotopes requires. In their refusal to privilege space over time or vice versa, chronotopes are asking for the same sort of temporal flexibility as Deloria, Smith, Cajete, and myriad other Indigenous scholars.

Lemke focuses on the role of material objects in linking different temporal scales (2000) and uses the principle of heterochrony, a mixing of timescales, in combination with chronotopes, to trace actors' movements along trajectories through cultural spaces (2005). In heterochrony, "processes on very different timescales exchange information" (p.189) via sign-users (readers and writers) interacting with semiotic artifacts (material objects that carry meaning). In this study we are specifically looking at the role of rocks, not simply as material objects to facilitate heterochronicity, but also as a direct embodiment of the land in which students stand, a concurrent participant alongside the instructors and the students in constructing the ecological landscape, and to shift the perspective from a purely anthropocentric one.

Reading and Narrating the Land as Indigenous Practices

The practice of reading the land while moving through it requires attention to multiple perspectives in both time and space (Marin 2013; Bang et al. 2015; Bang et al. in press; Pugh, McGinty, & Bang, in press). When land and its derivatives are positioned as relatives, the "reciprocal relations between one's social group and the natural world" (Cajete, 200, p. 70) are an important part of one's own identity. These identities are formed as a collective process, because they are based in relationships, and they are further shaped and perpetuated by narration (Marin & Bang, 2015).

Marin and Bang (2015) documented Native teachers' practices of using stories to represent and explain science phenomena and then designing and developing pedagogies to engage youth in story-telling. Thus stories are reclaimed as a central part of science education, and instead of focusing on Western-dominated content knowledge (which often winds up being presented as decontextualized fragments of information) education becomes "…centered on processes, practices, and narratives that are co-constructed." Stories then become "[E]pistemological frames of relational knowledge and knowledge construction" (p.46). This function of stories is especially helpful when working with geological concepts. Time is no longer measured in strictly quantified units that quickly pass into incomprehensible levels of magnitude, but instead becomes a malleable medium, magnified or condensed at the tellers' discretion. It allows us to zoom in or zoom out, depending upon the concept we are trying to illuminate, and thus effectively tie together quantitatively disparate phenomenon (Lockwood, 2003).

In our project, we are trying to develop and support Indigenous relationships to land, calling upon ancestral ways of knowing and moving through the world while at the same time moving through a world for the first and only time. The stories became instantiations of the co-constructed knowledge between humans and the MTH. Further, they were instantiations that travelled through time, both carrying the collective knowledge of the people and at the same time explaining new or emergent phenomena as students moved through time-space. In asking the students to move across different timeframes, we are asking them to simultaneously hold and move between different scales— much like the expertise in Levy and Wilensky sought to develop in their Agent-Aggregate Complementarity framework (2008).

By creating the curriculum used in this project, we consciously presented the students with several ways of narrating natural phenomena. We wondered what stories and information the students would take up, how (or if) they would combine the different narratives, and what connections to their lives the students would make.

Design and Methods

This paper is an account of one part of a larger community-based design project created to help Native students and their families in creating just, sustainable, and culturally healthy communities as they prepare for and act on the socio-scientific challenges of the 21st century, and to do so without ceding the deep knowledge and traditional practices of their communities. The project design enabled participants to integrate both forms of scientific understanding, a practice that has been shown to lead to richer mental models of ecosystems (Medin & Bang, 2014a). The work is an iteration of work begun in Chicago by the Native community (Bang, et al., 2014; Bang, Faber, Gurneau, Marin, & Soto, 2015; Bang, Medin, Washinawatok, & Chapman, 2010; Marin, 2013; Marin & Bang, 2015; Medin & Bang, 2014a). Previous versions focused on desettling science content (Bang, Warren, Rosebery, & Medin, 2013) and building place-based curriculum with Native youth. This project was one aspect of a larger design-based research project (Collins, Joseph, & Bielaczyc, 2004) using art and science in tandem to increase the participation of youth underrepresented in the STEM fields while fostering deep learning in a complex socio-ecological issue. Our team worked with the urban Native community in a large western city and focused on climate change. The greater project centered around developing a repertoire of four key practices – cultivating attention, making, critique, & exhibition. These key practices connect with the eight practices identified in the NGSS and we wished to determine whether they can support the deep ecological and scientific learning of Native youth.

Design Process

In in order to combine STEM learning, the arts, and Indigenous pedagogies, the research team decided to design a learning environment centered on field-based STEAM (science, technology, engineering, arts, and math) education for Indigenous youth, or I-STEAM. As a first step in beginning the process, the project's Principal Investigator, Megan Bang, acknowledged and followed community protocol by approaching the leaders of the Duwamish and Muckleshoot tribes and asking for permission to conduct the project on their ancestral lands.

Researchers / instructors. The instructors for the camp activities were a combination of members of the research group and community members. The instructional team covered a range of experience and characteristics among its members. Some instructors were well-established in their Indigenous identity, while others identified as non-Native. My own positionality is that of a teacher-researcher with predominantly European-American settler colonial ancestry. This was my first year working with Indigenous methods and pedagogies.

Designing for onto-epistemic heterogeneity. Fostering onto-epistemic heterogeneity (Bang et al., 2013; Bang & Marin, 2015; Roseberry, Ogonowski, DiSchino, & Warren, 2010) and facilitating onto-epistemic navigation between and among the varied forms of science are an important part of designing for Native student success. Due to the powered relationship between western science and Indigenous knowledges, this required drawing from decolonizing methodologies (Smith, 1999) and Land Education theory (Tuck, McCoy, & McKenzie, 2014), for if we failed to address the historicity of Native science education then we ran the risk of perpetuating the actions that we were trying to counter, namely the erasure of Indigenous science.

Indigenous methodologies were implemented from the very beginning of the project, by including youth, elders, researchers, scientists, educators, and community members in the first design meetings. These design meetings contained foundational structures that were carried throughout the design process into implementation at the camp, including ceremony; community inclusion and participation; honoring the land and waters; and representing both western and Native science. Each of these aspects served important purposes in undertaking a group endeavor of this nature, especially one that crossed cultural boundaries (academia to community, Native and Western sciences). In the first design meeting we established a space for Indigenous ways of knowing by opening with a ceremony that acknowledged the presence of ancestors, established communal intent, and requested guidance. Young people, scientists, elders, educational administrators, and other community members were expressly invited, making it clear that all roles were recognized and valued.

An important part of the project design was seeking guidance from Indigenous community members. We met with urban Native community members to learn about the land the camp was on and specifically invited key elders, leaders, families, and caregivers to attend the camp. One member of the design team was a storyteller. As we discussed the scientific and artistic processes that we would explore during the camp, he gifted the team with a series of appropriate stories. This was an important aspect of the program, as we have discussed with time earlier. For example, using designs inspired by plants and animals was a daily activity, so the story of Ay-yi-yesh, in which a young girl learns to make baskets with patterns, was selected. The researchers who would be serving as camp staff were expected to learn the stories, and to acknowledge the storytelling lineage while telling them.

The design team repeatedly walked the land where the camp would take place. The location had specific historical importance— in 1970 Native American activists reclaimed the ground on which the community center now stands (Allen, 2006). We consulted with local community members about the local phenomena and the best places to see them, while also learning the trails; familiarizing ourselves with the plants and specific growing zones; and studying the waterways and shorelines. These walks informed our design decisions—For example, a series of ponds prompted a 'water walk', following stormwater drainage from a marsh down through a series of ponds. Walking on the ocean beach with a Western-trained marine ecologist prompted a sea star lesson to gather data about sea star-wasting syndrome.

During this phase of the design, the team began to develop and document specific practices, especially observation, perspective-taking, and attention to internal states. We wanted to document the component practices of onto-epistemic navigation and these three practices are important for several reasons. Observation is a key skill in both Western and Indigenous sciences; perspective-taking is an important aspect of developing heterogeneous views, as is attention to internal states. As a design practice, attention to internal states was emphasized as a means of directing instructors' intellectual resources and expertise towards cultivating a relationship with the MTH. As a further move to close the distance between humans and the MTH, the design team made the decision to implement the practices of referring to plants and animals as our plant relatives or animal relatives.

Program design. These elements all carried into the program structure. The camp opened each day with a ceremony, with the entire group seated in a circle sharing songs and setting the intent for the day. We called these events and others like them "Launches". Launch activities set the tone and established the framework wherein themes and ideas were emphasized.

Activities conducted in a deliberate sequence. Launches could be nested within each other, and might be a story, song, or an activity. For example, the first launch of the day is the opening circle ceremony in which we introduced overarching themes. Within that first launch is a second, the storytelling activity, with a plot that reinforces and elaborate on those themes. For example, a story of a young girl receiving important knowledge from an old cedar tree reminds us to listen to MTH beings especially those that are older than we are.

Beach Lessons and Rock Stories

A series of lessons and activities took place on the beach, which was a mixture of rocky tide pools, mudflats, and eelgrass beds. This chapter focuses on an activity labeled "Rock Stories". Rock Stories was a lesson that emerged from an impromptu activity the previous year, where students made observations about a group of rocks and then generated their own stories. During that activity, students were encouraged to read the stories of the rocks, and several students shared creative and insightful stories of how the rocks came to be in both space and time.

Following the students' lead, the design team created a lesson plan that would illustrate geologic principles and encourage student narrative of the rocks' perspectives. The lesson goals were: to encourage theorizing about rocks' roles in stories and ecosystems, emphasizing that rocks are holders of ancient knowledge; prompt reflection upon rocks as our relatives; and cue student observation of rock features and form possible explanations about those observations. Two additional tools were enlisted to support the lesson. One was a sheet of prompts that focused on geologic properties (i.e. colors associated with certain minerals, relative hardness, cleavage and fracture planes [Appendix D]) and the other was a collection of pedagogical

discussion moves designed to prompt reflection, develop complex ecological systems thinking skills, and support epistemic navigation (Appendix E).

The students rotated through the lesson in three cohorts (Salmon, Deer and Eagles) which had been loosely grouped by age and social development. The instructor, Sonya, followed a designed lesson plan with a designated scope and sequence, and the same set of rocks, selected for characteristics that helped illustrate geologic properties (i.e. different colors, two or three pieces that fit together, with veins, rounded edges, sharp edges, exhibiting crystal formations, volcanic and sedimentary, etc.) were used for each lesson. While the finer details of the lesson varied according to the energy and flow of each student group, there were several elements that were emphasized across all three sessions — 'rock' terms, relationships, and stories. Each of these elements signified a particular orientation to time, or chronotope. These chronotopes cued the students to create a particular narrative, in which rocks, along with humans and other MTH entities, played an agentic role in creating and sharing knowledge.

Rock terms and concepts. Sonya invited each group to examine the rocks in the center of the circle. She then either supported the explanation of or drew attention to the processes that shape rocks (weathering, erosion, faceting). She made specific mention of rivers and the ocean as shaping agents. Finally, she pointed out glacial features, both in the landscape and in faceting[1] exhibited by rocks in the circle, and recounted the history of the most recent glaciation in the area.

Relationships. To support relational ways of knowing, the term "relatives" was used as an intentional pedagogical move to remind us of the relationships between humans, animals, plants, and other beings. Sonya reminded each group that they had been getting to know plant,

[1] A type of weathering specific to rocks that have been transported by glaciers

animal, and beach relatives, and introduced the session as the place where they would get to know their rock relatives.

Stories. Stories were both an action and a tool here. As rock relatives were introduced, it was emphasized that rocks covered large spans of time and thus held both very, very old stories as well as new stories. As part of the design work, a local artist and elder had gifted a set of traditional stories to the instructors. The stories were selected for their relevance to the overarching goals of the camp, and the staff worked to learn and tell the stories. At the beginning of the camp, the elder told several of these stories to the students. Sonya reminded each group what the storyteller had said when asked if the stories were real— that at one time we humans had been better able to hear and understand the stories from our relatives. In this sense, the stories serve as a guide for seeking knowledge. At the same time, stories were an act of co-creation, recruiting the tellers, listeners, landscape, history, and milieu into a narrative frame.

Data Collection and Analysis

The data for this study consists of two sets: field notes, audio recordings, and documents collected during the design meetings; and an implementation corpus. Sonya wore an audio recorder as she led the lessons, yielding 95 minutes of continuous audio data. A stationary camera recorded central segments of each lesson and one student was wearing a point-of-view camera during the lesson, yielding a total 82 minutes of video data. The field data is also supplemented by field notes. The analysis focuses on the time each group spent in the lesson as they jointly built an ecology / world.

The analysis that follows is a microethnographic approach (Erickson, 2004; Bang et al, 2015) primarily using conversation analysis and supplemented by interaction analysis when data permitted. At the beginning of each lesson, Sonya establishes several chronotopes through

narrative. These chronotopes exist simultaneously, even as they reference different narrative frames, some of which adhere to conflicting principles.

Story Time

One of the initial objectives of this lesson was to cue students to explicitly share their knowledge as a story. Stories have particular meaning to this group of students, as storytelling is a specific means by which cultural values, beliefs, and lessons are passed from generation to generation (Archibald, 2008; Marin & Bang, 2015). It is important to emphasize that honoring the power and responsibility that particular forms of knowledge carry requires recipients to share them appropriately. Thus, the knowledge in a story does not arrive as a set of independent facts, but as a series of nodes in a web of relationships and responsibilities.

Sonya calls the frame in which oral narratives operate, or 'story time', into play in two ways. Firstly, she reminds the students that stories carry knowledge over a long span of time and can connect us to an era when the normative relationships between humans and nature were different. "[The storyteller] said that some of these stories come from a long, long time ago. In a time where maybe we were better observers and better listeners to what was happening to our plant and animal relatives" (Sonya, Eagle transcript). She also points out that rocks hold a deep repository of knowledge— "[R]ocks also have stories. Rocks have very long, old stories. Some rocks have really old stories. Some rocks have really new stories. But rocks have lots of stories to tell us" (Sonya, Salmon transcript)— invoking a world where human capacities are insufficient for the scale and range of knowledge to be held.

Finally, she positions the Western science narrative as one of many stories, placing it on equal footing as the Indigenous knowledge shared via oral history:

> [S]ometimes that means that these rocks have been coming through glaciers, and as the glaciers receded the rocks got dragged and then picked up and dragged again and dragged again. *These are some types of stories*, but there's many, many more stories about how rocks, what their history is, why they're here, maybe where they'll be in the future. (Sonya, Eagle transcript, emphasis added).

Ricouer writes about the manner in which time is marked in both a narrative and phenomenological sense, noting that the history and fiction are often juxtaposed in opposition to each other, and calls for a form of knowledge interpretation that is able to recognize both forms as valid in shaping our sense of time. "The gap between historical and fictional narrative could only be bridged if we could show that both are grounded in the same basic temporality which provides to repetition[2] itself an existential foundation" (1979, p.34). Here, story time is that temporality, providing access to a wide range of possible futures, and at the same time holding the past, and holding it beyond the range of human memory.

Sonya repeatedly cues the students to share the rocks' stories and the students respond with a range of narratives. Some use geologic terminology: "My rock story is that a long time ago when the tectonic plates shifted, this rock came... a bit of the tectonic plates flew up and this rock was made. It went up to the surface here." (Dante, Deer transcript). Others respond with epic narratives that carry ethical implications:

> A long time ago there were two kids. One was very grumpy and didn't like anything. He was like, 'No! It has an extra sparkle there.' He's very picky. Then the other one was goofy and didn't care about anything. Okay? Then one day they had an argument about if you… if you should be like him or the silly guy. So then, when they're grown-ups they're

[2] Repetition is used in a Heideggeran sense here.

> passing by each other and then they decided to settle it with a witch, and then the witch turned them into a rock. So when you turn it on one side it's the angry guy, and on one side it's the silly, goofy guy. (Tahatan, Eagle transcript).

Finally, some responses held a distinctly social narrative, attributing anthropomorphic properties to the rocks:

> This rock called me and he told me that one time he was on a date, he literally peed his pants and his date left him and he never actually saw her. Then he got up and everybody started pointing at him and laughing at him (Daanis, Eagle transcript).

In each case, the student is enlisting a particular chronotope as an aid to negotiate their position in the group and consequently the world. Dante appears to be claiming authority on the basis of content knowledge; throughout the lesson he made declarations about the nature of the rocks, claiming school as his source of knowledge. Tahatan is using the rock's physical attributes as a cue for an allegorical narrative. Daanis is exploring social face, both that of the rock-character in her story, as well as her own within the group of students— there is considerable banter and joking throughout the lesson transcript, and humor is a form of social capital among the students.

It is important to highlight that these different narrated worlds are not mutually exclusive; in fact, the students are consistently co-constructing with both the rocks (and other MTH actors in the environment) and the other group members. In the exchange below, Migizi displays his science content knowledge and refers to geologic processes. He is describing the infilling of mineral veins during rock formation:

> *Migizi:* (holding rock out into middle of circle) These lines are from the rock breaking apart and then reattaching.
>
> *Sonya:* Rocks breaking apart and reattaching, okay.

Migizi: Yeah, and stuff goes inside it.

Shortly afterward, when another student begins a story with "A very long time ago...", Migizi chimes in with "*ʔal tudiʔ tuhaʔkʷ*", a Lushootseed phrase the storyteller used to introduce stories. *ʔal tudiʔ tuhaʔkʷ* roughly translates to "Once upon a time…" and indicates the beginning of a story. Migizi is upholding the lesson space as a place where science, Native knowledge, and story time are all factors in shaping the narrated world the group is creating.

Equating science time with school science time. Sonya asks the group to make observations about the rocks in the circle and references geological events, both of which bring in a geology-oriented temporality. "So, I'm going to pass around this rock and I want you to take some close observations of this rock." (Eagle transcript). In the following excerpt, when describing the expertise of a co-instructor, she clearly establishes the presence of scientific knowledge: "She's a rock expert. She knows rocks in a science way too. She was talking about how, long, long time ago... Does anyone know what a glacier is?" (Sonya, Salmon transcript).

Several students take up the science cue by using geology vocabulary that they have learned in school or at home. Student-volunteered terms included "erosion", "fossilized", "plate tectonics", "igneous", and "magmatic". In the following exchange, Dante, a student, specifically credits school as the source of his knowledge:

Dante: It's igneous rock.

Sonya: Why do you say igneous?

Dante: Or it's magmatic or igneous. It's magmatic rock.

Sonya: What does igneous mean?

Dante: Like from lava or something?

Sonya: Lava. Okay.

Dante: I learned this a few months ago in third grade.

Collin: I learned it in fourth.

Both Dante and Collin are alluding to what I term *school science time*, a chronotope that invokes school science, a frame with a very specific set of rules and expectations. As noted earlier, Duncheon and Tierney (2013) correlate school time with clock time. In their analysis of 'clock time', they trace its origins to the birth of modern (Western) science and tie it to positivist paradigms of capitalism and industrial production, both of which are ideologically anthropocentric frames that do not account for MTH values and agency (Watts, 2013). School science time calls to mind the hierarchical knowledge structures in science classrooms (Barton & Yang, 2002; Delpit, 2006) and the assumed authority of scientific positivism (Alsop & Gardner, 2017).

This did not always happen. On multiple occasions, students explained geologic and ecological concepts fluidly, using scientific terms while extrapolating on their ideas. In the earlier transcript, Migizi references scientific concepts and Indigenous language at the same time. Shortly after the exchange with Dante above, Collin explains how his rock came to be on the shore:

Collin: It looked like it got washed up, broke from a bigger rock, because it looks like it.

Sonya: What makes you say it got washed up from a bigger rock?

Collin: Like erosion broke up with a rock, probably somewhere out there.

Sonya: Okay. Erosion. What's this?

Collin: A crack.

Sonya: Oh. What else is happening with your rock here?

Collin: It's all sandy.

Sonya: Yeah.

Collin: Some are clear, like this little white dot back here.

Sonya: Cool. So what's the story with this rock? What do you think?

Collin: I think it's probably out from the ocean, kept on getting washed, lots of waves probably. Then this piece broke off from the big rock sticking out of the ocean, and started coming back, and washed up on shore.

In this exchange, he links his observations ('it looked like it got washed up,) to unseen phenomena ('a bigger rock somewhere out there') as well as dynamic processes propagated by a MTH change-agent (waves in the ocean) using unprompted geologic vocabulary (erosion), while still placing the rock in story time.

Relations time. "[T]he same thing is true for our rock relatives. Our rock relatives are very, some of them are very, very old. They have been around for a long time. Some rock relatives have been here for a relatively short time" (Sonya, Deer transcript). By naming rock relatives and pointing out the wide range of time that rock lifespans cover, Sonya highlights the complexity of relations-based knowledge systems and affirms the existence of knowledge that is outside the empirical capacities of humans.

These ideas are in accordance with the Indigenous knowledge systems and Native science that the camp sought to uphold. The students highlighted relationships between rocks and sea creatures, emphasizing rocks' protective capacities— "I think, well sometimes when you pick it up and you forgot it's a crab's home or like a sea worm, or like a snail" (Lucy). Other students highlighted the relationship as a measure of age— "I like the barnacles on there…The barnacles mean it's been the in the ocean for a long time because it's got barnacles on it" (Zara) — or as a marker for changes— "This [rock] got aten by a kelp and then it got back" (Nelson). The

students' tendencies to associate rocks with plants and animals is especially important when we consider that dichotomizing rocks and soil with plants and animals (abiotic vs biotic, living vs non-living) is a common pedagogical strategy in ecological education.

The narrated world called forth by these relationships is one that positions MTH entities as actors, engaging with each other and pursuing ends outside the realm of human attention. These interactions are what creates the complex matrix of ecological relationships, of which humans are a part, but not the focus. In these matrices, hierarchy is difficult to discern, if it is even present.

Digital / virtual time. There is a fourth chronotope that the students called our attention to. As mentioned earlier, one group, the Eagles, engaged frequently in wordplay and prop-based humor. When Sonya introduces the activity, she tells the students that "We're going to talk about [the rocks'] stories" and encourages them to listen. Soon the students are holding rocks to their ears and having conversations. Holding a fist-sized gray rock, Kevin says "This one is calling to me" and begins discussing a TV show as if he were on the phone. The rock/phone gets passed around the circle, and several people have conversations with beings who are not physically present. Incidentally, there is a cell phone lying in the sand next to one of the students while all this is going on.

Duncheon and Tierney (2013) bring up a construct that they call 'virtual time', defining it loosely as "time in a digital world". They posit that as virtual time reconfigures socially constructed meanings of time and space, it enables more temporal flexibility, namely in the form of online learning, social platforms, texting, and multitasking. Their point that students are coming of age in a technologically different world is well-made, but the re-organizing properties of digital time and space are still confined to an anthropocentric scale, leaving us to wonder

whether virtual time matters to a stone, and furthermore what is that stone's role in knowledge creation; in short, does the temporal flexibility that Duncheon and Tierney identify lead to epistemic flexibility?

A more complicated question of virtual time and space came up during the camp. The students and Sonya highlighted virtual time by use of the rock/cell phone and other contemporary cultural references such as the TV show *Breaking Bad*, advertising taglines like "finger-lickin' good", and singing phrases from popular songs. Cell phones are present throughout the camp as cameras, note-taking devices, clocks, communication devices, and access to field guides. Several of the older students were playing the (then) newly-released location-based augmented-reality game, *Pokémon GO*. This became a point of contention among some students and instructors, with debates about appropriate tool use. When phones were used to take photographs for reference or to identify plants and animals, their use was encouraged. However, when the students were playing games on the phones, they were seen as not being "present', that is distracted and not attentive to the activity at hand, their fellow students, or even their physical surroundings.

Discussion

Burton (1996) pulls from Bakhtin's work to remind us that Bakhtin himself claimed that multiple chronotopes exist at once, not only in terms of histories and futures in play, but also concurrently within a text, and that "…often, it is the struggle or dialogue between them that animates the narrative" (p.46). This is clearly seen in the complex, heteroglossic banter of the Eagles. At any given moment the conversation might be following one of several trajectories— school, rocks, Indigeneity, social standing, pop culture— but the exchange is thick with learning and knowledge building. Per Rosebery Ogonowski, DiSchino, and Warren (2010) this

heteroglossia, "varied ways of conceptualizing, representing, evaluating, and engaging the world through language" (p.351) is a vital component for meaning-making and emergent insight.

Each of the chronotopes introduced during the lessons connects to a set of characteristics, which I am calling a 'setting', (Table 1), each of which in turn holds its own implications. The social implications of each setting intersects with the students' varied identities. In emphasizing relational knowledge, we (the designers and instructional staff) sought to uphold and reinforce Indigenous ways of knowing and identities. The challenge is doing this in conjunction with science and math education, which has a fraught history when it comes to Native students, carrying the historical implications both of residential schools and of a deficit view of non-dominant students in academic STEM performance (Bang & Medin, 2010). By pointing out the scientific practices in Indigenous stories and holding Western science as another possible story, we undermined the power differential between Western, or school, science and Indigenous ways of knowing. This was an important step in supporting the students' epistemic navigation across multiple ways of knowing and viewing the world.

That said, the influence of school science remains strong. On more than one occasion, students used geology terms in isolation, throwing them out in response to instructor questions, following the well-known I-R-E pattern that we have all been indoctrinated into (Mehan, 1979). When asked to explain the geologic terms in relationship to the rocks' histories, one student simply asserted "I'm just smart" (Dante, Deer transcript).

The importance of these settings lies in their ability to help expand notions of identity, agency, and possible futures, both for the MTH elements in ecosystems and for the students as Indigenous scientists. By incorporating storytelling as both a skill and an accepted knowledge system, students are affirmed in their Indigenous identities as well as encouraged to explore the

wider realms of possibility for both themselves and for MTH beings. In story time boundaries are flexible and the roles of humans and the MTH are not so narrowly constrained by anthropocentric notions of power and agency. During the rock stories lesson, the students take free license with this, experimenting with positioning rocks as artifacts, communicative beings, entities within an ecosystem with specific roles, having feelings and needs, and deserving of proper treatment. They also share a wide and complex range of phenomena that the rocks both participate in and are subjected to.

Story-time flexibility also serves a cognitive purpose. Rather than insisting that people hold information on a rigid and conceptually taxing scale, the manipulation of time that occurs in stories allows people to place events in relative position to one another, experimenting with event sequence and other variations on cause and effect. Time can be cyclical, folded, simultaneous, and /or run backwards, allowing 'forgotten' skills (like listening to rock stories) to be claimed, re-claimed, and invented anew in the time/space of here and now. Holding these different modes simultaneously is a form of epistemic heterogeneity, which is a critical element in meaning-making (Roseberry et al., 2010) and leads to richer mental models of ecological systems (Medin & Bang, 2014a).

Conclusion and Implications: Possible Worlds

In the introduction, understanding complex ecological systems was partially framed as equity issue for land-based peoples, and this study has focused on self-identified Indigenous students. Access to science education plays a role in access to power (Barton & Yang, 2002). Scientists who are versed in multiple ways of knowing and employed in leadership roles near or in their home communities, especially in areas like land and water management, are sorely needed. While this is only a partial step toward Indigenous sovereignty, it is an important one.

There are also implications for people across the planet. As land-oriented peoples, Indigenous cultures have developed the capacity to understand ecological processes on levels and scales that far out-span modern, conventional methods (Cruikshank, 2010). When we look at the issue on a larger scale, all people are land-based; every human relies upon the Earth for everything, from the simplest elements to the most elaborately processed materials.

Given that we are still developing and refining our understanding of ecological systems on both micro- and macro- scales, it behooves us to design educational spaces that allow children to learn from as expansive a world as we can provide, especially as they continue the work of negotiating a changing planet. As students integrate stories, science, and phenomena through narration, they gain the opportunity to construct counter-narratives, re-shaping the relationships between Indigeneity, science, and power towards inclusive and ethical futures for all beings. An ability to create mental models that can utilize dynamic principles without sacrificing systemic structure may be the way forward for wide-scale science education that supports and encourages reciprocally healthy human-nature interactions.

Table 2

Chronotope / Type of time	Examples	Characteristics	Possible Implications
Stories	"Robert was saying that a lot of our stories are very, very old, and maybe a long, long time ago, we were able to listen to Grandmother Cedar and talk to Grandmother Cedar and hear Grandmother Cedar." "Sometimes there can be treasure or some crystals in the water."	- Oral histories - A wide range of possibilities - Lessons	- Time is changing and dynamic
Rocks / geology	"A mountain is a kind of rock, and the mountain will go into pieces and it will turn into, like one of kind of those rocks and then it will turn into a smaller rock than that and then it turns into like sand." "I have a piece of quartzite."	- Pertaining to rocks and rock formation - Time scale so long that it is abstract	- Rocks hold knowledge - There is vocabulary specific to rock properties and processes
Relations	"This one is like a rainbow except that it's not because it has a little bit of seaweed and shells." "I think, well sometimes when you pick it up and you forgot it's a crab's home or like a sea worm, or like a snail."	- Connection between like and unlike kinds	- Rocks hold knowledge; there is vocabulary specific to rock properties and processes
Indigenous	"It tells the story of the Tatonka." "Well, why don't you put it somewhere where you can hang on to it and then we'll ask an elder."	- Land-based culture and language - Indigenous knowledge systems	- Community - Interrelation between humans and MTH
School science	"I learned this a few months ago in third grade." "Oh, that's just compacted carbon."	- Vocabulary - Hierarchical - Content knowledges	- Nature is ordered by taxonomy
Digital	"I've been holding this call. Can I continue talking?" "They're cellphones. They are shell phones."	- Recent technology, cell phones, video games, pop culture	- Hyper connectivity
Social	"Look the sand can jump!" "This one says that it's finger-licking good."	- Interactions among peers - Humor - Pathos - Bids for attention	- Status among peers is important
Clock	"We'll be heading out in about ten minutes." "…spend two or three minutes in this area, just around here,…"	- Segmented - Quantified - Fixed, static	- Control, colonization

CHAPTER 5: A CONCLUSION AND A CALL

The three studies in this dissertation have focused on learning in school gardens, making relationships with plants, and listening to rocks. The dissertation as a whole is concerned with the foundational conceptions of what the human-nature relationship is, how to understand it, and why it should be understood— in other words, the ontological, epistemological, and axiological dimensions of the human-nature relationship. Broadly speaking, it is concerned with the ideas human society teaches its children about nature, and how those ideas become the basis of our actions, both as individuals and as a society. But why does this matter? What are the bigger implications of children learning about ecological science in a different way?

Allow me to approach from a different tack. I initially began this research work as part of an ongoing practice of climate change education. I wanted to figure out how to create effective lessons and curricula for the topic and sifted through theories of science pedagogy, environmental education curricula, and climate communication strategies to find the crux of the issue. Was it an issue of earth and space science concepts? Understanding how ecological systems work? Realizing the urgency of the matter? Firsthand experience outdoors, in nature? Knowledge of the facts, or what action to take? Understanding climate change involves all of these things, but in a classic systems perspective, deeply understanding the issue itself means realizing that is an emergent property resulting from the combination of all of these things, and even more.

Many climate change education efforts are more appropriately classified as climate change communication. Climate change communication follows a public health model, where the discourse centers upon a prescriptive dissemination of information and practices to the public in order to promote behaviors for climate change mitigation and/or adaptation (Pidgeon &

Fischhoff, 2011; Koepfler, Heimlich & Yocco, 2010; Maibach, Nisbet, Baldwin, Akerlof, & Diao, 2010; Moser, 2009). However, it has been well documented that cautionary knowledge alone is an insufficient basis for changing environmentally-oriented behaviors (Bamberg & Möser, 2007; Hines, Hungerford & Tomera, 1987; Kenis and Mathis, 2012; McKenzie-Mohr, 2011) and in the case of climate change, factors such as personal beliefs and group affiliations tend to play a greater role than level of education (Kahan, Jenkins-Smith, & Braman, 2011; Stern, 2011; C.R.E.D., 2009; Hulme, 2009).

Some scholars argue that the key to understanding climate change is a matter of improving and redirecting science education. (AAAS Project 2061, 2007; Assaraf & Orion, 2005; Covitt, Gunkel, & Anderson, 2009; Johnson, 2011). The argument is that we should be looking at the natural world as a complex system, and even go so far as to include social factors and human behavior in that system. This is a departure from the heavily physics-oriented, ever more-specialized science education that we have been experiencing since the mid-1960's, in the post-Sputnik era (DeBoer, 1991; Rudolph, 2002). The increased attention to systems and the incorporation of more social values is gaining traction in the US, and is exemplified in the development and implementation of the Next Generation Science Standards (NRC, 2012; NGSS Lead States, 2013).

Both of these approaches, prescribed content knowledge and systems-oriented education, have merit, but they are lacking in addressing the ethical aspect that underlies these problems. Climate scientist Mike Hulme (2009) argues that climate change is a metaphor for how to live in the world, as it requires us to think about what is at stake for ourselves, geographically distant others, and our future progeny. At the base of all this is the axiological belief of what the role of human-nature relationships should be. As many have pointed out, a structure of 'actually existing

neoliberalism' (Brenner & Theodore, 2002; Harvey, 2005; Hayes-Conroy, 2010; Lakes & Carter, 2011) has been driving social action at an increasingly global scale. In the process, materials, people, and nature have become objects to be manipulated towards an ends of accumulating capital.

Education is only one of many institutions in the neoliberal scheme, but in industrialized societies, science education is when many of us learn about the natural world. With its attendant ties to power (Barton & Tan, 2010; Barton & Yang, 2000; Venville, Rennie, & Wallace, 2012), science education is an equity issue. In the face of climate change this is even more so, as those with the least power experience the earliest and strongest effects. The issue is intensified even further in Indigenous communities, who are trapped in a double bind of having close ties to the changing land and waters, yet are denied full sovereignty over the very land and waters they stand on.

It has been said that 'responding to climate change will require a paradigm shift' so often that the phrase is a cliché. Cliché or not, if education is to live up to being an endeavor of hope, the way we teach our children about human-nature relationships must change. Referring to aspects of the environment as "natural resources" implies a measure of control that we do not have, and it imparts a degree of object-ness that does not exist. Future discourse about social issues must include the more-than-human in our concept of that-which-is-social.

When we return to sociocultural theory, culture becomes a double-edged sword. One the one hand, it is the primary tool leveraged to maintain a human-nature divide. On the other, culture can be a determinant force in shaping ontologies and epistemologies that allow us to fully realize the agency of the more-than-human. The use of tools and philosophies that recognize more-than-human agency can bring to light the importance and influence of natural factors on

the human world, allowing students to form more accurate mental models of complex ecological systems. Actor-network Theory, relational epistemologies, and Land education are specific approaches that contribute to a deeper ecological understanding by recognizing the both the capacity of the more-than-human and the possibility presented by learning and joint meaning-making alongside the more-than-human.

We must learn to live with the Earth. Or not. But it is immoral not to acknowledge that we have choices, and, especially in heavily industrialized, economically influential areas, that these choices have repercussions. Even if we choose not to recognize the interdependence between humans and the natural world, we must acknowledge the connections among humans. Changing ecosystems are already influencing 'human security' (Adger et al., 2014). Education that supports and develops these connections on ethical as well as content levels is our obligation to our progeny, future selves, and all the beings-to-come.

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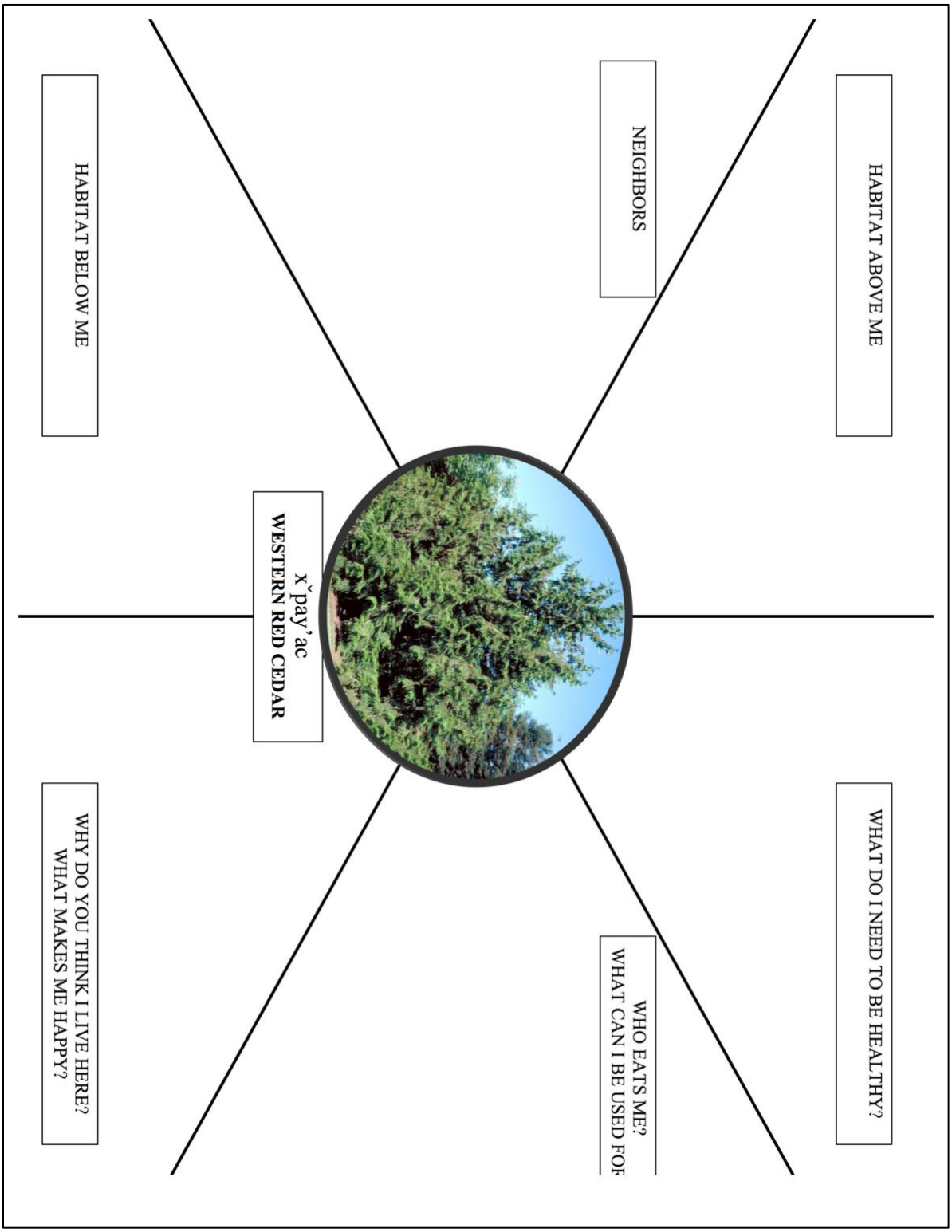
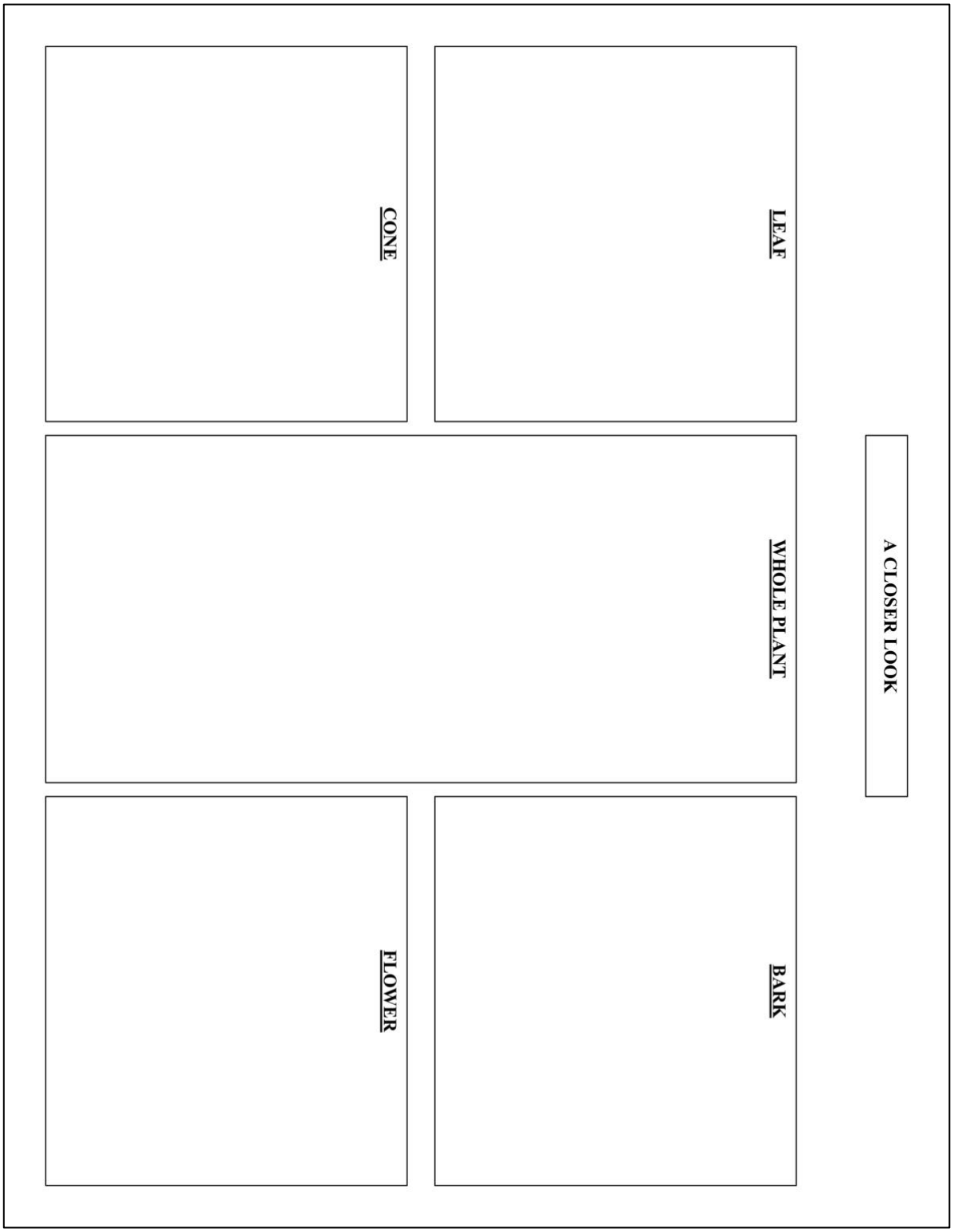
APPENDIX A - PLANT TEMPLATE TOOL - FRONT



APPENDIX B - PLANT TEMPLATE TOOL – BACK



APPENDIX C - ROCK STORIES LESSON PLAN

ROCK STORIES

1 Page overview of activity:

Preparation needed - Collect a handful of "rocks" from the beach beforehand. Make sure there is both variation and similarity in the samples. Look for rocks that have a variety of distinct characteristics- i.e. layers, cracks, smaller rocks in them, beach glass, shells, rounded edges, sharp edges, barnacles or seaweed. Try and select rocks that reflect the different aspects of the geological story in the area (i.e. volcanic, sedimentary, river cobbles, glacial till, human-built structures [concrete or brick])

Location and time - On the beach, ~30 minutes (Two adults is helpful, one can keep track of ideas on white board)

Framing Questions & Connections (short)

How did rocks come to be?

What role do they play in ecosystems?

What are the relationships between rocks and plants, rocks and water, rocks and other rocks, rocks and people?

What are some rock gifts?

Content Learning Goals (important)

- Get to know rock relatives
  - Observe rocks closely - notice x, y, z
  - Learn about how rocks are formed - birthed?
  - Learn about rocks relationships with heat, time, and land? Then list these specific things.
  - Learn about rocks relationships with water
  - Learn about bits that make up rocks, such as minerals
- Theorize about rocks' roles in stories and ecosystems
  - What roles will we emphasize?- Rocks are holders of very old knowledge.
- Think about rocks as relatives and how they have been a part of cultural ways of knowing?

Activity sequence (overview) - Look at rocks together, kids get own rocks, they tell a story about one or two rocks to the whole group

Attentional Directive, Discussion and Debrief Questions (Key part of document)
What are the stories here? / What's going on with this rock? / How do you know that? How do rocks form or get their stories? What are some names for these things or processes?

APPENDIX D - ROCK STORY LESSON PROMPTS

Color – How many colors do you see? Are they mixed together or do the colors show certain parts?

If you get the rock wet, does that make more colors show up?

If there is a freshly broken surface, does it show different colors?

Sometimes certain minerals show up as colors.

Iron often shows up as a red or orange color.
Deep black can indicate organic material, like wood or plants or animals
Black can also be a type of rock called basalt, which comes from volcanoes
White or gray can indicate quartz
Pink in rocks can be a mineral called feldspar

Patterns – Can you see lines or circles on the rock? Is there a pattern that is interrupted?

Texture – What does the rock feel like? Is it rough, lumpy, jagged, smooth, slick? What are some good words to describe the feel?

Are any parts of the rock shiny or glassy?

Does the rock seem to be made up of other tiny rocks? Use a magnifying glass to look.

Sometimes a shiny surface with angular edges can be the side of a crystal showing through

Angular – has sharp corners

Shape / edges – Does the rock have edges? Are they sharp? Is the rock rounded? How do you think the edges got that way?

Smell / taste – Does rock have a smell?

Hardness – How hard is the rock compared to other things? Can you scrape a line on it with a fingernail? Does it leave mark on a shell? Does a shell leave a mark on the rock?

Are you able to break the rock with your hands?

Test different items like wood, shell, metal, other rocks to see if the rocks scratch them or if they scratch rocks. See if you can arrange several rocks in order from softer to harder.

Density – Does the rock have holes in it? Are there crystals growing in the holes? Does it feel light for a rock of its size?

Other relatives: Does it have things growing on it? Are there marks from animals or plants that grew next to the rock or used it? Are there any fossils?

APPENDIX E - DISCUSSION MOVES

Note: Each discourse framework below is layered, interwoven within one another.

General (Some from TERC) / aka Reflective Discourse Moves			
Goal one: Help Students Share, Expand and Clarify Their Own Thinking	Goal Two: Helping students listen to, connect to, and add their ideas to each other	Goal Three Help Students Deepen Their Reasoning	Goal Four Help Students Think With Others
Time to Think · Wait time · Writing/Drawing as Think Time · Partner Talk	Encourage talking to each other and adding on. · "Does anyone have a question for grace about her idea?" · "Who can help Grace with her idea by explaining it in a different way?" (This is always followed by a question to Grace whether she thinks this is the same idea. If no, then ask why is it different.) · "Who can add onto the idea that Jamal is building?" · "Can anyone take that suggestion and push it a little further?"	Asking for evidence or reasoning · Why do you think that? · What is your evidence? How did you come to that idea?	Agree/Disagree and Why? · "What do people think about what Ian said?" · "Does anyone want to respond to that idea?"
Say More: Extending · Can you say more about that? · What do you mean by that? · Can you give me an example?		Challenge or Counter-example · "Does it always work that way?" · "How does that idea square with Sonia's example?" · "What if it had been a copper cube instead?	Explaining What Someone Else Means · "Who can explain what Aisha means when she says that?" · "Who thinks they could explain why Simon came up with that answer?" · "Why do you think he said that?"
Revoicing: So are you saying? · Let me see if I understand what you are saying.... Did I get that right?			
Rephrasing and repeating · Who can repeat what Sarah just said in their own words? · Ah, is that kind of like (give a parallel example)			

Complex Systems				
Goal one: Support students think about phenomena across temporal dimensions	Goal two: Support connect phenomena within spatial fields	Goal three: Support students in taking multiple perspectives and recognizing agency	Goal four: Support students reasoning at both the agent and aggregate levels.	Goal five: Make change, thresholds, emergence visible to students.
Past, present, Future	Support shifts on the vertical and horizontal access. "look at the acorn shells on the ground. Can anyone find a squirrel's nest up in the trees. Maybe that's the squirrel whose eating them!"	Recognize the agency of more than humans.	Emphasize singular animals in specific places. · "Look at the frog hiding by the lilypad?"	
Make connections between different temporal scales. "This tree lives for 200 years. How long do people live?"	Support toggling between observations/noticings.	Engage in reasoning, thoughts, desires, feelings, etc… from the perspectives of more than humans. · "the river wants to go to the ocean."	Connect specific agents to aggregate phenomena. · "That mussel is really hard to open, why would that help mussels to live?"	
Temporal Scales: human, nonhuman, geological, years, walk-level	Support spatial indexing Something in the spatial field becomes a representation for another idea, phenomena.	Emphasize the impacts of agentic action by more than humans. · "See how the river changed the land?"		

Supporting Epistemic Navigation				
Goal one: Support students in making home/community and school connections	Goal two: Reinforce Indigenous temporal continuity. This means not allowing past tense language to be the dominant register.	Goal Three: Reinforce students as part of communities with important roles to play.	Goal four: Focus on strengths and resilience of communities. This means not focusing on the loss narratives or framings.	Goal five: Support students in articulating contradictions and powered dynamics clearly.
Center phenomena in learners' community and lives. This is more than finding a local example. Explicitly talk about why phenomena of interest impacts and can help the people and places in children's lives. · "Why do you think X matters for your family/community?" · "What things do people in your community do that involves x?"	Refer to traditions, practices and culture both historically and current times.	Use psychologically close and inclusive language. "We, us, our." As opposed to they, them. Or abstracted categories, unless making explicit connections. Do not refer to scientists or artists in the abstract or as a monolithic group (Scientists do x.)		Voice similarities, differences, and complementarities in what counts as "evidence" and experience.
Locate expertise in students' family/community. · "Who in your family/community knows a lot about x?" · "How or why do they know that?"	Reinforce Indigenous presence and lands even in ceded territories.	Emphasize needs and responsibilities students have as youth.		Voice similarities, differences, and complementarities in the roles of knowledge exchange.
		Emphasize needs and responsibilities students can fulfill as adults. Link current strengths or interests they have to that future. · "Our community needs more engineers to help our governments build better infastructure, like water systems. You could do that!" · "Our communities need politicians who can help make our community better. You are really good at talking to people, you could be good politician."		