Spatial Indexing: An Interactional, Conceptual, and Mediational Analysis

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Abstract

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Understanding ecological systems is an increasingly important skill as we are faced with rapid global climate shifts. This endeavor is commonly taken up in science education, which asserts that it is necessary for both students and scientists alike to be able to understand how systems work in order to comprehend the complexity of the natural world. However, teaching and learning about complex systems has been a challenge. This dissertation addresses this challenge by advocating for and exploring two (interrelated) avenues of research about complex ecological systems thinking: 1) how cultural mediates knowledge development and organization, and 2) how context mediates knowledge development and organization. More specifically, I use and further develop a framework called spatial indexing to examine the interactional, conceptual, and mediational nature of sense making in two contexts: an informal STEAM (science,

technology, engineering, arts, and math) camp for Indigenous youth, and family forest walks with primarily European-American parents and children witnessing a seasonal salmon run. By studying these two contexts in the same urban forested park, I build out a theory learning that demonstrates how place, culture, and cognition are interrelated. Implications of this work include the equitable and transformative possibilities of field based learning opportunities for teaching and learning about complex ecological systems.

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DEDICATION

For Sierra.

Chapter 1. INTRODUCTION

Understanding ecological systems is an increasingly important skill as we are faced with issues such as climate change, rapid species extinction, and deforestation (Bang et al., 2014). This endeavor is commonly taken up in science education, which asserts that it is necessary for both students and scientists alike to be able to understand how systems work in order to comprehend the complexity of the natural world (NRC, 2012). However, teaching and learning about complex systems has been a challenge (Hmelo-Silver and Azevedo, 2006). Recent research suggests that there are cross-cultural (and within-culture) differences in the epistemological frames (the nature of knowing and how that gets enacted) that people employ in understanding natural systems (Bang and Medin, 2010, Hammer, Elby, Scherr, and Redish, 2004). Interactions between parents and children around ecological concepts can play an important role in how children come to make sense of ecological systems (Callanan, Rigney, Nolan-Reyes, and Solis, 2012; Eberbach and Crowley, 2009; Unsworth et al., 2012). Moreover, paying special attention to informal and nonformal learning environments can provide insight into the design of formal learning settings (Bell, Tzou, Bricker, and Baines, 2012; Zimmerman, Perin, Bell, 2010).

For a long time research on science-related cognition has primarily been conducted in settings in which place is abstracted or altogether absent (Anderson, Adey, and Bevan, 2010; Bang, 2015; Luce, Callanan and Smilovic, 2013). In other words, the subject matter, and the places in which these subjects are taught, are abstracted (Bang and Medin, 2010; Gruenwald and Smith, 2008). This type of research often overlooks the interactional nature of knowledge, and the ways in which place and context mediate conceptual organization of biological and ecological phenomena (Hutchins and Renner, 2012; Medin, ojalehto, Marin, and Bang, 2013). However, there has been robust research in theories of cognition and learning that have

highlighted the essential role of place and context in biological and ecological reasoning (Atran and Medin, 2008; Medin and Bang, 2014b). Additionally, there is a growing trend that recognizes scientific cognition, in particular, as embodied, interactional, and embedded in the world (Hutchins and Renner, 2012; Mogk and Goodwin, 2012). In this dissertation, I define place as the "nexus of culture and environment" (Gruenewald, 2008; p. 145).

This dissertation builds on these theories of learning to explore the interplay of place, culture, and cognition in outdoor, field based learning settings. To do this, I analyze talk-in-interaction (Jordan and Henderson, 1995; Marin and Bang, 2018; Taylor, 2013) through a framework called "spatial indexing" (Pugh, McGinty, and Bang, 2019) to locate moments in which participants are observing and sense making in place. Broadly, spatial indexing makes visible if and how people are reasoning across multiple scales of time and space in place-centered interactions. By exploring interactions, patterns of sense making, and the use of designed tools, this dissertation contributes to the design of equitable field based science learning environments, particularly ones that foreground and make visible Indigenous presence and survivance (Vizenor, 2008).

Culture, place, and cognition

Making sense of the natural world is a fundamental human capacity. We are shaped by and we influence the natural world, and our brains, bodies, and cultures have evolved within these natural systems (Lee, 2008). However, the human relationship with the natural world looks vastly different across cultures and histories. And, relatedly, knowledge organization that informs reasoning about the natural world is mediated by sociocultural and environmental interactions (Medin et al., 2006; ojalehto and Medin, 2015). In this dissertation, I examine the role of place and culture in sense making about ecological phenomena. I examine cultural

variation in knowledge organization, and the epistemologies and ontologies that inform sense making in field-based practices. I anchor this work in sociocultural theories of learning and development that recognize the social, contextual, cultural, and historical nature of learning in moments practices across settings.

The current research draws on sociocultural theories of learning in order to highlight the ways in which social structures and cultural artifacts mediate (and are mediated by) cognition and learning in place, and how knowledge organization influences how we make sense of the world (Bang and Medin, 2010; Lee, 2008; Atran and Medin, 2008; Vygotsky, 1978). This calls for an alternative framework that recognizes knowledge development as both temporally and spatially vast and variant. Temporally, spanning phylogenetic, cultural-historical, ontogenetic, and microgenetic processes (Cole, 2008; Vygotsky, 1978); and spatially, learning as distributed across individuals and the environment (Leander, Phillips, and Taylor, 2010). Thus, following the lines of Vygotsky and cultural-historical theorists, I engage in research that examines how place, culture, and artifacts play a pivotal role in shaping development and learning. More specifically, I attend to the repertoires and constellations of practice in which individuals are engaging and navigating (Gutiérrez and Rogoff, 2003). Bang, Faber, Gurneau, Marin, and Soto (Bang et al., 2015) define and operationalize learning and development as embedded in culture and constellations of practice:

> "…Viewing learning as dynamic cultural processes, or what is increasingly called learning in cultural ecologies, recognizes that all people explore, narrate, make sense of and shape their worlds, but they do so in varied ways, connected to the particular constellations of practice, relationships, values, goals, and worldviews of their communities" (p. 3).

In this view, learning and development are intertwined with cultural practices and participation, and cognition is socially constructed and distributed across social structures as well as material

and ideational artifacts (Bell, Tzou, Bricker, and Baines, 2012; Cole, 1996; Gutiérrez and Rogoff, 2003).

The endeavors of sociocultural research are broad, and one branch of this work focuses on how learning is contextually-mediated. Referred to as situated learning (Lave and Wenger, 1991), or "cognition in context" (Atran and Medin, 2008), this theoretical lens attends to the situated, cultural, and ecological, influences on knowledge organization and development. Research that takes up this perspective can happen at one or several grain sizes, from level of the individual to the level of the activity system (Greeno and Engeström, 2014). In their research on complexity thinking, Grotzer and Tutwiler (2014) postulate that patterns of reasoning unfold in coordination with perception, attention, and motivation, and "environmental noise"; this focuses on and contributes to theories of individual reasoning. At another grain size, Engeström and other activity systems theorists approach learning at the level of the activity, focusing on how people and systems interact towards goal-oriented learning (Engeström and Sannino, 2010). By examining situated sense making at the level of the individual, as well as sense making across place and mediational tools, this dissertation spans multiple grain size levels in order to design a comprehensive theory about how youth and adults, as constellations of learners (Gutiérrez and Rogoff, 2003; Bang, 2015), learn about ecological systems. In other words, I argue that studying the interplay between individual cognition and distributed and contextual sense making offer deep insight into both the nature of learning, as well as the design of learning environments.

Cultural variation in knowledge organization

Fields of cognitive science and psychology have a history of making universal claims about human behavior and development from a relatively narrow subset of the population, predominantly western and industrialized populations or what Henrich, Heine, and Norenzayan

(2010) call WEIRD societies (White, Educated, Industrialized, Rich, and Democratic). However, there is a growing trend in research that focuses on cross-cultural variation in learning and development in order to examine both cultural variation and similarities in developmental processes. This work is particularly important because a homogenous population sample does not generalize to societies writ large despite many researchers claiming the contrary (Henrich et al., 2010; Rogoff, 2003) On the one hand, attending to cultural variation has either aimed to address the presence (or not) of universal knowledge organizing mechanisms (Bailenson, Shum, Atran, Medin, and Coley, 2002); or, on the other hand, it highlights ontological, epistemic, and axiological diversity as a pivotal component of creating more equitable learning environments (Bang et al., 2015; Bang and Medin, 2010; Rosebery, Ogonowski, DiSchino and Warren, 2012).

Folkbiology, Folkecology, and Knowledge Organization. One avenue that this is taken up is in theories of folk, or "naïve" cognition. Folkecology and folkbiology literature has suggested that cultural worldviews influence categorical organization of biological phenomena and relationships (Bailenson et al., 2002; Medin et al., 2006; ojalehto, Medin, Horton, Garcia, and Kays, 2015). Folkbiological cognition refers to the ways in which we organize knowledge about the natural world, and informs how we understand and enact nature-culture relations (Bang et al., 2007). Research on folk theories suggest that there are specialized mechanisms that develop in order to organize knowledge about interrelated phenomena within certain domains; for instance, there has been research on folkphysics, folkpsychology, and folkbiology. Conceptual development and organization within domain-specific literature has been studied in a variety of ways. Some scholars have argued that domains develop separately and are specialized for certain phenomena, however recent research has demonstrated hat there are abstract concepts that can be transferred across domains (ojalehto et al., 2015). Claims are made both about

ontologies of knowledge organization, and how concepts develop and undergo transformations through learning. Scholars have questioned whether conceptual organization and development are universal, or if they are context or culture dependent. Relatedly, scholars have taken up the role of epistemologies as a critical component influencing knowledge organization and related behaviors (Bang et al., 2007; Bang and Medin, 2010). They articulate how knowledge is "embedded within epistemological orientations for organizing knowledge and behavior" (Marin, Medin, and ojalehto, 2018; p. 44). For example, Hammer and Elby (2005) have articulated a framework that considers epistemological resources as organizing frameworks that are activated in context-sensitive ways.

A branch of folkbiology research has focused on similarities in folk taxonomic thinking across cultures and levels of expertise (Atran and Medin, 2008; Bailenson et al., 2002; Medin et al., 2006; Medin, Lynch, Coley, and Atran, 1997). Findings have pointed to conceptual differences across populations, specifically in ecological (holistic understanding of system) versus taxonomic (hierarchical understanding of system) organization, even though there have been categorical similarities across groups. For instance, Medin and colleagues (Medin et al. (2006) expressed concern over confounding expertise with culture, and in a study comparing fishing experts across two cultural groups in the same area (Menominee and European-American), they found that while both groups had relatively equal *amount* of knowledge about fish, there were cultural differences in the organization of this knowledge. Menominee experts were more likely to sort fish ecologically, attend to habitat, and report positive or reciprocal relations; "majority-culture" experts reasoned taxonomically and were goal-related in their reasoning. This suggested a difference between groups in terms of knowledge organization regarding salience and "accessibility of ecological information" (p. 270); experts from different

cultural backgrounds but same geographic region organized knowledge differently, even with the same knowledge base.

Bang, Medin, and Atran (Bang et al., 2007) conducted a similar study with children, with participant samples across three groups: two rural groups, non-native European American and Native Menominee, and one urban non-Native group. The urban sample was included because the researchers hypothesized that being in a technologically saturated environment with limited interaction with non-domesticated animals and plants would impact biological knowledge organization (see also Kahn, Rucker and Hasbach, 2012). In fact, they did see this trend, Bang and colleagues found that both rural groups (Native and non-Native) reasoned biologically even from a young age, while the urban group reasoned anthropocentrically. This disputed the influential study by Carey (1985), who suggested *all* children (generalized from a narrow subset of the population) reason from a folkpsychological domain before understanding biological phenomena. Building from this, Unsworth et al. (Unsworth et al., 2012) conducted a study with a similar population sample and found that culture influenced folkbiological concepts in 5-7 year old children, suggesting that concept development starts before children have gone through schooling.

These studies are just a subset of the larger folkbiology literature however they represent the breadth of research in a few ways. First, these studies demonstrate how folkbiology research can serve different ends depending on the sample population: from studying expertise, to cultural influences, to human development. Findings from these studies suggest that culture and experience impact how people conceptualize the natural world. Second, in science learning (and in the conceptual change research) students are often presumed to have inadequate mental models, what some researchers refer to as “misconceptions” (diSessa, 1993) and they are

expected to either replace or rework their conceptual organization to fit the scientific model. While this is relevant for some subjects, it is often a barrier for academic engagement and achievement for nondominant or historically underrepresented students (Medin and Bang, 2014a). This is particularly relevant in ecology and biology, where cultural differences have implications for nature-culture relations, and thus environmentally-related behaviors and learning.

Folkecology and Complex Systems Thinking. The cultural variation that was evident in folkbiological reasoning demonstrated that some cultures (e.g. rural Menominee, Itza' Maya) reason ecologically while others (e.g. European American) reason taxonomically about the biological world (Bailenson et al., 2002). This has led some researchers to reconsider domain boundaries and instead adopt a systems-level organization or model of relationships (among parts in a system), such as folkecology (ojalehto et al., 2015). Folkecology refers to how people make sense of relationships among plants and animals; these organizing principles are linked to environmentally-related behaviors, such as sustainability or conservation (Atran, Medin, and Ross, 2005; ojalehto and Medin, 2015). They studied environmental behaviors, such as agroforestry and sustainability practices, across three groups living in the same geographic region of Guatemala: a native population (Itza' Maya), and two immigrant populations (Spanish speaking Ladinos, and Q'eqchi' Maya). The researchers found direct connections between ecological models and ecological action; the Native Itza' Maya had richer models of the forest and more complex practices and beliefs regarding sustainability.

The implications of Atran and colleagues' study suggest that management practices that are interrelated with a cultural history of the land and ecological practices result in sustainable, healthy practices. Environmental activist and physicist Vandana Shiva echoes this

socioecological framework as she writes about the roles and responsibilities of the commons: “A commons embodies social relations based on interdependence and cooperation” (2016; p.18). Shiva’s quote also troubles the Western scientific norm that the natural world (and arguably the socioecological world) is based on competition. Following these lines, ojalehto and Medin (ojalehto et al., 2015) conducted studies to compare Indigenous Panamanian Ngöbe and US participant populations’ folkecologies regarding cooperation versus competition. They found that the Ngöbe participants were more likely to attribute cooperative properties to animals. The findings, coupled with other research, suggest that how people think about relationships in the natural world may reflect culturally different forms of knowledge organization.

A folkecological framework may better account for complex relationships that are not always prevalent in Western (reasoning and scientific) models. For example, folkecological organization attends to the relationships among parts of a system (e.g. species to species), and is reflected in sustainability-oriented behaviors. These orientations reflect different axiological positionings (Bang et al., 2015) that ground the work in this dissertation. More specifically, taking seriously the cultural differences in knowledge organization determines what is possible in the design of learning environments, and thus has implications for environmentally-related actions.

Bang et al. (2012) build on Cajete (2000), to propose a framework for sense making that is indicative of IWOK, referred to *relational epistemologies*:

> “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, [everything is] connected in dynamic, interactive, and mutually reciprocal relationships”.

This framework stems from literature in Native science (Cajete, 2000; Kawagley, 2006), and similarly can be used to understand the ecological forms of reasoning that emerged in Indigenous participants in some of the folkbiological and ecological reasoning studies. Broadly speaking, both implicit and explicit epistemologies shape how we reason about natural systems; in turn, our interactions and engagement with the natural world shape our epistemologies (Bang et al., 2007). Research that demonstrates cultural variation in worldviews challenges the assumption, seen in much of the extant conceptual change literature, that children come into science classrooms with inadequate theories or conceptual ideas about scientific phenomena. This closes out multiple ways of knowing and engaging with scientific concepts, often in culturally meaningful ways, which allows for the creation of socially and culturally equitable spaces that embraces epistemic diversity (Bang and Medin, 2010; Rosebery et al., 2010). Bang and colleagues (2014) refer to these hegemonic structures as "settled" science, which, among other things, carries epistemic assumptions of human dominance over the natural and in turn influence what is considered acceptable meaning making. Moving to desettle science, they argue, means embracing epistemic diversity, and designing educational environments from and with "epistemological resources" that students bring (Bang and Medin, 2010; Hammer and Elby, 2003). Embracing epistemic diversity and foregrounding the epistemic ecologies of historically nondominant communities can create expansive opportunities for teaching and learning about complex ecological systems, for instance, which often lack adequate teaching methods for understanding the relational and dynamic nature of these systems. This model is particularly important in this dissertation because I examine how learning about ecological systems is mediated by place, context, and culture. From this, I explore the implications for designing field based learning environments foster complex systems thinking in equitable and just ways.

Complexity, Culture and Education

There seems to be a paradigm shift in educational research and scholarship towards embracing and *working with* complexity. This spans many domains and fields of inquiry – social systems, technology-societal relationships, ecological and socioecological systems, and finally complexity in our research parameters and how we design learning environments. Understanding complex socioecological phenomena is necessary as both an academic demand (e.g. science education; NRC, 2012), as well as a necessary component of living in today's increasingly global society. Across the board scholars are calling for curricular improvements to attend to and understand complexity; from socioeconomic issues of equity and access in schooling, to socioecological interconnections and changes. This call, particularly in science education, breaks away from a trend of a simplification. For a long time, science curriculums have been designed with the assumption that people, especially youth and "novices", need to have information broken down into linear, simple connections; this runs contrary to increasing evidence that youth and other non-experts are in fact able to attend to and understand complex phenomena. This is both reflected in our curriculums, as well as in how we structure our learning environments.

There are several hypotheses that have been put forth to explain why students have a difficult time learning about complex systems (and instructors are challenged to teach it). Most consider there to be a novice-expert distinction, in which novices either: a) only grasp cause and effect relationships instead of multiple interacting or emergent elements of a system (Grotzer and Tutwiler, 2014; Hogan, 2002); b) attend to structures but not behaviors and functions of system elements (Grotzer, Kamarainen, Tutwiler, Metcalf, and Dede, 2013; Hmelo-Silver, 2004); or c) novices either focus on agent or aggregate levels of phenomena but have difficulty seeing relationships among them (Levy and Wilensky, 2008).

While this is a broad look at some of the literature, the takeaway message from many researchers seems to be that novices fail to understand the dynamic and emergent properties of complex systems. However, much of this research focuses on attentional and information constraints (Grotzer and Tutwiler, 2014) yet these studies are limited in two important ways. First, there has been little to no consideration of cultural variation in reasoning and how these may or may not impact complexity thinking. Given that culture impacts what and how we think (Bang, Medin, and Atran, 2007), it is important to recognize the structural affordances, or constraints (e.g. material artifacts, context, etc.), that are in place that shape our thinking. In this dissertation I define culture as historically and contextually mediated practices through which people engage and develop (Gutierrez and Rogoff, 2003; Rogoff, 2003). For example, studies on epistemic variations in biological and ecological cognition have demonstrated that privileging linear reasoning (e.g. favoring unidirectional cause and effect explanations instead of attending to webbing or secondary relationships; Grotzer et al., 2013) may be a cultural phenomenon that is not shared by everyone. Forms of reasoning may, in fact, be a result of cultural differences in knowledge organization (see (Medin et al., 2006; Davis and Sumara, 2006), although linear forms of reasoning have primarily been taught ins science classrooms.

Second, the literature on complex systems reasoning has broadly focused on what students know, but little attention has been paid to how they come to know it; addressing this gap in knowledge forms a key motivation for the studies reported in this dissertation. More specifically, the practices in everyday and structured (learning) settings that contribute to biological and ecological knowledge. With an increased focus on field based sciences in the Next Generation Science Standards (NRC, 2012), there is a need to cultivate certain practices such as using observations to support, refute, or create hypotheses. Observations are both a scientific practice

and a community-based practice – although not mutually exclusive (Marin, 2013). Tracing these practices both in informal settings as well as structured educational settings provides a deeper understanding of how science can be personally meaningful to participants (Bricker and Bell, 2013). Understanding how these practices unfold in field based learning settings, and the connections to biological and ecological reasoning, are relatively understudied but promising areas of inquiry (Mogk and Goodwin, 2012).

These assumptions are also reflected in the ways in which learning environments are structured. For example, learning science in classrooms is often decontextualized (Bang and Medin, 2010) and does not reflect the whole process of scientific inquiry and exploration (Mogk and Goodwin, 2012). Additionally, given that the NGSS is leaning towards more authentic practices, incorporating field-based science investigations as sites of learning and meaning making are imperative in teaching and learning about ecological phenomena (NRC, 2012). However, there is a need for more robust research into the role of field based science learning and complex systems thinking. This dissertation takes this up by focusing on the interactional and contextual nature of learning, and explores how place and culture mediate sense making about complex ecological systems.

The Case for Place

This dissertation pays special attention to the role of place in sense making. Sociocultural perspectives have often considered place as a backdrop in theories of learning and development (Bang, 2015; Preston, 2005), and in research methods more broadly (Tuck and McKenzie, 2015b). In considering the role of place in epistemic orientations, Preston writes,

> "Knowledge claims…are rarely given a physical location in a particular geographical or material environment. This unfortunately has left a residual anthropocentrism in epistemology. Only the human context of a knowledge claim gets examined, even in

> the face of what are otherwise helpful and humbling efforts to contextualize. Nothing physical in the epistemic agent's environmental context is seen to count." (Preston, 2005; p. 374).

Overlooking the role of place in both the methods and theories of learning are in part rooted in settler-colonial framework that does not recognize land as relevant and agentic (Bang et al., 2014; Tuck and McKenzie, 2015b). However, it does not mean that a place-focus has been wholly absent, but rather that it has been constructed on Cartesian terms that separate "mind from body, and body from land" (e.g. Tuck and McKenzie, 2015a; p. 154). Centering place has been a cornerstone of Indigenous scholarship in the fields of science education (Barnhardt and Kawagley, 2005; Brayboy and Castagno, 2008; Cajete, 2000). For example, in explaining a "sense of place" in Native science, Cajete (2000) writes,

> "All human development is predicated on our interaction with the soil, the air, the climate, the plants, and the animals of the places in which we live. The inner archetypes in a place formed the spiritually based ecological mind-set required to establish and maintain a correct and sustainable relationship with place." (p. 187)

In the notion that human development is "predicated" on interactions with place, Cajete is articulating a particular ontological, epistemological, and axiological orientation that is present in IWOK (Bang et al., 2015). Making visible these orientations across cultural groups, that is in an Indigenous STEAM camp and in forest walks with primarily European-American families, contribute to theories human learning and development that take seriously the role of place, and thus form a core focus of this dissertation.

Within educational research, considering place means attending to relationships between humans and the natural world. This endeavor has often been taken up in fields related to environmental education, in which researchers and educators alike have directed energies to addressing and acting on some of the Earth's most pressing issues. Environmental educators, sociologists, and psychologists alike have tried to figure out the disconnect between knowing

about environmental problems and caring about environmental problems. Orr (1992) claims that one of the reasons for this disconnect is the over-specialization in educational curricula. Because fields of science, history, and social studies, for instance, are taught separately, students do not have a chance to learn the myriad interconnections that stem from places. However, others have found that field based learning environments offer chances for learners to engage in deep sense making that can foster deeper understanding of interrelated systems (Mogk and Goodwin, 2012). Thus, outdoor learning sites offer potential for impactful learning if they are designed to foster attention to interrelated phenomena. The takeaway here seems to be that despite the social nature of learning, if studies of ecology and biology are done in abstraction and isolation from place, then we are missing a key element of the learning environment.

A central component of place-based education is to connect students to the natural world, to rebuild relationship to the wild, even if that wilderness is the crack in the schoolyard filled with rogue weeds. Gruenewald (2003) defines place-based education as comprised of the following:

> "It's practices and purposes can be connected to experiential learning, contextual learning, problem-based learning, constructivism, outdoor education, indigenous education, environmental and ecological education, bioregional education, democratic education, multicultural education, community-based education, critical pedagogy itself, as well as other approaches that are concerned with context and the value of learning from and nurturing specific places, communities, or regions" (p. 3).

Place-based education is another way of bringing lessons closer to home, connecting the subject matter with the student by drawing on local and relevant concepts (Sobel, 1994, Louv, 2005). In other words, the aim of place-based education is to "ground learning in local phenomena and students' lived experience" (Smith, 2002; p. 586).

However, at the same time many of these theories are attempting to ground learners in place, they are predicated on the erasure of many of the histories and interrelated stories that make place (Massey, 2005). Scholars such as Bang and colleagues (2014) have recognized place-based and environmental education as sites of struggle for decolonization because they have reified settler narratives (see also Tuck and McKenzie, 2015a). Place-based pedagogies have often overlooked the deep histories that are present on lands and instead replace it with a dominant narrative that erases other narratives, what has been called zero-point epistemology (ZPE; Bang et al., 2014). These orientations to land stem from nature-culture relations which "grounds much of human activity and figures centrally in core ontological, epistemological, and axiological frameworks across social and scientific domains" (Bang and Marin, 2015; 531). Thus, the design of learning environments that consider ecological systems and environmental phenomena must take seriously the lived histories and interrelations that make place (Massey. 2005). Below, I explore how place has been considered in language and learning, and offer insight into how this can support a place-embedded theory of learning.

Place, Language, and Learning

A place-based sociocultural lens on recognizes the role of place in theories of learning and human development. For instance, this has been taken up in linguistics and semiotics research (Goodwin, 2018; Kohn, 2013). Anthropologist Eduardo Kohn (2013) asks if we are "forever trapped in our linguistically and culturally mediated ways of thinking" (p.41). He argues no; we, as humans, are taking part in many forms of representation, some of which we share with the rest of the more-than-human world, which recognizes communication that is not solely on human terms, or what others call "anthropocentric". More specifically, Kohn provides an overview of Charles Peirce's (1991) sign systems on three levels to account for the various ways

in which humans and more-than-humans communicate. The levels of representational modalities are: 1) icons, which are representations of something; 2) indices, or representation of something that points to something else; and 3) symbols, which take on meaning in systematic relation to other symbols (e.g. human language). Kohn argues while symbols are unique to humans (although this is disputed), icons and indices "form the bases for all representation in the living world" (p. 31). In other words, there are forms of communication that take place across more-than-humans (and sometimes involving humans). Kohn argues that signs themselves are alive in that they are "ongoing relational processes", termed *semiosis*. Through this ongoing, living process, signs grow, not just in a mind, but across minds; they span time and space.

Similarly, in an ecopsychology approach, Kahn, Ruckert and Hasbach (2012) introduce the term *nature language*, which is "a way of speaking about patterns of interactions between humans and nature, their wide range of instantiations, and the deeply meaningful and often joyful feelings that they engender" (p. 55). Comprised of units called interaction patterns, Kahn et al. suggest a framework for pinpointing and understanding the dynamic manner in which humans and nonhumans are mutually engaged in reciprocating relationships, and the subsequent psychological impacts of these interactions. A key component of Kahn et al.'s nature language is the attention to language itself, or addressing the need for a common sign system to talk about the varied and invaluable interactions we experience with the natural world in a variety of ways. Although they are still operating with language as a human construct, this similarly points to the recognition of more-than-humans as part of the dialogic environment.

Another domain of research that takes this up is sociolinguistics, which recognizes that language is not formed and used in isolation of context, but instead mutually shaping and being shaped by context (Hansfield and Crumpler, 2013; Goodwin, 2000; Gutiérrez et al, 1995). Kahn

et al.'s interaction patterns can "rarely exist by themselves" (p. 55); all of the participants, both human and nonhuman, in a given dialogic environment play contributing roles to meaning making, and thus negotiating the relationships between humans, more-than-humans, and the land. For example, Kahn and colleagues (2012) address this in an interaction pattern they call *recognizing and being recognized by a nonhuman other*, an instantiation that, when occurring in natural environments, has meaning for both (or all) parties involved. Encountering a wild animal, for instance, may influence how one navigates a space, where one decides to attend his or her focus, as well as innumerable other cues about the environment. Relatedly, in his book *What the Robin Knows,* naturalist and tracker John Young (2012) explains how cues from robins and other animals in the forest inform us about who is around; if a robin is giving an alarm call from a particular location on the lower canopy it could mean there is a ground predator nearby such as a fox or coyote. This is an example of both iconic and indexical communication that Kohn refers to as a shared representational modality across most living beings. This is especially salient in our reasoning about natural phenomena as the result of multiple, intertwining interactions among various members of a particular environmental location.

The innate interrelations between land, language, and culture are present in many Indigenous cultures throughout the world. Cajete (2000) writes: "Native language are intimately tied to the landscape that has inspired their development", and we can see this in Rasmussen and Akulukjuk's (2009) piece as they talk about the differences between Inuit and English ways of speaking about and representing environmental phenomenon such as weather (numerical versus embodied). In their discussion on indigenous Inuit languages being inherently tied to the land, they highlight: "languages encode a culture's way of understanding relationships and attributes

of the participants in both the human and natural communities…" (p. 282). In other words the environment is constantly shaping language and culture, and vice versa.

To follow what Kohn lays out, if we are only privileging a language form that we assign to human communication, then that is inevitably contextual and on human terms. But recognizing and attuning to indexical and iconic forms of representations expand beyond the human. Understanding communication on this level seems to recognize the situated nature of cognition. And not just situated physically, but also temporally, spatially, and culturally.

Chapter 2. METHODOLOGICAL BACKGROUND

This dissertation is split into three separate but interrelated papers that develop and examine the framework of spatial indexing: form, function, and mediation. Together these papers provide a unified analysis of what spatial indexing is and how it manifests in and across learning settings. Implications will lead towards refining the design and implementation of field-based science learning settings.

Knowledge and Interaction Analysis

This dissertation utilizes Interaction and Knowledge Analysis (KAIA) methods of inquiry (DeLiema, Lee, Danish, Enyedy, and Brown, 2016). Jordan and Henderson (1995) describe interaction analysis (IA) as an "interdisciplinary method for the empirical investigation of the interaction of human beings with each other and with objects in their environment" (p. 39). With roots in ethnography and conversation analysis, this method relies on video technology to investigate activities, and takes participation as a basis for understanding learning. Knowledge analysis (KA), on the other hand, focuses on knowledge (in the mind) and ways to "access" conceptual organization (Gupta, Elby, and Sawtelle, 2016). The two methods have often been considered incommensurable, but have been combined as different means towards a similar end, to capture learning ecologies of people in interaction with their environment. A blended approach is best summed up in the following quote:

> "Cognitive elements are activated in response to acting within the socio-material environment and that some (most?) of the stabilities in a person's behavior stem from emergent properties of the system that includes those knowledge elements and features of the socio-physical context, with that system constantly affecting and affected by the person's behavior" (Gupta et al, 2016; pp. 260-261).

A blended KAIA approach can use KA to identify stabilities and shifts in sense making, and IA to show how epistemological stances are co-constructed and maintained by a participant. I rely on video and audio data, as well as complementary field notes to capture the interactions, movements, and conversations in each setting.

Community Engaged Design Research.

The ISTEAM data are from a larger community-engaged design research project (Bang, 2015). Community engaged design research stems from the lineage of design research, or design experiments, and more specifically community based design research (Bang et al., 2015) and social design experiments (Gutiérrez and Vossoughi, 2010). Design experiments were developed as a way to implement and study learning settings that not only contributed to learning theory, but also directly to practice (Brown, 1992; Collins, 1992). Design research is an iterative methodology of design, implementation, analysis, and redesign of learning environments; through this process, findings can contribute to the design process itself, thus perpetuating the iterative cycles (Collins, Joseph, and Bielaczyc, 2004; Schoenfeld, 2006). DBR is based on the premise that to understand learning, the researcher cannot rely on sterile, experimental settings, but rather must study the complex learning *in situ* (Collins et al., 2004). While design experiments have added a much needed dimension to research in learning, some have argued that there is a need for greater attention to building theory, towards ontological innovations (diSessa and Cobb, 2004). Bang, Faber, Gurneau, Marin, and Soto (2015) that disrupt settler-normative, powered, and often extractive relationships between researchers and historically marginalized groups of people. They write:

> "Ontological innovations in the study of learning have expanded and deepened what we know and how we design learning environments in countless and invaluable ways. However, design-related fields of education have made less progress in designing

> learning environments that sustainably disrupt historically shaped inequities and cultivate transformative agency from within communities" (p. 2).

A blend of design research and community-based participatory action research (Bang et al., 2015; Bang, Marin, Faber, and Suzukovich, 2013) as well as decolonizing methodologies (Smith, 1999), *community-based design research* (CBDR) designs from and with communities, in which all participants are key decision makers and drive the design, implementation, and participate in the analysis of research. The first study site that this dissertation draws from, an Indigenous STEAM camp, is considered *community-engaged* highlight the ways in which we designed learning environments that were based in community and family practices. From here on out I will refer to it as *community-engaged design research* (CEDR).

Analytic Framework

General Data Analysis

This dissertation uses engages in three layered lines of inquiry over the course of two learning programs: the forms, functions, and mediational impacts on spatial indexing in outdoor learning environments. These three lines of analysis build on one another to characterize the scope of spatial indexing as a conceptual and interactional practice that is situated and culturally mediated. I draw on Saxe and Esmonde's (2005) *form-function* analysis of spatial indexing in microgenetic and cultural-historical processes as a guiding theoretical and analytical framework throughout the dissertation. To do this I code and chunk transcripts from each video into semiotic episodes (Goodwin, 2018; Marin and Bang, 2018) based on talk about biological and ecological phenomena. Included in these semiotic episodes is attention to interactions and the unfolding talk. These layers use spatial indexing to understand how place and culture manifest in the semiotic landscape. This analysis aims to establish the nuances of the semiotic field, as

negotiated through cultural-historical and situated frames. Each paper summary will go into greater detail about the analytic framework.

Observing and Sense Making in the Natural World.

One mechanism for studying the entanglements of place, social structures, and cognition are through observations. In this dissertation I utilize this method and I argue that observing, or attending to phenomena in the perceptual field can offer insight into the entanglements of sense making and place. Observations have typically been positioned as a simple, routine attentional practice that primarily contributes evidence to subsequent reasoning (Eberbach and Crowley, 2009). However, there has been recent research that demonstrates observing practices as culturally nuanced (Correa-Chavez and Rogoff, 2009), theoretically driven (Eberbach and Crowley, 2009), and rich sites for epistemic development (Marin, 2013). The use of observation is a key component of scientific reasoning, particularly in the cultivation of new theories (Smith and Reiser, 2005), as well as an age-old practice that humans have used to develop within ecological systems.

While fostering particular attentional habits is a cornerstone of most learning environments, there have been a number of studies in observation and attention literature that demonstrate cultural differences in what people attend to, and the function that it serves (Correa-Chavez and Rogoff, 2009; Nisbett, Peng, Choi, and Norenzayan, 2001). Marin (2013) argues that while focusing attention is often privileged in learning environments, it is important to understand cultural variation especially in field-based activities because they are directly relevant to how people make sense and reason about the natural world. In her work, she found that attention was coordinated through movement and spatial orientation in the physical environment, and thus: "coordination of attention is an emergent and complex process tied to movement

through the environment" (p. 128). Observations, therefore, offer insight into how place and sense making are bound together.

Spatial Indexing as a framework for studying place, culture, and cognition

I propose a framework of "spatial indexing" to describe a critical component of the practice of observing, or "reading the land" (Cajete, 2000; Bang and Marin, 2017; Pugh, McGinty, and Bang, 2019). Drawing from theories of geosemiotics (Scollon and Scollon, 2003), and distributed semiotics (Kohn, 2013), spatial indexing can be defined in its most abstract as a form of meaning making in which a phenomenon that is spatially present - is located in the perceptual field - and is immediately discursively connected to a different temporality or phenomena that is not explicitly present. This builds upon previous research by Ananda Marin (2013) who demonstrated how bodily orientation, interaction and sense making were intertwined on family forest walks. While indexing is a routine practice in human sense-making that varies across cultural communities and activity systems, in this paper I am interested in moments of spatial indexing in which complex socio-ecological reasoning unfolds. I describe this below.

More specifically, I surface the interconnections of spatial, temporal, and relational dynamics that lead to sense making about complex ecological phenomena. Although engaging in very different approaches, both Scollon and Scollon (2003) and Kohn (2013) elaborate on Charles Peirce's (1991) theory of semiotics to contextualize language and signs in place. Scollon and Scollon introduce the theory of *geosemiotics* to attend to the ways in which signs in the material world orient and mediate emplaced interpretations and actions. Elaborating on Peirce, they describe three ways that a sign (representing something else in the world) can have meaning; as an icon (direct representation), a symbol (abstract or arbitrary representation), and an index (context-dependent representation). Geosemiotics primarily focuses on indexicality, and

refers to how the meaning of a sign depends on its placement the world. However, a limit of this theory is that it only focuses on the social world and social placement of signs, and does not consider the semiotics of the natural world. Therefore, while I find the contextual nature of indexicality useful in that it draws explicit attention to how place is embedded in the social semiotic world and incorporates temporal and relational dynamics of sense making. Here I follow the lines of anthropologist Eduardo Kohn (2013), who articulates an "anthropology beyond the human" (p. 7) that recognizes that the entire living world communicates via semiotics. He argues that semiotics have been constrained by a dependency on sociocultural contexts to provide meaning, and that instead there is a need for a framework for understanding humans in relation with other life-forms.

Positioning land as a semiotic actor (Marin and Bang, 2018) is a cornerstone of many Indigenous epistemologies (Cajete, 2000; Kawagley, 2006). While indexing can draw attention to more-than-humans, it is through an epistemological positioning that land is made relevant (Marin and Bang, 2018). Similarly Kohn articulates that "it is through our partially shared semiotic propensities that multi-species relations are possible, and also analytically comprehensible" (2013; p. 9). Indexing, therefore, provides an opening to study the ways in which place, people and sense making are entangled. Spatial indexing, then, is particularly useful for studying ecological systems thinking, which require sense making across multiple scales, levels, and relationships. Moreover, the unfolding interaction can offer insight into the origins and interactional nature of sense making, and how it grounds epistemic action that follow (Goodwin, 2013). Therefore, spatial indexing can link epistemic action with interaction.

Additionally, articulating and developing the framework of spatial indexing draws attention to how people orient to place while in motion, providing a lens for epistemic and

ontological frameworks that are enacted. I suggest that attentional practices are enmeshed with the semiotic frame in which an individual understands and communicates in the world (e.g. Bang and Marin, 2017). It is important to recognize that although I am drawing in part on theories of semiotics, recognizing land as a semiotic resource in sense making is deeply rooted in Indigenous epistemologies (Marin and Bang, 2018). In response to the resounding assumption in western science that non-humans lack agency (see also Latour, 2013), Bang and Marin assert:

> "This marks a critical ontological difference in western scientific ways of knowing and IWOK [Indigenous ways of knowing]. In many IWOK (though maybe not all) humans are not the only intentional and agentic actors in the world, nor do humans occupy a privileged status that divests us of responsibility, humility, and reciprocity (Kawagley, 1993, 2006; Cajete, 2000)." (2015; p. 532)

They continue to explain how this ontological distinction permeates through dominant scientific theories and practices. Building with Linda Smith (2012) and Giddens (1984), they articulate the idea of "memory traces", entanglements of space and time in interactions that are "fused with social and ecological unfoldings of history and knowledge systems" (p. 533). In conversation with Doreen Massey's (2005) idea of places as "stories so far", this recognizes that the stories that are called forth, down the very ontological and epistemological frame, are rooted in social and cultural structures; they are not emergent in the sense of historical erasure, but rather are dependent upon these histories to determine what is possible.

In a recent study (Pugh, McGinty and Bang, 2019), we used a micro ethnographic approach to analyze the forms of sense making that unfolded in moments of indexing among Indigenous youth in a STEAM (science, technology, engineering, arts and math) camp. That is, when participants indexed something in the spatial field, we analyzed the talk that unfolded about ecological kinds. We found that throughout the walk participants, three young boys engaged in a plant embodying activity, continually indexed phenomena in the spatial field in ways that were

indicative of emergent complex systems thinking. More specifically, observations often led to talk that toggled across spatial and temporal scales, levels (agent-aggregate), and perspective taking. Not only do these indicate emergent complex systems thinking, they are also evident of a relational epistemology (Bang and Medin, 2010) orientation to sense making in mobility.

In this dissertation, I built out the framework of spatial indexing to study how learning unfolds in ecologically-rich places in three separate papers: 1) interactional constellations of spatial indexing, 2) conceptual constellations of spatial indexing, and 3) meditational constellations of spatial indexing. It was through these three layered analyses that I articulated more deeply the form and function (Saxe and Esmonde, 2005), of spatial indexing in field based learning environments. I also conducted cross-cultural analyses across groups – intergenerational participants in an Indigenous STEAM camp and primarily European-American participants in Salmon Walks – as they went for forest walks in the same forested, urban park. Implications for contribute to the design of field based learning environments that take seriously the practice of observing as a mechanism for not only drawing attention to phenomena in the perceptual field, but also as a critical mechanism for understanding complex ecological systems. Finally, by doing a cross-cultural analysis, I also characterized how culture mediated conceptual organization of biological and ecological reasoning as participants learn on the move.

Unit of Analysis

"As footprints are made in soft ground rather than stamped on a hard surface, their temporality is bound to the dynamics of its formation. These dynamics are a function of the weather, and of reactions across the interface between earth and air… Knowledge is formed along paths of movement in the weatherworld" (Ingold, 2010; S121)

In these studies, the unit of analysis was focused at the level of the utterance; what Goodwin (2013) calls substrates, I refer to as *epistemic actions* to encompass both talk and the

paired attentional frame. I focus on epistemic actions in the following sense: "epistemology is not seen as in an abstract philosophical sense but rather is conceived of as being embedded, carried, and brought to life in peoples' socially situated everyday practices" (Bang, 2015). I marked moments when the participants referenced *natural kinds* (e.g., plant, animal, land, water etc.) and the subsequent conversations that took place, which allowed me to trace conversation that centered on ecological phenomena (e.g. Marin, 2013). The sense making that emerged after the initiating substrate was considered as part of a semiotic episode (Marin and Bang, 2018). The end of a semiotic episode was marked when there was a linguistic or gestural marker that closed the conversation (such as a redirect "okay let's keep walking" followed by a new topic).

I am not only interested in the cognitive, or sense making, constellations within the social group, but rather am interested in the way place co-constitutes this sense making. In theories of embodied cognition or distributed cognition, place or materials have been considered as mediators in sense making. In a land-centered framework, land is recognized as being enmeshed in sense making (Brayboy and Castagno, 2008; Cajete, 2000; Kawagley, 2006; Marin and Bang, 2018; Tuck and McKenzie, 2015a).

Research Questions

This research examines how the semiotic landscapes of Ravine Park (an urban park in the Pacific Northwest) afforded particular forms of sense making across two cultural groups as they walk the park. The first context (described below) is a STEAM camp for Indigenous youth, and the second is Salmon Walks with primarily European American families. To do this I asked: How do place, culture, and cognition mediate sense making about complex ecological systems? To answer this, I examine three subsequent research questions and layered lines of analysis to

characterize the form, function, and mediation of spatial indexing across two learning settings. These are:

1. Interactional constellations of spatial indexing:
    1.1. What are the forms of observations in sense making about ecological phenomena during forest walks? How are observations positioned or utilized within semiotic episodes?
    1.2. How do cultural and place mediate the practice of observing in biological and ecological sense making?
2. Conceptual constellations of spatial indexing:
    2.1. What are the forms of sense making that emerge during forest walks, and how are these mediated by culture or place?
    2.2. What is the role of observations in sense making about biological and ecological systems?
3. Mediational constellations of spatial indexing:
    3.1. What is the role of designed materials (physical tools and instructional prompts) in sense making about ecological phenomena during forest walks?
    3.2. How does this look different across cultural groups?

Implications from this work include the development of design principles for future outdoor education programs that seek to engage and build with heterogeneous epistemologies (Bang, Warren, Rosebery, and Medin, 2012; Rosebery, Ogonowski, DiSchino, and Warren, 2010). And this new information has the potential to be foundational in promoting equitable learning opportunities in the area of better understanding, and acting in relations with, complex ecological systems.

Summary and links to research studies

The current research aims to speak to multiple literature bases. On the one hand, I aim to make a case for the need for field-based practices of observation as a promising (and critical) site for understanding complex ecological systems. To do this, I argue that we need to continue a research agenda that bridges knowledge and interaction analyses. Simultaneously, this dissertation aims to surface the cultural differences across groups as they engage in forest walks. Through a careful examination of the role of observations, and other abstracted and/or mediated forms of engagement, I examine how nature-culture relations are reflected in epistemic orientations.

Context

In order to examine how learning unfolds in, and is mediated by culture and place, this dissertation spans two informal outdoor learning programs in the same urban park. Ravine Park (Figure) is a 200-acre densely forested city park that borders the Puget Sound. The park consists of diverse forest ecosystems, wetlands, multiple streams that merge and run into the sound, and both a rocky intertidal and sandy beach area. The park is a large ravine, and part of a larger watershed now called Cascading Creek Watershed. This park is on traditional Duwamish land, and is believed to be important fishing grounds for them and for the Suquamish tribe, located across the sound, prior to European settlement. There was once abundant salmon runs in this watershed, but detrimental effects from a sea wall and a railroad running parallel to the water cut off the once vibrant and essential estuary that connected Cascading Creek and the sound; thus, the last natural salmon run was in 1927. Additionally, urban development and runoff greatly polluted the creek, making the waters uninhabitable for salmon despite the culvert that was built to reconnect to the sound. Now, due largely to volunteer and community efforts, Ravine Park

hosts one of the few salmon runs in the Seattle area. In partnership with Suquamish tribe, whose hatchery provides chum (a species of salmon) eggs and fry (juveniles), volunteers since the mid-1980s have built and maintained a small imprint pond in which the salmon adapt to the smells and chemical makeup of the stream before being released to the ocean. Since then, there have been successful salmon returns almost every year; now with numbers between 200-500 per fall season.

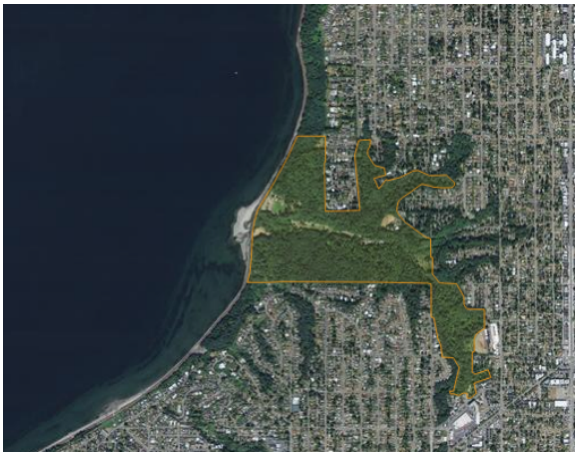


Figure 2-1. Aerial Image of Ravine Park

Ravine Park is a vibrant and popular place for the public to enjoy the beach, hike the trails, and picnic. Additionally, there are several education programs that run in the park, including summer environmental education camps, a year-round outdoor pre-school, a daycare, and other visiting camps and school trips. This project explores two informal, outdoor learning programs: An Indigenous-STEAM (science, technology, engineering, arts, and math) camp, and a Salmon Days program that educates the public about salmon in the park.

Study Site 1: I-STEAM

The data in this study is pulled from a larger Community Engaged Design Research (CEDR) project in which development of youth programs was in response to a call for more expansive science education grounded in Indigenous ways of knowing (IWOK) and generatively supported

Indigenous students' engagement with Western science (Bang et al., 2015). Building from previous work in Chicago, the current project manifested in the design of a Summer I-STEAM (science, technology, engineering, arts and math) program for indigenous youth in the greater Seattle area that runs for one to two weeks per summer in one of two large, forested urban parks with wetlands, rocky intertidal zones. Foregrounding Indigenous observation practices, such as attending to relationships, roles, and reciprocity were critical in the pedagogical practices and mediational tools developed for the program.

The project was a partnership that included several organization partners, including Red Eagle Soaring, a Native youth arts program, a Native Alaskan corporation, and the University. In addition there were a range of urban Native community members, artists, ocean scientists, parent volunteers, and graduate students engaged in the design of the program. The program was designed through a series of design meetings that utilized place-based designing (Bang et al. 2015), professional developments, and art inquiries, for a substantial part of the work. For example, program facilitators and designers participated in collective professional developments to prepare for the program through field days with scientists as well as storytelling workshops with a local Native artist. In addition, program facilitators walked and planned in the places we would take youth.

Site 2: Salmon Days

Salmon Days is a volunteer-based community program in partnership with Seattle Public utilities, The Ravine Watershed Community Action Project, and the local Seattle community. The program engages the public in place-based learning about salmon, their life cycle, habitats, and the local efforts to maintain the seasonal run. The program takes place on the weekends throughout the late fall during salmon spawning season. The Salmon Days program was started

to teach the community about salmon, and to further ensure efforts to protect the stream and surrounding habitat through stewardship practices. Volunteers interact with the public, and are trained by staff from Seattle Public Utilities and Seattle Parks and Recreation. Some of the Stewards are also involved in other salmon-related volunteer efforts at the park.

Salmon Days were trained at Ravine Park in a one-day intensive training that covered salmon life cycle, habitat, history of the salmon run in the park, and other detailed information about programs and city-park relations. Then the instructors took the trainees outside to the stream so they could become familiar with the place. Salmon Days volunteers set up an informational tent every weekend during the salmon run, and walked along the stream to engage with park visitors, answer questions, and inform them of ways to help maintain a healthy stream and watershed. Some of the volunteers were new to the program, and some were returning stewards; there was a varied level of experience and expertise regarding either salmon or the park itself.

Participants

I-STEAM: In the I-STEAM program, youth range in age from 6-13 years old, and were from of various Indigenous nations and tribes from the United States and Mexico. All of the instructors were co-designers of the program, this included: graduate students (most of whom are students of color, some identify as white, and some who are Indigenous), Indigenous faculty, and an Indigenous elder. The program deliberately worked to include families as central to educational change both through co-design of the program but also in implementation (Bang, Montaño Nolan, and McDaid-Morgan, 2018; Ishamaru, Barajas-López, and Bang, 2015). Families were involved with co-designing the camp and attended meetings during the academic year to help plan. In addition, families were invited to participate in camp as much as they

wanted. Some families were asked to share their expertise with camp and helped to implement different activities. This dissertation focuses on youth and instructors while in the field during the camp.

Salmon Days: This program aims to inform the public, the local community, about salmon. This study focuses on interactions between the Stewards (who range in age from early 20s to late 60s), and families who are exploring the park with children between the ages of 6-13. Some families have never seen the salmon at Ravine before, and some visit the park each year during the run.

Researcher Positionality

I am an Indian-American female – whose mother emigrated from India, and father is European-American – with mixed identities as both a person of color and white. Professionally, I identify as an environmental educator, and worked at Ravine Park from 2011-2013. I have been volunteering with salmon programming and other community projects at Ravine since 2012, and am now a member of the advisory council for the park, and a new Salmon Steward. These various engagements have given me a deeper understanding of the intricacies the park as a web of socioecological connections.

I have been involved in the ISTEAM project as a graduate student since the initial design of the Seattle camp in 2014, and have engaged in research and curriculum design, teaching, and data analysis. I bring an environmental educator lens to the work, and am also deeply passionate about creating equitable learning environments for youth. I am both an insider and an outsider (emic and etic perspectives) in the ISTEAM community. As an insider, I have co-designed and implemented the programs. However, I am not Indigenous and over the years had been navigating ontological and epistemological differences between her culture and family and the

pedagogical orientations in the camp. While I was experienced in teaching and learning about plants, I had approached this from a western frame (e.g. Bang and Medin, 2010; Hammer, Elby, Scherr, and Redish, 2004). This manifested in instructional habits and discourse, such as using "species" instead of "relatives" or "relations" when referring to plants, or prompting observations without first thinking with stories. The year that this camp took place, 2017, was my fourth year in this iterative CEDR process, with iterations, feedback, and learning opportunities for epistemic navigation (Bang and Medin, 2010). Talking with peers and families, and engaging in activities outside of the camp, had been vital for member-checking and making deeper sense of the data.

Walks

"[Walking is] itself a way of thinking and of feeling, through which, in the practice of pedestrian movement… cultural forms are continually generated." (Ingold, 2008; p. 2)

For a long time, theories of cognition and learning did not consider mobility as central to learning. This has also been prevalent in the classroom. Now there is increasing research into learning on the move (Taylor, 2013) and walking as a cultural practice (Marin, 2013). This study builds on previous research by Ananda Marin (2013) who put forth a framework for studying the role of attention and observations in learning during parent and child forest walks. Utilizing interaction analysis methods, Marin studied talk-in-interactions (in forest walks), demonstrating how talk and sense making are linked with corporeal arrangements. In the present study, I build with this work to examine how observations mediate sense making, and more specifically how place (or land) figures into this sense making. Following the lines of Marin and Bang (2018), this paper understands land is not a fixed entity but is a relevant semiotic field in meaning-making (Pugh, McGinty, Bang, 2019).

Salmon Walks

Recent research on informal learning settings highlight family discourse practices as rich sources of knowledge development (Callanan et al., 2012; Goodwin, 2007). Within parent-child conversations, the epistemological standpoints that parents hold regarding science, or science-related concepts, can impact how children make sense of the natural world (Luce et al., 2013; Callanan et al., 2013). Walks generally followed the creek in which salmon were running. However, some families went up a trail that traversed the south end of a ravine, leaving the creek and heading farther into the forest. Other families continued along the creek, past the point where salmon were running, although these families did not realize the salmon had turned up another stream. There were 7 walks in total over the course of two Saturdays, and video recordings of these walks ranged from 5 minutes to nearly 1 hour and 6 minutes, with an average of 40m42s. One video (Jake) was not usable because of participants' unfamiliarity with the GoPro, and thus wanting to end the walk.

The Salmon Days volunteer program was taking place at the park. Volunteer Salmon guides had a tent set up with information about salmon, including local salmon run numbers, salmon life cycle displays, and information about the park. Volunteers were also stationed at viewing points along the creek, and twice a day offered guided salmon walks (none of the families in this study participated in the guided walks while wearing cameras, and none reported doing it earlier).

#	Date	Location	Participants (A=Adult, C=Child)	Length of video	Walk Distance	Map
SW 1	11.1 9.17	Cascading Creek, South Bluff	(A) Mom M, Mom (C) Zac, Izabel	01:05:54	0.58 mi	

SW2	11.1 9.17	Cascading Creek, South Bluff	(A) Mom, Dad; (C) Tommy, Ali	00:52:39	0.78 mi	
SW3	11.1 9.17	Cascading Creek	(A) Mom (C) Alyse	00:10:25	0.11 mi	
SW4	11.1 9.17	Cascading Creek, Cascading Orchard	(A) Mom, Dad; (C) Adam and Ernie	00:45:58	0.68	
SW5	11.2 5.17	Cascading Creek	(A) Mom; (C) Claire	01:04:06		
SW6	11.2 5.17	Cascading Creek	(A) Mom; (C) Colin	00:05:39	0.16	

Figure 2-2. Data Corpus: Salmon Walks

ISTEAM

In this study I explore the talk and interaction during walks with adults and youth. The youth in this study range in age from nine to thirteen. Many of the youth were returning to the camp for the second, third, or fourth time; a few were attending their first ISTEAM camp. Walking was a key pedagogical component of the ISTEAM because it is a deeply cultural practice tied to Indigenous Ways of Knowing (Marin and Bang, 2018; Cajete, 2000). Walking was recognized as an activity for knowledge making. Ingold refers to this type of movement as *wayfaring*, in which

the "concern is to seek a way through" rather than arrive at an end destination. Walks served different purposes depending on the day, location, and activity, and I characterized camp walks based on how they were designed and thus labeled them in one of two categories: designed walks and destination walks. Designed walks consisted of an organizing theme, such as *plant relatives,* and children and adults walked in small groups. Destination walks encompassed general movement from point A to point B, such as a few children and adults walking to the bathrooms. I take up the former, designed walks, in my analysis.

Within designed walks, there were further distinctions based on purpose and/or intention. We had prompts for every designed walk, whether or not the walk was intended to get from point A to B. Many of these walks fell under a general category of "plant relatives", and subsequently were further specified by domain - such as "math walks". All walks, although with starting and endpoints in mind, were pedagogically designed *as a learning activity*. In order to bound the data and examine the role of observations in designed walks, I selected *Plant Relative* walks on two days of the camp, Day 2 and Day 4. Within this data corpus, I chose walks that included both adults and children in order to examine the interplay of intergenerational interactions and place. I also chose walks that were in forested ecosystems. There were five designed (intentional) walks (Appendix A), and I analyzed four. One set of walks on day 1 was not considered because either the video was disjointed (a child wearing a POV separated from group to run to the bathroom) or the footage took place on the beach. I also did not analyze whole group activities that were sedentary. In the data corpus in this study, there was 9 hours and 3 minutes of video, with an average video length of 23 minutes and 27 seconds.

#	Date	Location	Participants (A=Adult, C=Child)	Length of video	Walk Distance	Map

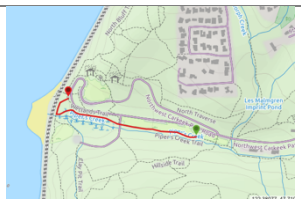
IS1a	7.25.17	Beach to field: Wetlands	Group: (A) Maya, Ron; (C) River, Andy, Runa, Koa	00:20:48	0.42 mi	
IS1b	7.25.17	Beach to field: Road	Group: (A) Mary, Dave; (C) Malik, Alana, Dante, Noah, Luna, Ava	00:21:38	0.36 mi	
IS2	7.25.17	Imprint Pond	Group 1: (A) Minna; (C) Caden, Dante, Luna Group 2: (A) Oscar; (C) Ava, Dalia, Koa, Malik Group 3: (A) Maya; (C) Alana, Noah, Andy Group 4: (A) Sani; (C) River, Camila, Luka	G1: 00:07:42 G2: 00:08:26 G3: 00:26:28 G4: 00:26:28	0.18 mi	
IS3	7.27.17	Wetlands	Group: (A) Mary, Oscar, Sani, Sam, Amy, Luis; (C) Ava, Camila, Dalia, Malik, River, Kali, Runa, Hana, Andy	00:26:21	0.34 mi	
IS4	7.27.17	North Bluff[1]	Group 1: (A) Maya; (C) Noah, Jesse, Alana, Tara Group 2: (A) Oscar, Anna; (C) Hana, Dalia, Kali, Andy Group 3: (A) Sani; (C) River, Runa, Camila, Ava Other groups: (A) Mary, Stella; (C) Malik, Dante,	01:06:26 – 01:19:25	0.58 mi	

Figure 2-3. Data Corpus: ISTEAM Walks

[1] This was a whole group walk with multiple POV and mobile cameras. Although there were 4 initial groups to begin with, children and adults were enmeshed throughout the walk for some of the groups. Thus, it is hard to distinguish the boundaries for groups and cameras. The length of video contains a range to reflect the length of the actual walk, which took about 1hr20 minutes from start to finish.

Limitations and Considerations

Throughout this dissertation, I look at video and audio data from walks across two contexts. I have chosen to look at walking data because walking can be, and often is, a pedagogical activity in which people and the environment become enmeshed. Or to put it another way, "the touched, smelled and heard proximate material world is thereby woven into the walker's sensory field, leading him or her to experience the landscape as a topological realm of contiguous places." (Olwig, 2008; p. 84).

> Where participants walk, what participants notice, and whether or not agency is recognized in the more-than-human world provide a lens for looking at the how land, as a unit of analysis, is a co-constituent (or not) in sense making.

I recognize that by focusing on the talk that happens during walks, I still run the risk of prioritizing sense making at the level of the human, and at the level of the individual. However, this dissertation aims to contribute to a growing field that recognizes that even within this prioritization, there is a choice: place can either be recognized as entangled, or it cannot. While I think this dichotomy is somewhat reductive, I do think it bears an important point – or rather a point of departure. *If* place is recognized as entangled, then this could become evident in the talk that takes place as participants walk. Finally, I attempt avoid this slippage into the dichotomization of placed or not in two ways: 1) in recognizing that within each opening semiotic action, there is a potential to re-ground talk in place (thus the initiating and subsequent epistemic actions I will lay out in the methods section); and 2) doing an interaction analysis that both zooms in to the micro-practices *and* zooms out to the way participants are moving through space. Thus, in this spatial turn, I hope to not only illuminate how interactions and sense making are grounded in place, but how thought is wholly enmeshed *within* place.

Chapter 3. PAPER 1: INTERACTIONAL CONSTELLATIONS OF SPATIAL INDEXING

Introduction

Observing is a ubiquitous human practice in making sense of the world. Understanding how and what people attend to offers insight into the culturally-variant and contextually-mediated nature of human learning (Gutiérrez and Rogoff, 2003). Studying the cultural and contextual nature of observations in field based learning environments is a step towards creating effective and equitable opportunities to teach about complex ecological systems (Marin and Bang, 2018; Hmelo-Silver, Jordan, Eberbach, and Sinha, 2017). Contextually speaking, scientists, particularly ecologists and biologists, routinely engage in field investigations that utilize observations throughout the scientific inquiry process (Eberbach and Crowley, 2009). Additionally, observations are an everyday practice that both reflect and scaffold epistemic development, and cue individuals to attend to phenomenon in culturally-specific ways (Correa-Chavez and Rogoff, 2009; Luce et al., 2013; Rogoff, 2014). Of particular importance to this study, observations are foundational to Indigenous ways of knowing (IWOK) about the natural world, and thus an integral part of Native Science (Barnhardt and Kawagley, 2005; Cajete, 2000; Cajete, 2012). Therefore, investigating the explicit link between observations and sense making about complex ecological systems is an emerging trend in studies of learning (Grotzer et al., 2013; Marin, 2013; Marin and Bang, 2018).

This purpose of this paper is to employ these perspectives to investigate the form and function of observations in sense making about complex ecological systems by: (1) exploring the interactional dimensions of observations in informal and nonformal learning settings, and (2) articulating how culture and place mediate observational practices. This study examines the role

of observations across two contexts in the same urban, forested park. The first context is called Salmon Walks, and follows primarily European-American families on autumn forest walks as they watch salmon spawning up a stream. The second context is an Indigenous STEAM (science, technology, engineering, arts, and math) camp that takes place for a week during the summer. Both of these contexts are intergenerational, with youth ranging from ages 6-13 and adults.

Spatial Indexing: A Framework for Studying Emplaced Learning

The current study utilizes and further develops an approach called *spatial indexing* (Pugh, McGinty, and Bang, 2019) to study how observations manifest in sense making about complex ecological systems. Focusing on talk and interaction provide theoretical and methodological lenses to explore how people collaboratively reason about biological and ecological phenomena. Spatial indexing stems from theories of human action (Goodwin, 1999) and theories of semiotics as it relates to learning (e.g. Peirce, 1991; Erickson, 2004; Kohn, 2013; Ochs, 2012; Scollon and Scollon, 2003). Indexing refers to signs that are context dependent. Indices can take a number of forms in interactions; they can be linguistic in the form of a deixis (e.g. “here”, “this”), gestural in the form of pointing, or a representation of something in the physical world (e.g. a stop sign). Indexing does not necessarily allude to things that are spatially present, for instance, as a purely linguistic marker, indexing can refer to a topic that was previously talked about (see also, Erickson, 2004). To distinguish the types of indexing that are relevant in discourse, Scollon and Scollon (2003) introduce the term “geosemiotics” to focus on how the meaning of a sign is dependent on its placement in the world (e.g. a stop sign). Spatial indexing more deeply examines the act of indexing with sense making along multiple spatial, temporal, or relational scales. In its most abstract form, spatial indexing is a type of meaning making in which a

phenomenon that is spatially present (is located in the perceptual field) is immediately discursively connected to phenomena that is not immediately present.

In this research context, spatial indexing allows the researcher to link the practice of observations to the process of sense making about complex ecological systems. There have been numerous studies that suggests teaching and learning about complex systems is a challenge (Grotzer et al., 2013). Most consider there to be a novice-expert distinction, in which novices either: a) only grasp cause and effect relationships instead of multiple interacting or emergent elements of a system (Grotzer and Tutwiler, 2014; Hogan, 2002); b) attend to structures but not behaviors and functions of system elements (Grotzer, Kamarainen, Tutwiler, Metcalf, and Dede, 2013; Hmelo-Silver, 2004); or c) novices either focus on agent or aggregate levels of phenomena but have difficulty seeing relationships among them (Levy and Wilensky, 2008). However, much of this research focuses heavily on individual cognitive constraints and thus are limited in two important ways. First, there has been little to no consideration of cultural variation in reasoning and how these may or may not impact complexity thinking. Second, there has been little inquiry into complex systems thinking as a situated, interactional activity (for exceptions see Danish, 2014; Enyedy and Goldberg, 2004). This paper aims to heed this call by exploring how observations practices in everyday and structured (learning) settings contribute to the construction and organization of biological and ecological knowledge. More specifically, in this cross-cultural analysis of sense making in interactions, I intend to challenge the notion that complex systems thinking is a) a purely cognitive capacity, and b) the ubiquity of the expert-novel distinction. Tracing the practice of observations in both unstructured settings (such as forest walks) as well as structured educational settings (including field-based learning programs)

provides a deeper understanding of how science can be personally meaningful to participants (Bricker and Bell, 2013), and, in turn, has implications for the design of learning environments.

This study closely examines the interactional nature of observations as an everyday practice in semi-structured and unstructured forest walks. This purpose of this study is to understand and characterize the interactional constellations of spatial indexing as it supports ecological and biological cognition. To do this I consider the role of observations in semiotic episodes (Goodwin, 2013; Marin and Bang, 2018), during which participants are sense making about biological and ecological phenomena.

1. What are the forms of observations in sense making about ecological phenomena during forest walks? How are observations positioned or utilized within semiotic episodes?
2. How do cultural and place mediate the practice of observing in biological and ecological sense making?

The findings are presented in two sub-studies that look at the different forms of: (1) semiotic openings, or "substrates" (Goodwin, 2013), (2) the role of observations throughout a semiotic episode. These findings contribute to a theory of human action in learning, which considers place and culture as foundational to sense making about ecological systems.

Theoretical framework

This study draws on sociocultural theories of learning in order to highlight how social structures and cultural practices influence cognition and learning in place, and in turn how knowledge organization influences how we make sense of the world (Bang and Medin, 2010; Lee, 2008; Atran and Medin, 2008; Vygotsky, 1978). A core tenet of sociocultural theories is that learning and development are mediated by histories, social context, and cultural artifacts, and are enacted through constellations of practices (Vygotsky, 1978; Gutiérrez and Rogoff, 2003; Saxe, 1991).

This study adopts a situated learning perspective (Lave and Wenger, 1991) to explore the role of place and culture in sense making about ecological systems (Bang et al., 2015). More specifically, I examine talk-in-interaction (Marin, 2013; Headrick Taylor, 2013; Jordan and Henderson, 1995 to illuminate how observations mediate, or are mediated by, knowledge organization about biological and ecological phenomena.

Place-based Sociocultural Framework

Sociocultural theories have often considered place as a backdrop in theories of learning and development (Bang, 2015; Preston, 2005). In considering the role of place in epistemic orientations, Preston writes,

> "Knowledge claims…are rarely given a physical location in a particular geographical or material environment. This unfortunately has left a residual anthropocentrism in epistemology. Only the human context of a knowledge claim gets examined, even in the face of what are otherwise helpful and humbling efforts to contextualize. Nothing physical in the epistemic agent's environmental context is seen to count." (Preston, 2005; p. 374).

Overlooking the role of place in both the methods and theories of learning are in part rooted in settler-colonial framework that does not recognize land as relevant and agentic (Bang et al., 2014). However, it does not mean that a place-focus has been wholly absent, but rather that it has been constructed on Cartesian terms that separate "mind from body, and body from land" (e.g. Tuck and McKenzie, 2015a; p. 154). Centering place has been a cornerstone of Indigenous scholarship in the fields of science education (Barnhardt and Kawagley, 2005; Brayboy and Castagno, 2008; Cajete, 2000). For example, in explaining a "sense of place" in Native science, Cajete (2000) writes,

> "All human development is predicated on our interaction with the soil, the air, the climate, the plants, and the animals of the places in which we live. The inner archetypes in a place formed the spiritually based ecological mind-set required to establish and maintain a correct and sustainable relationship with place." (p. 187)

In the notion that human development is "predicated" on interactions with place, Cajete is articulating a particular ontological, epistemological, and axiological orientation that is present in IWOK (Bang, Faber, Gurneau, Marin, and Soto, 2015). Making visible these orientations across cultural groups, that is in an Indigenous STEAM camp and in forest walks with primarily European-American families, contribute to theories human learning and development that take seriously the role of place, and thus form a core focus of this study.

In adopting a place-based sociocultural framework, this study takes an activity theory lens (Goodwin, 1999) to examine the role of human action in the environment; this is considered by focusing on micro-interactions (e.g. Cole, 1991). Goodwin (1999) contributes to a burgeoning theory for studying human action, which is "built through the simultaneous deployment of a range of quite different kinds of semiotic resources" (p. 1489). By semiotic resources, Goodwin calls attention to the ways in which the physical world, including artifacts or tools, are imbued with (human) meaning and thus become part of the semiotic field within which sense making occurs. For example, consider the following clip (Table 4) from a parent and child dyad. A mom and her child, Claire, are walking along a stream in the forest. They are looking for stinging nettle and the mom asks Claire what stinging nettle looks like and how to identify it.

1	Mom:	What does stinging nettle look like?
2	Claire:	Stinging nettle looks like... [walking along path to keep
3		looking]. Hmmm. Oh that's funny, it looks exactly like this,
5		this leaf right here. Well not really, it's more green and more
6		heart-shaped. But it has the same jagged lines on the edge. =
		Except even more jagged.

This excerpt is a bounded unit of talk, what I call a semiotic episode (Bang and Marin, 2018; Goodwin, 2012). Sense making occurs as the mom and child walk along the path, searching for the plant stinging nettle. Patterns of reasoning unfold in coordination with

perception and attention (Grotzer and Tutwiler, 2014). The mom asks Claire to describe what stinging nettle looks like, and Claire is looks along the side of the trail to find the plant. She attends to cues in the perceptual field, and indexes ("this", line 3) another plant to compare morphological features of other plants. Without considering the surrounding environment as a semiotic resource (Goodwin, 1999; Marin and Bang, 2018), this interactional unit would not make sense. But with this consideration, it also offers a glimpse into knowledge elements and indicators of knowledge organizing structures such as attending to morphological features of plants (Eberbach and Crowley, 2009; Smith and Reiser, 2005). As a unit, this excerpt demonstrates how learning is coordinated in interactions among people, place within a system (Goodwin, 1999). Put another way, "studying interactions in activity [make] visible the multiplicity of orientations to the natural world, carrying implications for how we might understand peoples' conceptual and epistemic ecologies." (Bang, 2015). By examining sense making both at the level of the individual, as well as sense making across place, this study looks at the interplay between individual cognition and the culturally- and contextually-mediated nature of knowledge organization. More specifically, I how youth and adults attend to place while walking in ecologically-rich forests.

Context and participants

In order to examine how learning unfolds in, and is mediated by culture and place, this study spans two informal outdoor learning programs in the same urban park. Ravine Park (Figure 1) is a 200-acre densely forested city park that borders the Puget Sound. The park consists of diverse forest ecosystems, wetlands, multiple streams that merge and run into the sound, and both a rocky intertidal and sandy beach area. Within this park, I explore two informal, outdoor learning

programs: An Indigenous-STEAM (science, technology, engineering, arts, and math) camp, and a Salmon Days program that educates the public about salmon in the park.

Study Site 1: I-STEAM

The data in this study is pulled from a larger Community Engaged Design Research (CEDR) project in which the development of programs for Indigenous youth was in response to a call for more expansive science practices that grounded in both Indigenous ways of knowing (IWOK) and Western science (Bang and Marin, 2015). This manifested in the design of a Summer Indigenous STEAM (science, technology, engineering, arts and math; ISTEAM henceforth) program for youth that took place in large, urban forested parks within the city.

The project was a partnership that included several organization partners, including a Native youth arts program, an Alaska Native Corporation and the University. In addition there were a range of artists, ocean scientists, parent volunteers, graduate students, and Native community members that engaged in the design of the program. The planning for the program took place during a series of design meetings that utilized place-based designing methods (Bang et al. 2016), professional developments, and art inquiries. For example, program facilitators and designers participated in collective professional developments to prepare for the program through field days with scientists as well as storytelling workshops with a local Native artist. In addition, program facilitators walked and planned in the places we would take youth. The program was intentionally designed around the tides to highlight the integral role that land and waters play in designed learning settings.

The lands on which the camp took place are traditional Duwamish, Suquamish, and other Coast Salish Peoples' territories and have undergone dramatic transformation since European contact. A core tenet of the ISTEAM camps is to remake or build on existing relations with

lands, waters, and Coast Salish communities. Indigenous pedagogies and intergenerational cultural practices were central throughout the design and implementation of the ISTEAM camp. Learning activities were designed around “walking, reading, and storying the land”, which are routine practices in which individuals enact nature-culture relations that foreground relationships, roles, and reciprocity (Marin and Bang, 2018; Cajete, 1999). This includes activities that are centered on remaking relations with plants during scaffolded observation activities and plant relative walks. Instructors carried back-pocket guides with reminders about verbal and physical facilitation prompts to scaffold attention and observations in ways that were aligned with relational epistemologies (Cajete, 1999).

Site 2: Salmon Days

Salmon Days is a volunteer-based community program in partnership with the public utilities department, a local community watershed non-profit, and the local community. The program engages the public in place-based learning about salmon, their life cycle, habitats, and the local efforts to maintain the seasonal run. The program takes place on the weekends throughout the late fall during salmon spawning season. The Salmon Days program was founded to teach the community about salmon, and to further ensure efforts to protect the stream and surrounding habitat through stewardship practices. Volunteers interacted with the public, and were trained by staff from the public utilities and parks and recreation departments. Some of the volunteers were also involved in other salmon-related volunteer efforts in the park. Families frequent the park to watch the salmon run, and often interact with the volunteers to ask questions or participate in a guided walk. Recruitment of families for the study took place during these times. The families in this study are primarily European American identifying, and the children ranged in age from six to thirteen. The walks were unstructured, and all of the participants were recruited at the park

while they were already either about to go on a walk, or had been walking. Many families had not seen the salmon run prior to this day.

Methods

This study utilizes interaction and discourse analysis to explore sense making while people are walking in the forest. At its core, interaction analysis (IA) is an "interdisciplinary method for the empirical investigation of the interaction of human beings with each other and with objects in their environment" (Jordan and Henderson, 1995). The methods, theoretical implications, and use of IA has varied over the years, but central aim for IA in this study will be to enact IA as an approach to study "knowledge in use" (Hall and Stevens, 2016). A bulk of interaction analysis research has focused on stationary interactions, privileging talk and gesture to understand the social construction of knowledge. Recent trends have shifted to understand learning on the move (Taylor, 2013) to better understand the distributed nature of interactions (Hall and Stevens, 2016) and how these interactions mediate learning.

Discourse analysis has been an educational research tool used to study interactions between learners, teachers, and subjects. In this study, discourse analysis is employed to attend to the interactions between participants, and participants within the physical environment (Callanan et al., 2012; Goodwin, 2007). Including the material world as part of the interactional unit opens avenues for viewing more-than-humans as part of the semiotic environment (Goodwin, 2012; Kohn, 2013; Marin and Bang, 2018), and provides a lens to examine the affordances of learning outside. It also frames cognition as embodied rather than solely in the mind (Goodwin, 2000a).

In order to closely examine the form and function of observations (and thus bound the data), I used conversation analysis (Goodwin, 2000b) to trace participants as they walked, read, and storied the land (Marin and Bang, 2018). I translated the audio using a modified version of

the Jefferson transcription system (Appendix A; Sacks, Schegloff, and Jefferson 1978). To conduct this analysis, I viewed data multiple times, including audio and video, identifying salient interactions and conceptual threads in which participant talk hovered around ecological phenomena broadly.

In order to find out how place was constructed in sense making about biological and ecological phenomena, I characterized the semiotic episodes as participants walk through the forest (Goodwin, 2012; Goodwin, 2018; Marin and Bang, 2018). This, in part, stems from Goodwin's (1998) idea of *contextual configuration*, that refers to the "array of semiotic fields that participants demonstrably orient to" (p. 1489). I leaned on Goodwin's (2012; 2017) substrates framework to develop an analytic framework to capture the entanglements of land, attention, and language. Goodwin (2018) lays out a framework that explores how an indexical operation in an initial action provides the materials for subsequent action. These initial actions, marked by an utterance, are called "substrates" because they form the foundation upon which subsequent actions build. In turn, subsequent actions, including talk and other action types, are bounded by the transformation of "the very materials that composed the earlier utterance" (p. 48). This rests on a theory of human interaction in which meaning is constructed in situated activities.

Additionally, I adopt the stance that attentional practices are enmeshed with the semiotic frame in which an individual understands and communicates in the world (e.g. Bang and Marin, 2017; Hammer et al., 2005). It is important to recognize that although I am drawing in part on theories of semiotics, recognizing land as a semiotic resource in sense making is deeply rooted in Indigenous epistemologies (Marin and Bang, 2018). In response to the resounding assumption in western science that non-humans lack agency (see also Latour, 2013), Bang and Marin assert:

> "This marks a critical ontological difference in western scientific ways of knowing and IWOK [Indigenous ways of knowing]. In many IWOK (though maybe not all) humans are not the only intentional and agentic actors in the world, nor do humans occupy a privileged status that divests us of responsibility, humility, and reciprocity (Kawagley, 1993, 2006; Cajete, 2000)." (2015; p. 532)

They continue to explain how this ontological distinction permeates through dominant scientific theories and practices. Building with Linda Smith (2013) and Giddens (1984), they articulate the idea of "memory traces", entanglements of space and time in interactions that are "fused with social and ecological unfoldings of history and knowledge systems" (p. 533). In conversation with Doreen Massey's (2005) idea of places as "stories so far", this recognizes that the stories that are called forth are rooted in particular ontological and epistemological frames (Hammer, Elby, Scherr, and Redish, 2004). Thus, I refer to talk and interactional patterns as "epistemic actions" to examine the cultural orientations within which knowledge and practice are organized during forest walks.

Unit of Analysis

In this study the unit of analysis was focused at the level of the utterance; what Goodwin calls substrates, I refer to as *epistemic actions* to encompass both talk and the paired attentional frame. I focus on epistemic actions in the following sense: "epistemology is not seen as in an abstract philosophical sense but rather is conceived of as being embedded, carried, and brought to life in peoples' socially situated everyday practices" (Bang, 2015). I marked moments when the participants referenced *natural kinds* (e.g., plant, animal, land, water etc.) and the subsequent conversations that took place, which allowed me to trace conversation that centered on ecological phenomena (e.g. Marin, 2013). The sense making that emerged after the initiating substrate was considered as part of a semiotic episode (Marin and Bang, 2018). The end of a

semiotic episode was marked when there was a linguistic or gestural marker that closed the conversation (such as a redirect "okay let's keep walking" followed by a new topic).

Walks

"[Walking is] itself a way of thinking and of feeling, through which, in the practice of pedestrian movement… cultural forms are continually generated." (Ingold, 2008; p. 2)

For a long time, theories of cognition and learning did not consider mobility as central to learning. Now there is increasing research into learning on the move (Taylor, 2013) and walking as a cultural practice (Marin, 2013). This builds on previous research by Ananda Marin (2013) who put forth a framework for studying the role of attention and observations in learning during parent and child forest walks. Utilizing interaction analysis methods, Marin studied talk-in-interactions (in forest walks), demonstrating how talk and sense making are linked with corporeal arrangements[2]. In the present study, I build with this work to examine how observations mediate sense making, and more specifically how place (or land) figures into this sense making. Following the lines of Marin and Bang (2018), this paper understands land is not a fixed entity but is a relevant semiotic field in meaning-making (Pugh et al., 2019).

Salmon Walks

Recent research on informal learning settings highlight family discourse practices as rich sources of knowledge development (Callanan et al., 2012). Within parent-child conversations, the epistemological standpoints that parents hold regarding science, or science-related concepts, can

[2] Corporeal arrangements refer to body positionings in relation to other people or focal object. See also Kendon (1990).

impact how children make sense of the natural world (Callanan et al., 2012; Luce, Callanan, and Smilovic, 2013; Goodwin, 2007).

Walks generally followed the creek in which salmon were running. However, some families went up a trail that traversed the south end of a ravine, leaving the creek and heading farther into the forest. Other families continued along the creek, past the point where salmon were running, although these families did not realize the salmon had turned up another stream. There were 7 walks in total over the course of two Saturdays, and video recordings of these walks ranged from 5 minutes to nearly 1 hour and 6 minutes, with an average of 40m42s. One video was not usable because of participants' unfamiliarity with the GoPro, and thus wanting to end the walk.

The Salmon Days volunteer program was taking place at the park. Volunteer Salmon guides had a tent set up with information about salmon, including local salmon run numbers, salmon life cycle displays, and information about the park. Volunteers were also stationed at viewing points along the creek, and twice a day offered guided salmon walks (none of the families in this study participated in the guided walks while wearing cameras, and none reported doing it earlier).

ISTEAM Walks

In this context, I explore the talk and interaction during walks with adults and youth. The youth in this study range in age from nine to thirteen. Many of the youth were returning to the camp for the second, third, or fourth time; a few were attending their first ISTEAM camp.

Walking was a key pedagogical component of the ISTEAM because it is a deeply cultural practice tied to Indigenous Ways of Knowing (Marin and Bang, 2018; Cajete, 2000). Walking was recognized as an activity for knowledge making. Ingold (2011) refers to this type of

movement as *wayfaring*, in which the "concern is to seek a way through" rather than arrive at an end destination. Walks served different purposes depending on the day, location, and activity, and I characterized camp walks based on how they were designed and thus labeled them in one of two categories: designed walks and destination walks. Designed walks consisted of an organizing theme, such as *plant relatives,* and children and adults walked in small groups. Destination walks encompassed general movement from point A to point B, such as a few children and adults walking to the bathrooms. I take up the former, designed walks, in my analysis.

Within designed walks, there were further distinctions based on purpose and/or intention. Many of these walks fell under a general category of "plant relatives", and subsequently were further specified by domain - such as "math walks". All walks, although with starting and endpoints in mind, were pedagogically designed *as a learning activity*. I selected *Plant Relative* walks on two days of the camp, Day 2 and Day 4 to provide consistency in the walk goals. Within this data corpus, I chose walks that included both adults and children in order to examine the interplay of intergenerational interactions and place. I also chose walks that were in forested ecosystems. There were five designed (intentional) walks, and I analyzed four. One set of walks on day 1 was not considered because in one case the video was disjointed (a child wearing the GoPro separated from group to run to the bathroom) and in another the footage took place on the beach. I also did not analyze whole group activities that were sedentary. In the data corpus in this study, there was 9 hours and 3 minutes of video, with an average video length of 23 minutes and 27 seconds.

Findings are presented in the form of two sub-studies to explore the interactional constellations of spatial indexing, or observations that attend to phenomena on multiple spatial, temporal, and/or relational scales.

Study 1: Initiating Epistemic Actions

I coded for initiating epistemic actions to study the ways in which people initially oriented to land (or not) when talking about ecological systems. In the first round of coding I marked whether the initial substrate, or *initiating epistemic action* (IEA) stemmed from place or was abstracted. More specifically, I noted whether the IEAs were *place emergent, place speculative, tool-based,* or *place extracted* (Table 3). Identifying these four epistemic actions came about in two ways. One, in line with prior research in observations and attention I was interested in how land, as a semiotic actor, was positioned in sense making about ecological phenomena (Marin and Bang, 2018). Initially, I developed codes for *place emergent* (observations), and *place extracted* to dichotomize possible epistemic activities. That is, I wanted to know if participants were observing phenomena in the local environment (such as a plant, animal, landscape, waterway, etc.), or if they were talking about phenomena that was either extracted from place (e.g. holding a berry or leaf that is removed from where it was found, and in a transformed context). After second pass through video and transcript data, I identified two other opening epistemic actions that were also abstracted but relevant to the local place. Epistemic actions that considered place, such as anticipating what would be seen or recalling a past event were coded as *place speculative*; when attention was focused on, or stemmed from, *tools* (physical tools, such plant information cards, maps, etc.) I coded as *tool*. Attending to epistemic actions along these four parameters allowed me to first make visible the substrates from which constellations of activity emerge in sense making (Hall and Stevens, 2016).

Table 3-1. Initiating Epistemic Actions

Epistemic Actor	***Epistemic Action (substrate)***	***Definition***	***Example***
Child	Place Emergent	Observation that is located in or emergent from place; something in the sensory or perceptual field that is in the surrounding environment	*"Hey, it's a little mossy tree"*
Adult	Place speculative	Anticipating what was or will be seen (or perceived) during walk (not in present moment)	*"Next time we see salmonberry just make sure we stop"*
	Tool	Reference to a material tool (such as *plant relative* information card) or ideal tool (pedagogical maneuvers)	*Material: "what is your plant relative [on card] that you are looking for?" Symbolic: "Remember the story Leroy [storyteller] told us about Cedar?"*
	Place Extracted	Abstracted phenomena that is not located in place, either in the present moment or anticipatorily	*"[holding a grape in hand] this Oregon grape is super sour"*

Within this first round of coding I also attended to which participants, adult or child, opened the epistemic sequence, what I call *initiating epistemic actors* (IAs).

I hypothesized that place driven observations would account for more initiating epistemic actions; that is, that place would drive most of the emergent conversation and sense making on the trail. This is in part because, regardless of the complexity of sense making that unfolds (which I explore in Paper 2), novices – that is children or non-expert adults in biological or ecological science fields – tend to focus on salient features in the environment (Eberbach and Crowley, 2009; Hmelo-Silver, 2004). In this vein, I also hypothesized that due to observations being a foundational practice in Native Science, there would be a greater number of both place emergent and place speculative epistemic actions for ISTEAM than for Salmon Walks. I also anticipated that adults would account for more initiating epistemic actions, based on prior

research that has showed adults (such as parents or teachers), are more likely to guide observations or knowledge development (e.g. Eberbach and Crowley, 2009; Luce et al., 2013; Zimmerman, Reeve, and Bell, 2010).

Results

There were a total of 364 initiating epistemic actions (IEAs), or semiotic episodes, across both walk groups. There were 203 IEAs in the ISTEAM walks and 161 in the Salmon Family walks.

Initiating Actors. Initiating epistemic actors were coded based on who opened a semiotic episode. Results showed that in Salmon Walks adults accounted for slightly more than half of the initiating epistemic actions (56.5%), and for ISTEAM children initiated more than half of the opening epistemic actions (56.1%) (Figure 4-1). Semiotic episodes in which the initiating epistemic actor was both an adult and child (instances in which it was indistinguishable) accounted for less than 10% of the IEAs for each group.

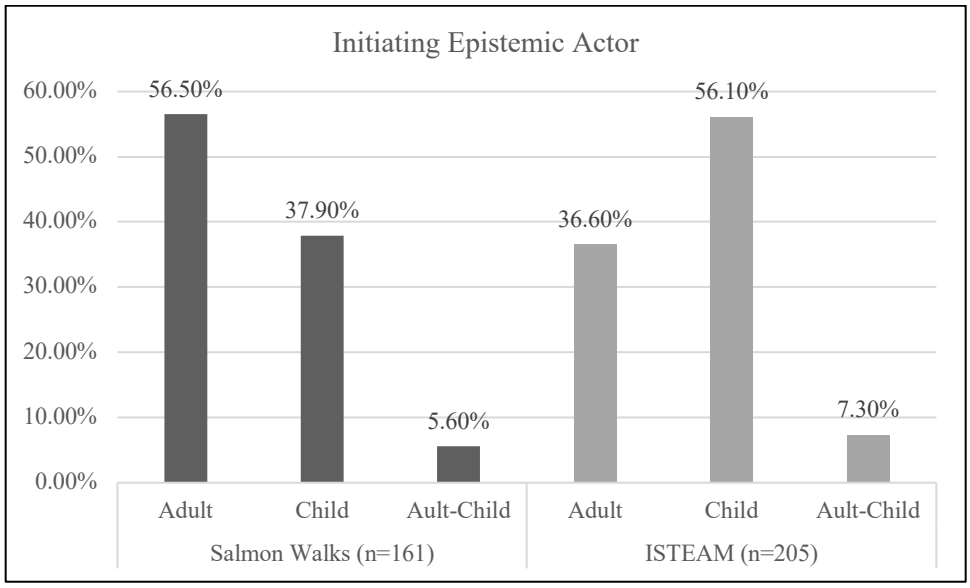


Figure 3-1 Percentage of Initiating Epistemic Actor

The differences in these contexts could be explained by both context and culture. Contextually, the ISTEAM walks consisted of groups of adults and children, with a ratio of

about 1:4 (adult to child) ratio on a given walk. This being the case, children likely had more opportunities to talk and to share observations. The Salmon Walks were typically 1:1 adult to child ratio, with either one parent and one child or two parents and two children. This group configuration is thought to be typical for many U.S. middle class families, whereas intergenerational and collaborative arrangements have been attributed to many indigenous-heritage communities (Mejía-Arauz, Rogoff, Dexter, and Najafi, 2007). In addition, research on parent-child dyads has shown that adults play a significant role in scaffolding epistemologies in children (Luce et al., 2013). Building on this, adult-driven interactions, as in initiating substrates within semiotic episodes, would likely drive much of the sense making for the predominantly European-American families that participated in Salmon Walks. On the other hand, for the participants in the Indigenous STEAM camp, the greater presence of child-initiated substrates suggest that the collaborative, intergenerational social organization of youth and adults made space for children to share observations.

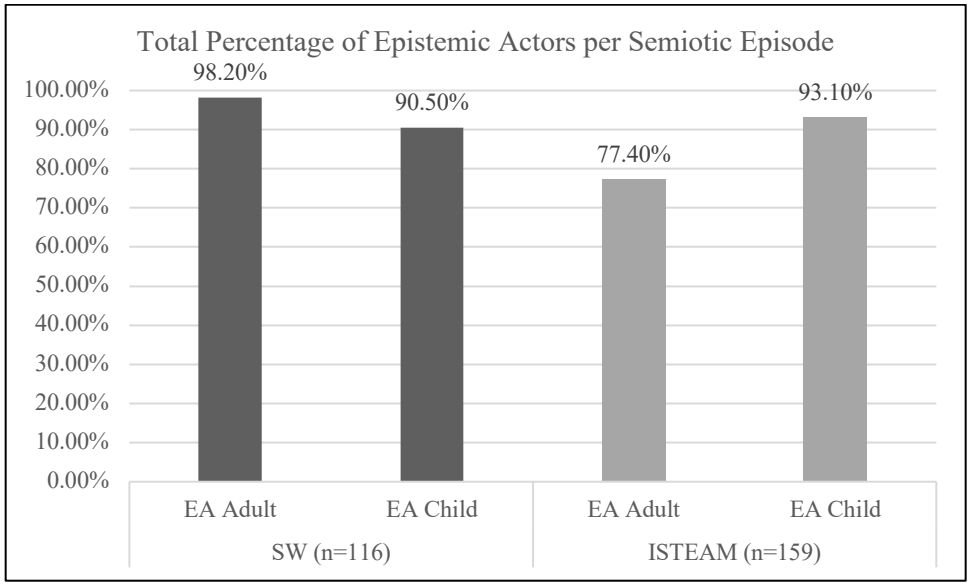


Figure 3-2 Percentage of Epistemic Actors within Semiotic Episodes

Although there was a higher rate of adult-initiated epistemic actions in the Salmon Walks, and child-driven EAs in the ISTEAM walks, these account for just over half of the IEAs. Across both contexts it is evident that one group (either adult or child) does not dominate all talk. These findings suggest that walking in ecologically-rich settings afforded opportunities for both adult and child-driven sense making. This is evident when we look broadly at who was contributing to semiotic episodes (Figure 4-2); both adult and children most of the semiotic episodes.

Initiating Epistemic Actions. Place was the most common substrate during the Salmon and ISTEAM walks, demonstrating that participants organized sense making around place-emergent observations. Results showed similar trends across both data sets in terms of initiating and subsequent epistemic actions (Figure 3). In both contexts, place-emergent epistemic actions accounted for the most initiating epistemic actions (SW=62.7% and ISTEAM=66.8%). Speculative epistemic actions, those that were anticipatory or reflective about place, accounted for nearly one third of IEAS (29.8% for Salmon Walks, and 22.9% for ISTEAM), followed by Tool-initiated substrates (18.6% for Salmon Walks, and 15.1% for ISTEAM), and then place extracted (3.7% for Salmon Walks, and 9.8% for ISTEAM). Additionally, there were IEAs in which the initiating epistemic action was indistinguishable, and I coded these as “multiple” and these accounted for 10% of IEAs for both walks.

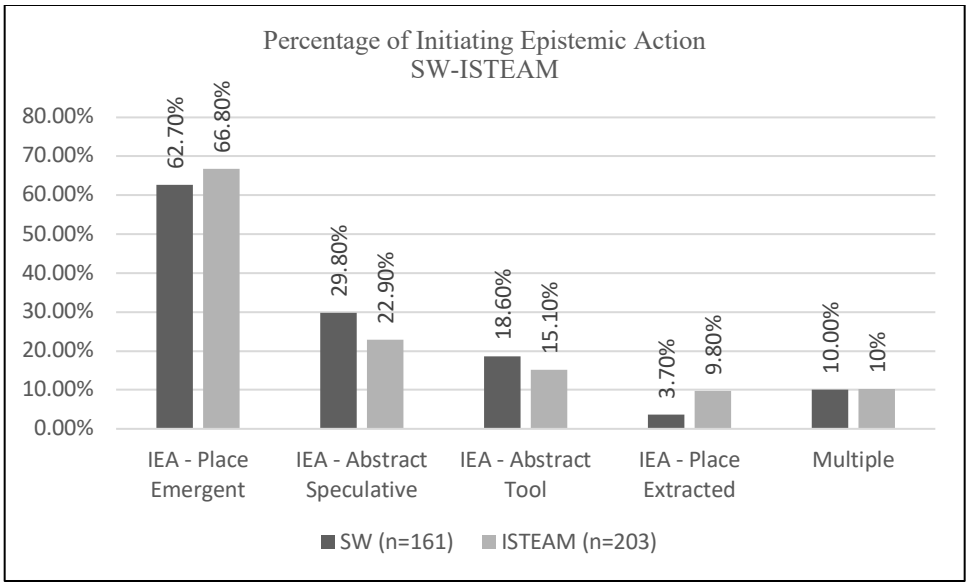


Figure 3-3 Percentage of Initiating Epistemic Action

In other words, emplaced observations were the most common initial substrate from which attention and sense making emerged for both contexts.

The large difference between place emergent and the rest of the IEAs show that attending to place, as an indexical operation, was foundational in semiotic episodes across both contexts; in other words, place drove epistemic action. This result is important because it demonstrates that when learning occurs in outdoor places, the natural world is not only central to sense making, but thought emerges from place. This overall finding is especially important to consider when thinking about the structure of education systems, particularly science education. The implication is that when these systems do not engage learning in places that is outside of the classroom, it shapes thinking and sensemaking in significant ways. For instance, as science instruction increasingly takes place in enclosed, technologically-saturated settings (e.g. in school buildings), where place (or land) has been either wholly absent or rendered static, the subject of study

becomes decontextualized (Bang and Medin, 2010). This has led to a "deterioration in common-sense understanding of the everyday living world" (Atran, Medin, and Ross, 2004; p. 402).

Conclusion

While there were cultural differences in who opened the semiotic field, initiating actions broadly looked similar across both the ISTEAM and the Salmon Walks contexts. These findings reflect two different yet interrelated points. First, children were more likely to initiate sense making during emplaced observations during forest walks in the ISTEAM context. Second, place drives epistemic action when people are outside. This was made visible in moments of spatial indexing, that is when participants were engaged in place-driven sense making about ecological phenomena.

Study 2: Characterizing the form and function of initiating epistemic actions

Study 1 revealed that initiating epistemic actions were placed. This led me to want to understand how the initiating epistemic action may have shaped subsequent epistemic actions. This analysis characterized the form and function of initiating epistemic actions to explore whether and how place, via observations, was taken up in in the sense making that emerged from that IEA. This was accomplished first by coding the initiating epistemic actions (presented in the study above), and then the subsequent talk that emerged. Goodwin (2018) describes the role of subsequent action as a mechanism for change in co-operative action; he says "…not only does subsequent action include within its own organization materials created by predecessors, but it also transforms those materials in the ways required for adaptation to current circumstances" (p. 7). When studying talk in sense making, these materials included various combinations of semiotic mediums that when considered together, form what Goodwin calls a "lamination – a set of layers

organized with reference to each other [that] provides a simple and vivid way to look clearly at how a variety of semiotic fields with quite different properties work co-operatively with each other simultaneously to build evanescent actions" (p. 123). I argue that this framework can also be applied to understand the epistemic orientations that participants enact in mobility, and thus provide a lens to study how learning happens in the outdoors.

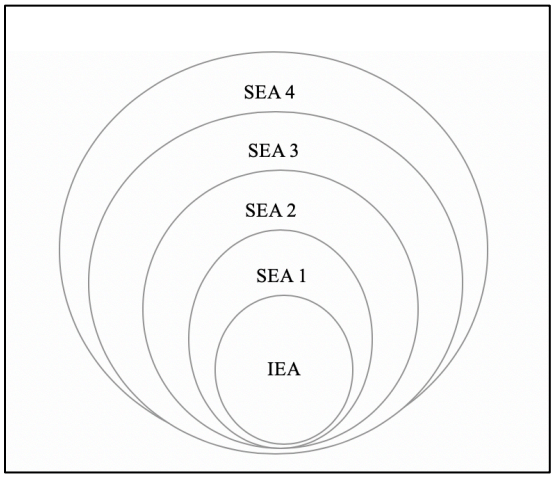


Figure 3-4 Initiating and Subsequent Epistemic Actions

In order to understand the role of place in sense making about ecological systems, I examined the relationship between initiating and subsequent epistemic actions (Figure 4). An initiating epistemic action marked the beginning of a semiotic field (Goodwin, 2018), or a sequence of talk-in-interactions. Once an initiating epistemic action was coded, the talk that ensued was bounded into a semiotic episode; the duration of a semiotic episode was marked by uninterrupted talk about the focal phenomenon. Within this semiotic episode, I then coded for the layers of interactions that unfolded within that episode[3]. For each initiating epistemic action (IEA), there were anywhere from zero to four subsequent epistemic actions (SEA). Sometimes there were no

[3] While this analysis focused on the unfolding interactions within each bounded semiotic episode, I recognize that semiotic episodes could also be distributed across place and time in interrupted sequences. This different analytic lens is not considered in this study, but could be examined in future studies.

subsequent observations or attentional directives after an IEA and sense making was tied to only one substrate. Other times the IEA led to a series of place-emergent or place speculative orientations (or a combination of both). In this study, I was particularly interested in the nature of this relationship, and wanted to discern patterns of relationships between an IEA and SEA in both the epistemological form and the function.

Findings are presented along the four substrates, or initiating epistemic actions (place emergent, place speculative, tool-driven, and place extracted). I calculated the percentage of each subsequent action *per* initiating action. For instance, for every semiotic episode that was initiated by a place emergent observation (IEA Place Emergent), I calculated the percentage of subsequent epistemic actions that were emplaced, speculative, tool-driven, or extracted; I then did this for all four IEAs. It is important to note that there were times in which the IEA was entangled between two substrates, such as a tool and place; in these instances, I coded both as an IEA. This occurred a total of 37 times out of the 364 total semiotic episodes across both groups (Appendix B).

Based on research that had demonstrated cultural variation in observations (Correa-Chavez and Rogoff, 2009; Rogoff, 2014), I anticipated there would be differences in the likelihood of subsequent epistemic actions between the Salmon Walks and ISTEAM walks. More specifically, thinking with the literature on Native Science practices (e.g. Brayboy and Castagno, 2008; Cajete. 1999), I anticipated more place emergent subsequent epistemic actions across the board.

Results

IEA – Place Emergence.

I coded an initiating epistemic action as place emergent when a participant observed something the surrounding environment. I hypothesized that place emergent semiotic episodes would be more likely to stay emplaced in the ISTEAM walks than the Salmon Walks. This is in part because social structures and cultural practices mediate knowledge organizing mechanisms (Gutiérrez and Rogoff, 2003), and attentional practices (Nisbett, Peng, Choi, and Norenzayan, 2001; Rogoff, 2014). Whether or not participants continued to orient to place in subsequent epistemic actions could therefore culturally-variant practices. I also hypothesized that children would be more likely to initiate place emergent IEAs than adults in ISTEAM, and the reverse would be true for Salmon Walks. Following the same line of reasoning as in study 1, dyad dynamics in the predominantly European-American context would lead to more adult-led observations, whereas the ISTEAM would be more collaborative.

Initiating Actors. There were differences across the two cultural groups regarding who opened the place emergent initiating sequence (Figure 5). Children in both walk groups were more likely to initiate the epistemic action, although both adults and children initiated place emergent IEAs in both contexts. In the Salmon Walks, adults and children were about equally as likely to open a semiotic episode with an emplaced observation. This in part could be attributed to context, the dynamic and exciting nature of the salmon run led to sense making that was emergent and piqued the interest of both adult and children. During the salmon run, salmon are swimming upstream and negotiating both territory and mating privileges; likewise, many of the place emergent observations attended to these behaviors. Furthermore, witnessing the salmon run was novel for many of the families in this study, particularly for the adults. At the same time, many of the children had learned about salmon in their classroom through a salmon-focused curriculum that was prevalent in many schools in the city. Thus, both the excitement of activity

and the distribution of domain knowledge (e.g. Eberbach and Crowley, 2009) account for both adult- and child-driven observations.

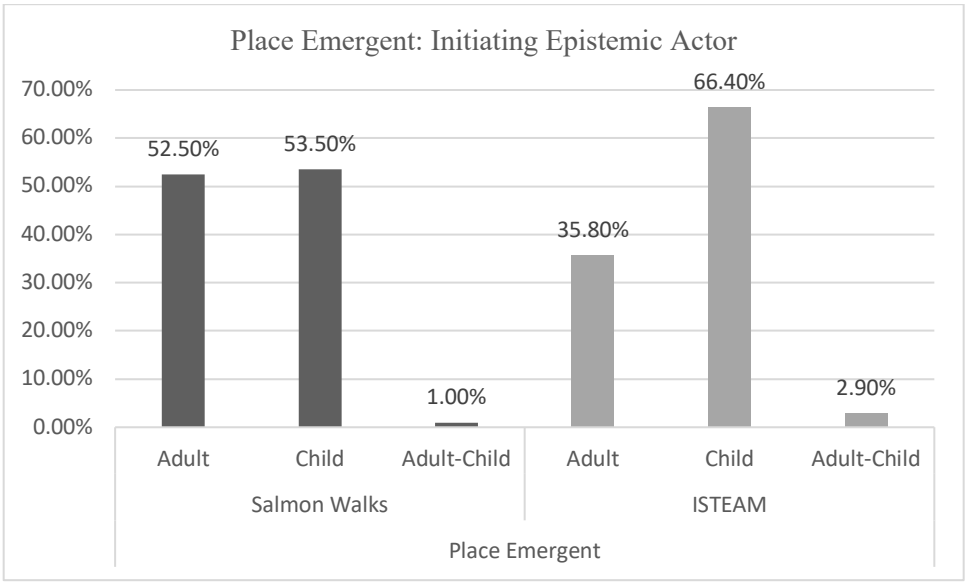


Figure 3-5 *Place Emergent IEA*

Child-initiated observations were more likely to open semiotic episodes in the ISTEAM context; just over 70% were child-initiated, compared with 39% initiated by adults. As discussed in study 1, this reflects both cultural and contextual differences in group organization and the value of collaborative learning processes (Mejía-Arauz et al., 2007). This manifested in a couple of ways. First, the contextual nature of this learning program allowed children to walk the trails in groups, with opportunities for interaction without an adult immediately in the vicinity. However, it is important to hold that semiotic episodes were bounded around talk about natural systems (biological and ecological phenomena). Thus, these findings demonstrate that children were not only more likely to draw joint attention to phenomena in the surrounding environment, but that these observations drove shared sense making.

Initiating and Subsequent Epistemic Actions. I calculated the percentage of subsequent epistemic actions, or laminations, that stemmed from place emergent observations. Each SEA

(SEA 2-4) was calculated based on the percentage from the previous SEA; SEA 1 was the percentage of epistemic actions based on the total amount of IEAs, SEA 2 was based on the total number from SEA 1, and so on. Results show that when the initiating epistemic action was place emergent, the subsequent epistemic actions were more likely to stay emplaced. Details discussed below.

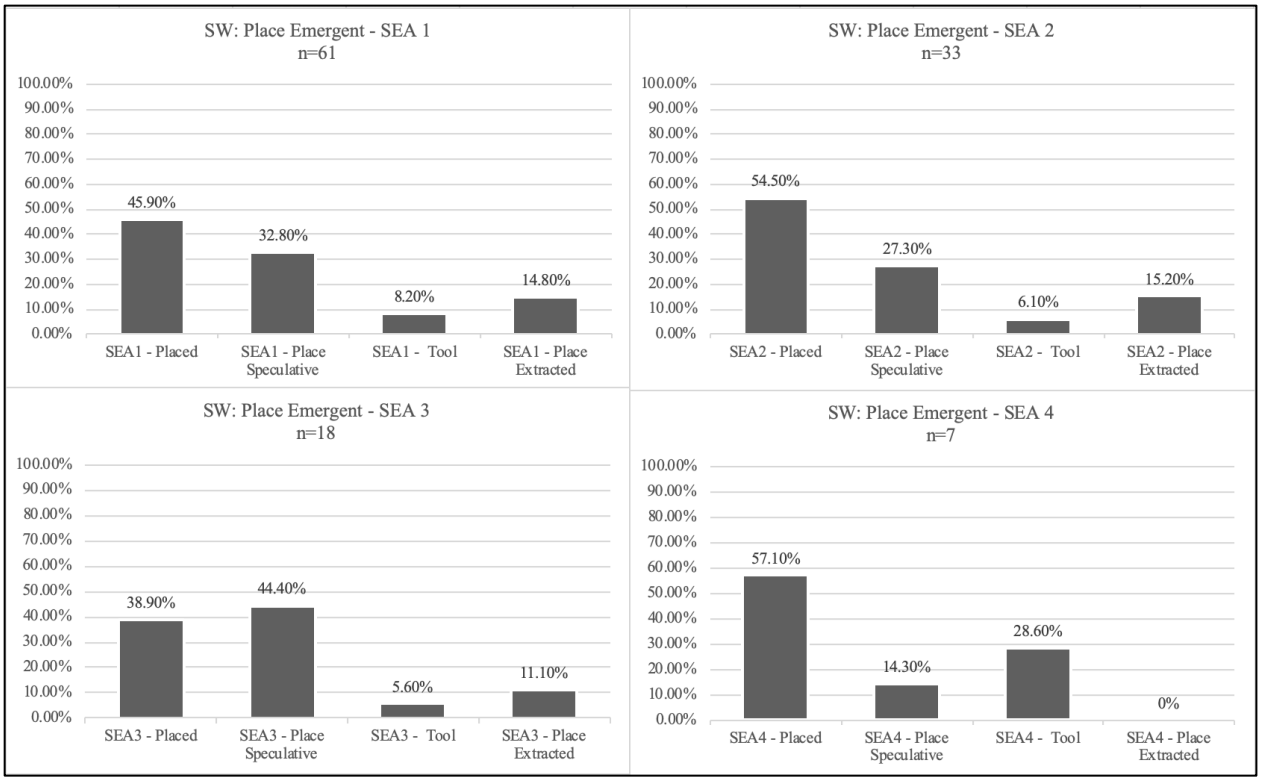


Figure 3-6 Percentage of Subsequent Epistemic Actions for Place Emergent IEA – Salmon Walks (n=101)

There was a similar trend in the Salmon walks for the first two subsequent epistemic actions (Figure 6). Laminations were emplaced for the first SEA (45.9%) and for the second SEA (54.5%). There was an increase in place speculative SEAs in the third lamination (44.4%, compared with 38.9% emplaced), but then an increased percentage of emplaced SEAs in the fourth lamination (57%). This increase in place speculative epistemic actions in SEAs typically signaled that after an emergent observation, participants were anticipating what they would see

next. This is demonstrated in the following excerpt in which Tommy (aged 7) and his family are watching the salmon make their way up stream. In this clip, Tommy's family is overlooking a large pool of water that sits at the convergence of two creeks: Cascading Creek (where the salmon had been spawning up as they made their way from the Puget Sound), and Swift Creek (where the salmon are supposed to turn up because they were imprinted in that creek). The rest of Cascading Creek is blocked off by a culvert (pipe that directs the flow of water underground), so while water is still flowing, salmon cannot get up there.

Excerpt 1 Place Emergent IEA: Salmon Walks

1	Tommy:	There's tons of salmon over here. [looking down	***Place Emergent***
2		into water pooled by culvert] Look! Look!	
3	Mom:	What do you see?	
4	Tommy:	Salmon holes - holes for tiny salmon. And their	
5		predators can also be racoons!	
6	Mom:	They're tryin to get out of there!	
7	Ayla:	Why - what is that?	
8	Mom:	They're tryin to get back to where they're born	***SEA 1-***
9		they can smell their land but they gotta go =	***Speculative Abstract***
10	Ayla:	= poor them	
11	Tommy:	And there's pipes blocking their - blocking - But	***SEA 2 - Placed***
12		they could go over there [pointing] but a big - !!	
13	Mom:	They're supposed to go that way. I think they're	
14		confused. They're supposed to go [pointing up	
15		Swift Creek] =	
16	Tommy:	[…] Daddy, does she know? See that, see that	***SEA - Placed***
17		pipe? [pointing] They can't get through it but	
18		there is an opening they can get through but even	
19		bigger salmon that's taking a rest is blocking it.	

In this excerpt, Tommy is the initiator and calls over his family to look at the salmon in the deep pool (Excerpt 1). Observing phenomena in the immediate environment serves as the substrate for the ensuing epistemic activity, and we see the participants toggling between observing the behaviors of the salmon directly, anticipating where the salmon will go and what they will do (lines 8-9, 13-15), and then more emplaced observations. Their prior knowledge about where the

salmon are supposed to go, “back to where they’re born” (Mom, line 8) is a form of domain knowledge that scaffolds their attention to the possible next moves by the salmon. While this demonstrates how domain knowledge can scaffold attention (e.g. Eberbach and Crowley, 2009) it is evident that place itself is also a critical part of the constellations of interaction – it serves as a substrate that both opens and carries through in the semiotic episode. Additionally, this shared substrate allows for a form of spatial indexing that is both distributed across family members, and toggles across spatial and temporal scales.

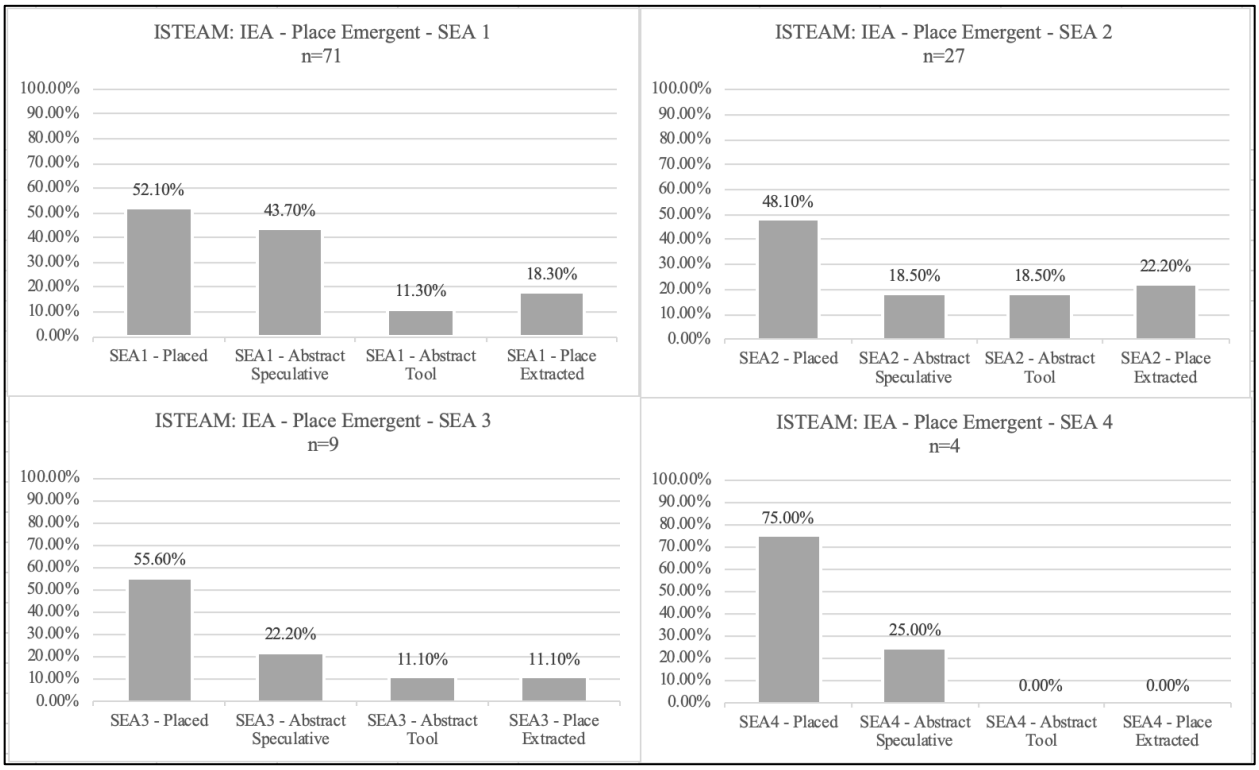


Figure 3-7 Percentage of Subsequent Epistemic Action for Place Emergent IEA – ISTEAM (n=137)

For the ISTEAM context, Native participants were generally more likely to attend to place than any other epistemic action across all four SEAs (Figure 7). More specifically, when place emergent observations were the initiating epistemic action, 52% of the first subsequent epistemic

actions were emplaced, 43.7% were place speculative, 11.3% referenced a tool, and 18.3% referenced place extracted phenomena. By the fourth subsequent epistemic action 75% of the laminations were emplaced. These results show that youth and adults continually re-oriented to place during talk about ecological or biological phenomena. When place was the initial substrate, place was more likely to stay in focus in subsequent laminations. This suggests that the Native participants in ISTEAM were more likely to hold land as a relevant semiotic resource across all four subsequent epistemic action, which suggests a psychological closeness to nature (Medin and Bang, 2014b).

However, in SEA1 place speculative laminations were also very likely, suggesting that initial emplaced observations led to speculations about what the participants were likely to see or why the phenomena was happening in this place. As discussed above, this orientation reflects a toggling between the localized observations and temporal or spatial variability. For example, in the following excerpt, one of the youths in the ISTEAM camp notices salmonberry on the side of the trail, which prompts him to continue to look for the plant.

Excerpt 2 Place Emergent IEA: ISTEAM

1	River:	Wait, is that salmonberry right there?	***IEA – Place Emergent***
2		[pointing along trail] Right there. I	
3		think that's salmonberry, right there	
4		and right there.	
5	Luka:	Oh yeah, it is.	
6	Sani:	Where is salmonberry?	
7	Luka:	Oh that’s not salmonberry.	
8	Sani:	Butterfly leaves [touching plant]	
9	Luka:	Oh, yeah, it does.	
10	River:	I see maple leafs over here- There	***SEA 2 – Place Emergent***
11		might be salmonberries. [walking	***SEA 3 – Place speculative***
12		across bridge]	
13	Sani:	No, we're supposed to go over there.	
14	Speakers:	[crosstalk 00:05:06] Where's	
15		salmonberry?	
16	River:	Salmonberry over there too.	***SEA 4 – Place Emergent***

This semiotic episode opened with a child, River, noticing salmonberry on the side of the trail (Excerpt 2). The place emergent observation is the opening substrate upon which emplaced and speculative subsequent epistemic actions are laminated. In the first move after River notices salmonberry, he continues to look in the surrounding environment for more of the same plant. Sani, an instructor draws joint attention to the leaf structure of the plant in order to determine if it is in fact salmonberry. Sani is scaffolding attention to morphological features of the plant, using a mathematical concept as a heuristic for noticing plant structures and patterns in the forest, a common practice in biological sciences (e.g. Eberbach and Crowley, 2009). River continues to hold the initial substrate, the place emergent observation of salmonberry, in the next lamination; he turns away from the plant and sees "maple leafs" (line 10), speculating that he will therefore see salmonberry. In this interaction, River is demonstrating that he knows salmonberry and maples in part by their relationship with one another, they cohabitate. This way of knowing is indicative of a relational epistemologies framework (Bang et al., 2015; Pugh et al., 2019) that manifests both in his understanding of plants, as well as in the way he orients to place. Relational epistemologies has been associated with Native science practices and ways of knowing, was embedded in the instructional and artifact design of the camp. River, who had been coming to the camp since it started in 2014, was not only familiar with this particular orientation because of experience, but also had been attuned to it from the beginning.

In summary, these two excerpts demonstrate the ways in which place, as an initial substrate, carry through in semiotic episodes. In both contexts, the children and adults do not only talk about what they see, but engage in a form of reading the land (Marin and Bang, 2018) in which both spatial and temporal scales are entangled (Pugh, McGinty, and Bang, 2019). In the Salmon Walks excerpt, the speculative subsequent epistemic action attended to the behaviors of

the salmon and their likely destination. In the ISTEAM walk, the intent was for participants to come to know their plant relatives in relational ways. These findings suggest two things. First, place was central in scaffolding attention. Second, even when attention was scaffolded similarly across the two contexts, differences in epistemic orientations were visible in the way they attended to phenomena.

IEA – Place Speculation

This substrate was coded whenever the initiating semiotic substrate was anticipatory or rooted in idea about the place in which the participants were in. A key difference between speculative and place emergent substrates is that although participants still attuned to the surrounding environment, they did not attend to localized phenomena in the present. Rather they talked about the prior experiences, anticipated what would be observed, or speculated where something could be found. I hypothesized that ISTEAM would be more likely to have emplaced SEAs.

Initiating Actors. There were different trends across the Salmon Walks and ISTEAM contexts (Figure 8). In the SW program adults were far more likely to initiate and place speculative epistemic action than children (72.9% adult-initiated, 37.5% child-initiated). This substrate was reflective and anticipatory, thus scaffolding sense making across temporal and spatial scales. Following earlier lines of analysis, it follows suit then that parents would be doing this scaffolding in the dyadic context of Salmon Walks. There was a different trend for the ISTEAM participants. Although adults were slightly more likely to open a semiotic episode with a place speculative substrate (48.9%), children accounted for almost half of these IEAs (46.8%), suggesting a more collaborative and distributed orientation in sense making across temporal and spatial scales.

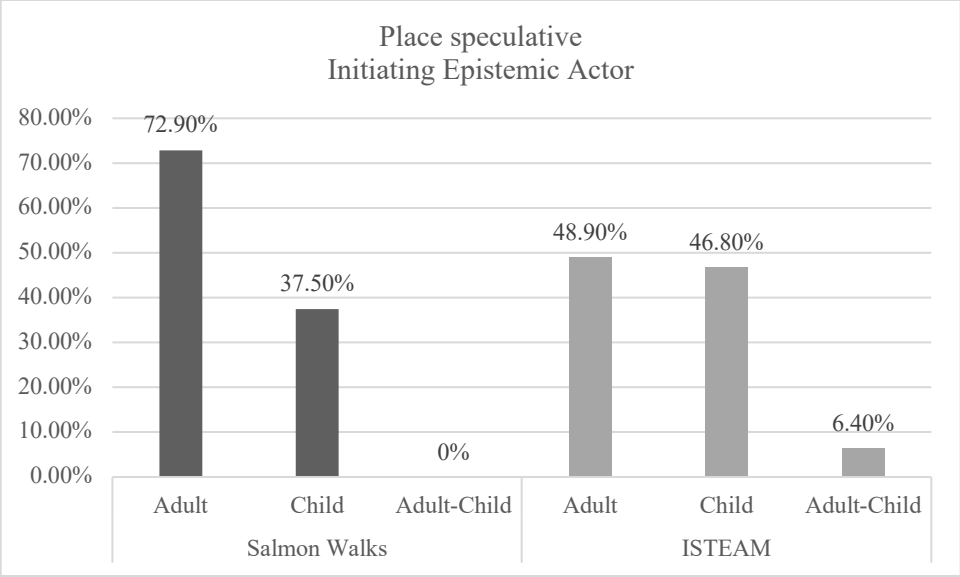


Figure 3-8 Place Speculative Initiating Actors

Initiating and Subsequent Epistemic Actions. Next, I analyzed the forms and percentages of subsequent epistemic actions that emerged from place speculative IEAs. When the initiating epistemic action was an abstract speculation about ecological phenomena, place was consistently attended to as a substrate in the first and second initiating substrates across both walk groups. That is, when an idea or speculation about place opened a semiotic episode, participants were likely to initially pivot to place. This trend holds true for ISTEAM across all four subsequent epistemic actions (Figure 10), and for three of the four SEAs for Salmon Walks (Figure 9). These findings demonstrate two things. First, even when place did not open a semiotic episode, participants were likely to reorient attention to land; land was consistently positioned as relevant in sense making. Second, as we saw in the place emergent IEA, the Native participants in ISTEAM were more likely to hold land as a relevant semiotic resource across all four subsequent epistemic action, which suggests a psychological closeness to nature that carried through even when sense making was initially abstracted (Medin and Bang, 2014a).

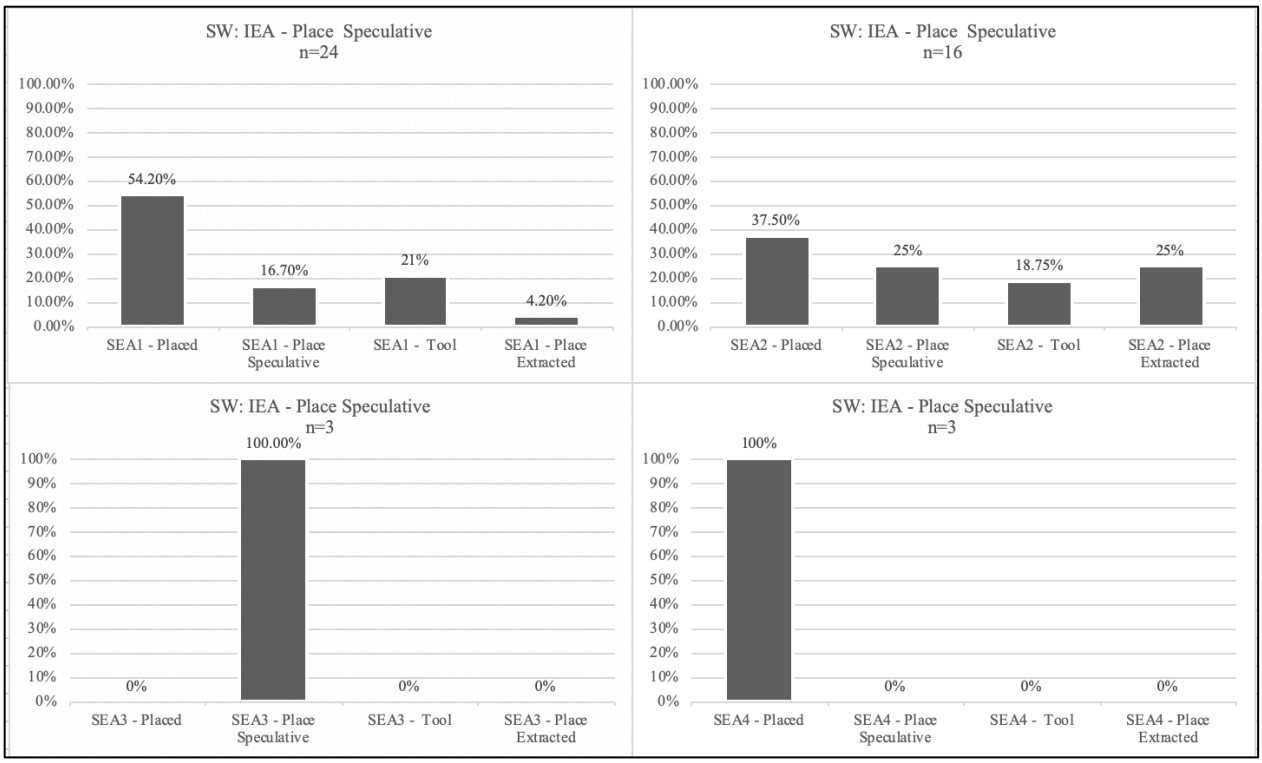


Figure 3-9 Place Speculative IEA – Salmon Walks (n=48)

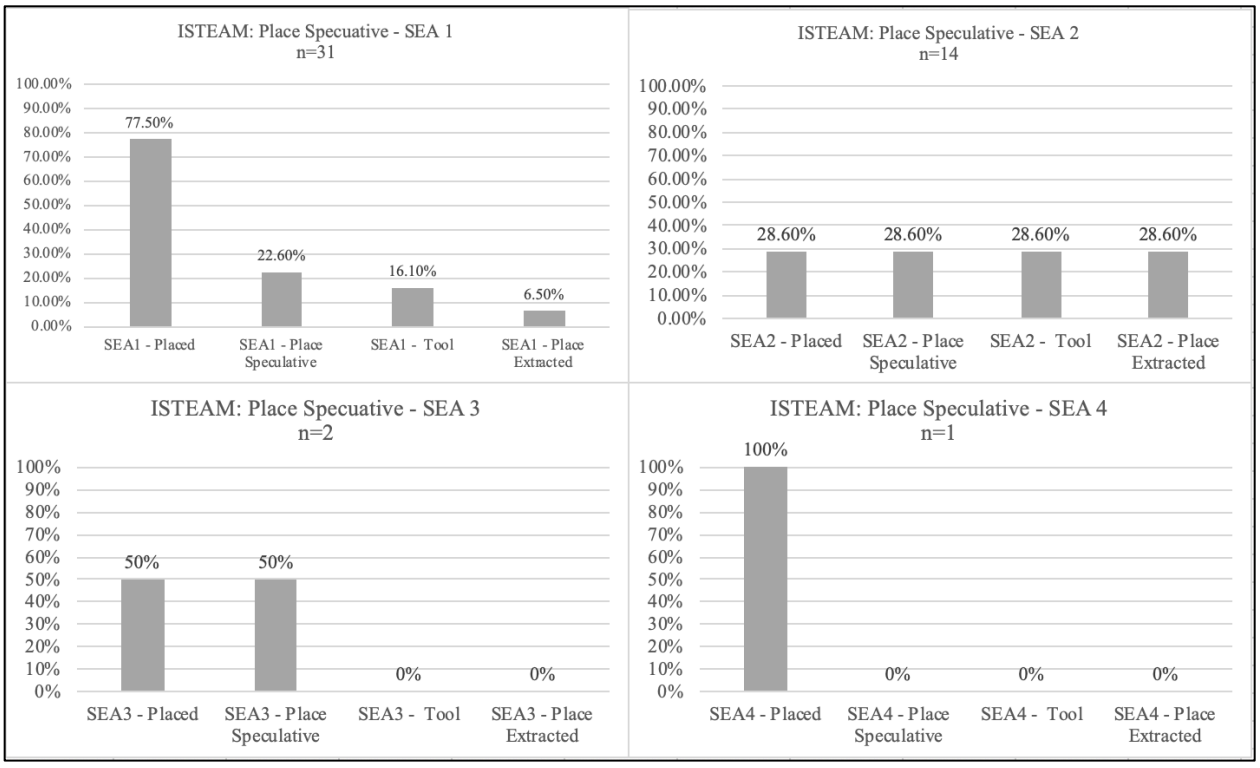


Figure 3-10 Place Speculative IEA – ISTEAM (n=47)

IEA - Tool

This substrate was coded whenever the opening semiotic substrate stemmed from a tool. Tools ranged from "plant relative" cards (plant ID cards; ISTEAM), Salmon Scavenger Hunt (Salmon Walks), to maps or trail markers[4]. The designed tools in both Salmon Walks and ISTEAM had different attentional prompts to place. For instance, in the Salmon Walks the prompts asked families to think about salmon life cycle or behavior in various stages of life or in different parts of the stream. The plant tools in ISTEAM were designed to scaffold relational and systems-level observations steeped in indigenous observing practices. I hypothesized that ISTEAM may be more likely to have both place emergent and place speculative SEAs.

Initiating Actors. Adults were more likely to initiate a tool-driven epistemic action than children (Figure 11). Results show that the percentage of an adult-driven IEA that stemmed from a tool is higher in the Salmon Walks (67.6%) than in ISTEAM (61.3%) although the difference was slight. However, the difference between children-driven IEAs that stemmed from tool is greater in the Salmon Walks (only 23.5% of children initiated this type of substrate) compared with the ISTEAM children (35.5%). There are a couple of possibilities for this. First, in thinking about material tools, each student in the ISTEAM context had a plant relative, and were each given a plant relative card. In the Salmon Walks, tools were often in the form of shared maps, trail signs, and a shared scavenger hunt sheet that was distributed at the Salmon Days volunteer tent. Tool-driven IEAs typically emerged in the form of wayfinding (Ingold, 2001), in which adults were often referring to a handheld map or the scavenger hunt. Similarly, adults in the ISTEAM context often referred to tools to guide students in finding and getting to know their plant relatives. Finding plant relatives was intentionally designed as a scaffold for many of the

[4] A deeper analysis of tools can be found in Paper 3: Mediational Constellations of Spatial Indexing

walks, and instructors would often ask about a child's plant relative, or scaffold attention based on instructional designs.

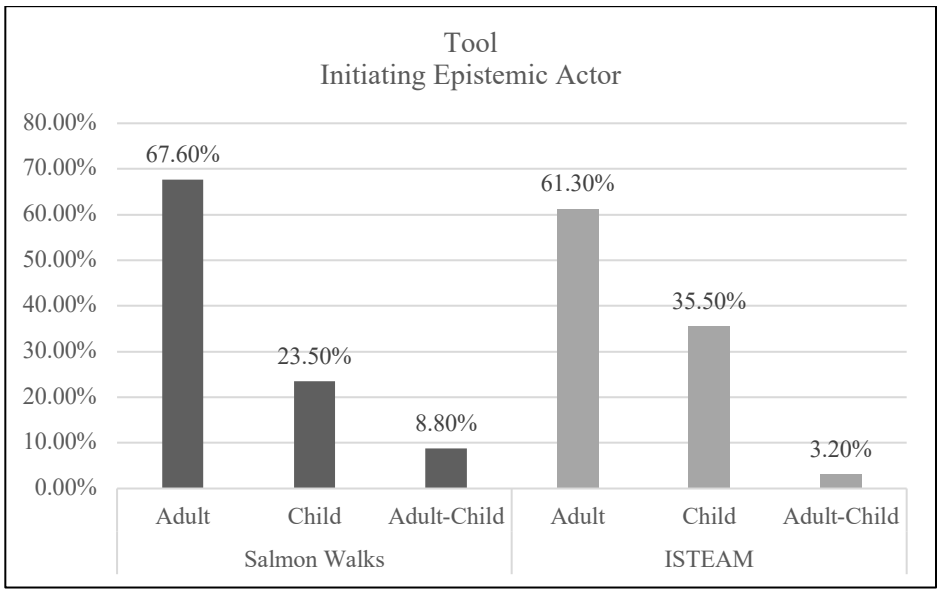


Figure 3-11 Tool – Initiating Actors

Initiating and Subsequent Epistemic Actions. A closer look at the SEAs reflect a difference between the two walk groups for a number of SEAs. For example, ISTEAM was much more likely to engage in an emplaced SEA 1 (Figure 13), while SW were more likely to engage in place speculative, tool-based, or place extractive SEAs (Figure 12). There are a couple likely reasons for this. For one, the ISTEAM plant relative cards explicitly scaffolded attention to place; detailed information about plant relationships, including co-habitants, role in the food web or human-plant relationships were provided on the card. In addition to this, instructors were prompted to scaffold attention to emplaced relations. Throughout the rest of the SEAs, we see a slight increase in likelihood for placed SEA2 in the SW walks, but then a robust difference for ISTEAM for emplaced SEAs in the third and fourth actions. Overall, ISTEAM participants were much more likely to attend to place after a tool prompted an opening epistemic sequence. SEAs

were generally for the Salmon Walks. This suggests that attentional design dramatically shaped epistemic activity.

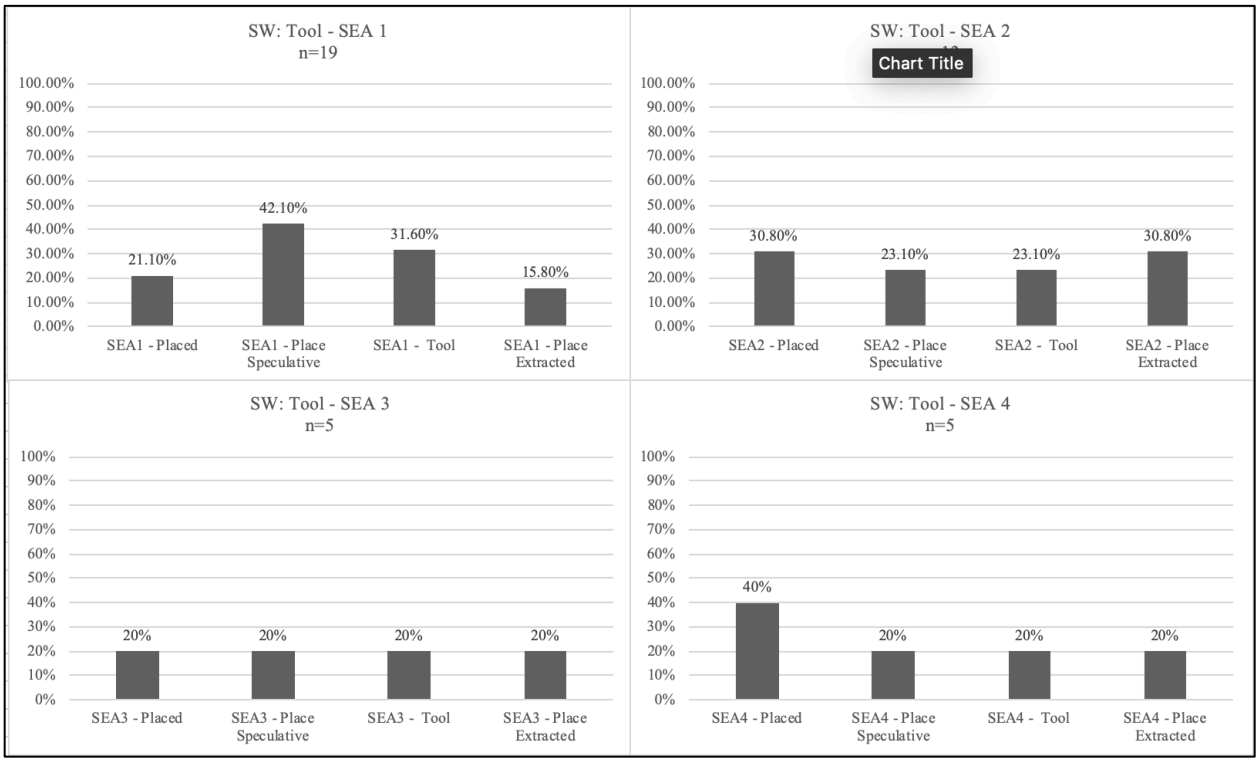


Figure 3-12 IEA Tool – Salmon Walks (n=30)

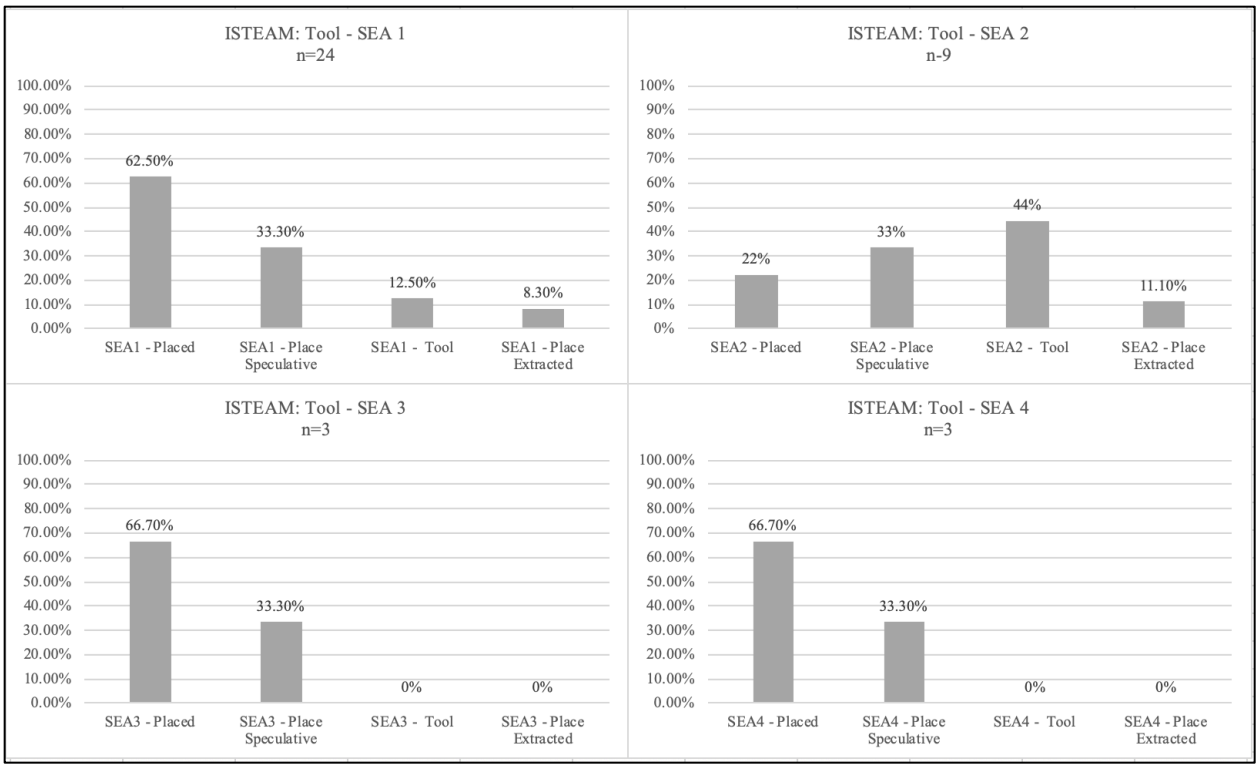


Figure 3-13 IEA Tool – ISTEAM (n=31)

IEA – Place Extractive

This initial substrate was coded whenever an opening epistemic action was not grounded in the surrounding environment, but rather focused on phenomena that was either not relevant to the local place or was extracted from the environment. This code was created to account for epistemic actions that were not based in observations, but instead attended to phenomena outside of the field of perception. I hypothesized that this form of epistemic action would look different across both groups. More specifically, while place extracted sense making is typical in many science classrooms, the ISTEAM camp was intentionally grounded in relational epistemologies and Native science. I therefore hypothesized that place extracted substrates would lead to a reorientation to place in the ISTEAM context, but not in the Salmon Walks.

Initiating Actor. There were differences between the two walk groups regarding the initiating actor of place extracted IEAs. Adults were more likely to initiate a place extractive substrate in the SW than in ISTEAM (50% adult-driven, 33% child-driven, and 17% adult and child combined) (Figure 14). Children in ISTEAM, on the other hand, were far more likely to initiate a place extractive IEA (85% child-driven and 15% adult-driven). A closer examination of how this manifested across the two contexts revealed critical differences in the epistemic orientation even within the code. For example, in the Salmon Walks, place extracted episodes were often about how the children were connecting what they saw in the park that day with phenomena that was not grounded in the local environment. Or, similarly, they were making connections to media or other activities that peripherally, or closely, related to what they were seeing. In a different vein, the place extracted IEA looked vastly different in the ISTEAM camp. There was a great deal of plant harvesting for eating and for medicine. For instance, some berries were in season (e.g. blackberries and Oregon grape) during the camp, and the children and adults would often pick a handful of berries and share with others.

How the place extracted substrate manifested signals different epistemic orientations to place. Adults and children in the Salmon Walks were more likely to discuss biological or ecological phenomena in ways that positioned the local environment as nearly absent, whereas the adults and children in the ISTEAM context were more likely to engage in sense making that was still place-bound.

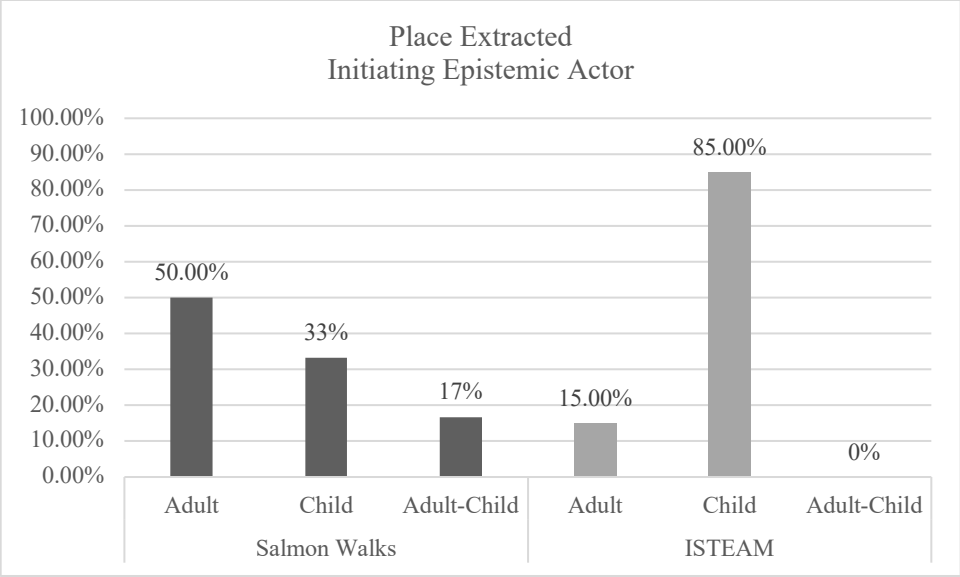


Figure 3-14 Place Extracted Initiating Actor

Initiating and Subsequent Epistemic Actions. A closer examination of the types of SEAs reveal interesting findings. If the initiating epistemic action was place extracted, then there were either no subsequent epistemic actions, or the SEAs were also place extractive (Figure 15). That is, if the initiating epistemic action was not grounded in place, participants likely did not reorient to place. These findings demonstrate a psychological distance from nature (Medin and Bang, 2014b). This was not the case for the ISTEAM program; findings show that there was greater variability in the type of SEAs that emerged (Figure 16). For the first three SEAs in ISTEAM, substrates were more likely to be grounded in place than anything else. For the fourth one, however, all of the EAs were place extractive. This shows that overall even IEAs that were not tied to place were still reconnected back to place in following epistemic actions. This attention to place suggests that land is still a relevant semiotic agent within the ISTEAM activity systems, and part of the constellations of practices through which participants were "reading the land" to make sense of phenomena (Marin and Bang, 2018).

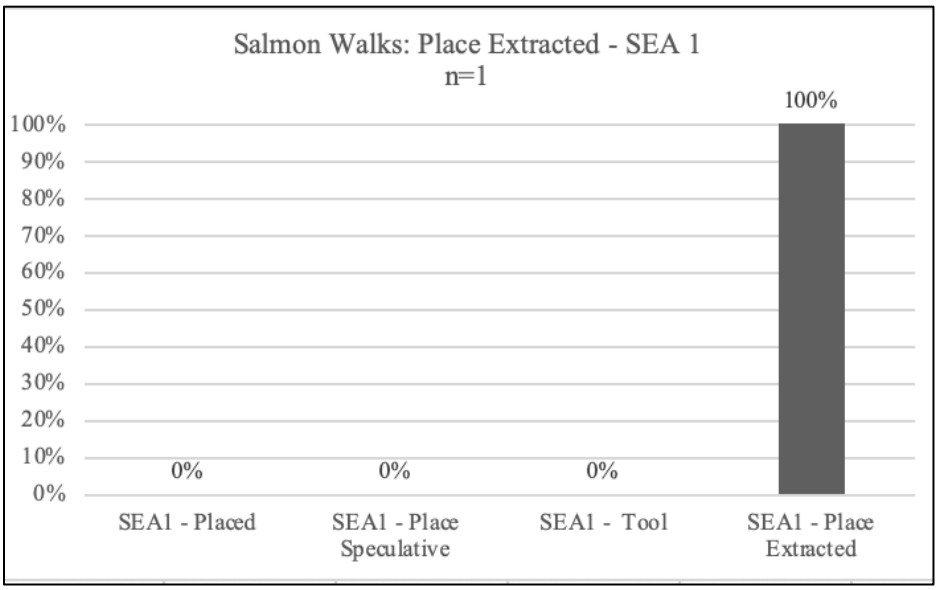


Figure 3-15 IEA Place Extracted – Salmon Walks (n=6)

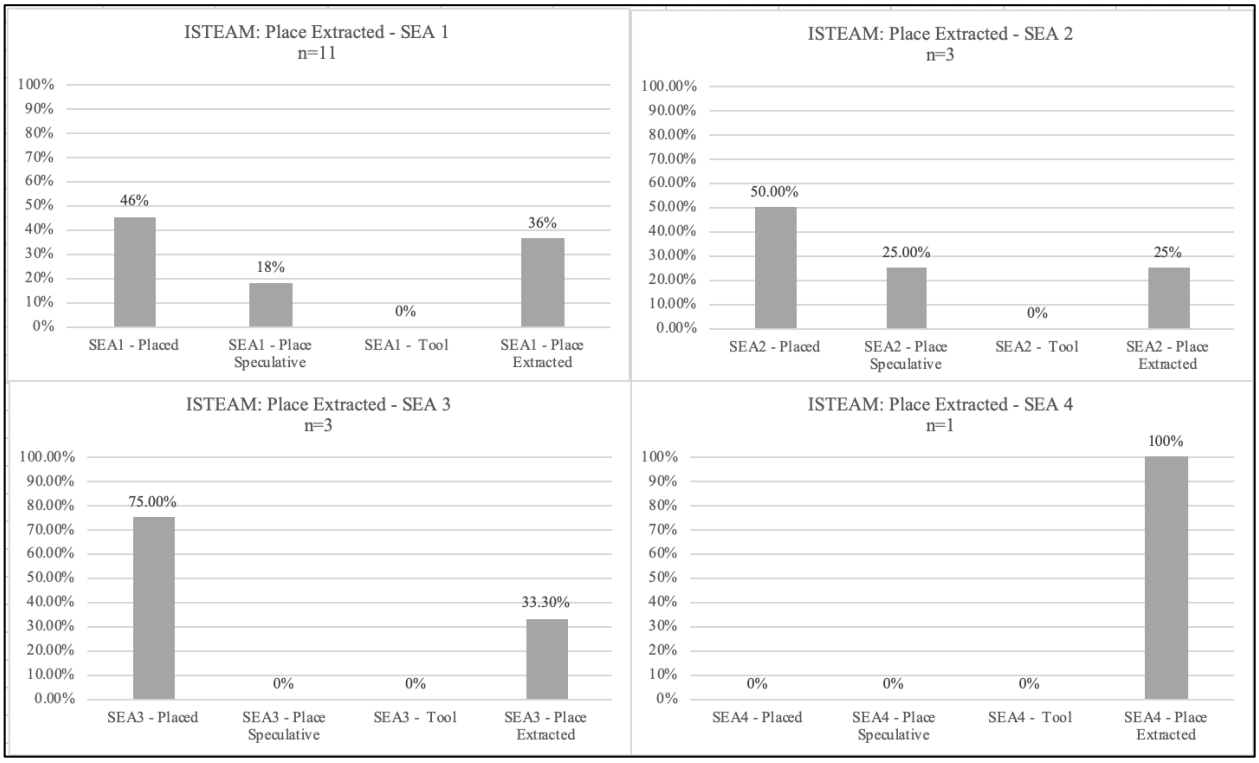


Figure 3-16 IEA Place Extracted – ISTEAM (n=20)

This is evident in the following example from ISTEAM, during which Alana (12 years old) is showing Mary (an elder) and Caden (10) some plantain that she found growing in gravel along the side of the trail.

Excerpt 3: ISTEAM Place Extracted

1	Alana:	Big huge thing of Plantain [holding plantain in hand].	***IEA - Place Extracted***
2	Mary:	Have you noticed there's a lot of that in the field where	***SEA 1 – Place***
3		we've been sitting? The field has got, pretty dry -	***speculative***
4	Alana:	And small.	
5	Mary:	Yes small and dry.	
6	Alana:	I found Plantain in the desert. Like-	
7	Caden:	What's Plantain?	
8	Alana:	This. [Shows Caden plantain in her hand] This is Plantain.	***SEA 2 – Place Extracted***
9	Caden:	Is it toxic?	
10	Alana:	No.	
11	Caden:	It sounds toxic.	
12	Alana:	It heals you.	
13	Dalia:	People can eat it.	
14	Caden:	It sounds toxic.	
15	Alana:	Not eat it but chew it.	
16	Dalia:	Can I chew some?	
17	Alana:	You can chew this and put it on ... It doesn't taste very well but you can put it on bug bites.	

In this excerpt (Excerpt 3), Alana is holding a plantain in her hand that she had picked earlier. This initiating epistemic action is marked as “place extracted”, because although there is shared attention on something, the natural kind that they are looking at has been removed from its habitat and thus disassociated from other relations (e.g. Goodwin, 2000; Latour, 1995). Alana shows Mary and a group of camp youth some plantain that she had picked from the trail. While this initial epistemic action is place extracted, in the next move (line 2), Mary, the camp elder, asks Alana if she remembers seeing the plantain in the big field that served as home base for the camp. This move re-places plantain in a habitat, and although it is not in the immediate perceptual field it layers place-specific and contextual information into the semiotic episode. Within this subsequent epistemic action, Mary adds contextual information about the field, that it is dry (line 3), and Alana layers morphological information that she noticed about plantain growing there (line 4) – namely that it was small – and an additional connection to a prior

experience in which she found plantain in a desert environment (line 6). Caden, returning to the plantain in Alana's hand, layers in another epistemic orientation by asking about the relationship between plantain and people (line 9), and Alana explains the healing properties of plantain and how to apply it to bug bites.

This semiotic episode depicts orientations to place and relationships that are not surprising given the extensive research on Indigenous knowledge organizing frameworks. Folk ecology and biology literature has suggested that cultural worldviews influence categorical organization of biological phenomena and relationships (Atran and Medin, 2008; Medin and Bang, 2014b). For example, research on knowledge organization about biological kinds has shown that, with levels of expertise being the same, Native American youth and adults are more likely to organize knowledge about the biological world along ecological relationships, while European Americans are more likely to reason taxonomically (Bailenson et al., 2002; Medin et al., 2006; ojalehto et al., 2015; Washinawatok et al., 2017). Bang and colleagues have attributed this difference to both implicit and explicit epistemologies, which shape how we reason about natural systems (Bang et al., 2007). In particular, relational epistemologies (Bang, 2015) is a "theory of knowing that recognizes all entities, human and more-than-human, as related and interconnected in mutually reciprocal, interactive, dynamic, and always-becoming relationships (Cajete 1999); this shapes the sources, scope, and validity of knowledge and knowledge making" (Pugh, McGinty, and Bang, 2019; p. 3). In the excerpt above, Alana, Dalia, Caden, and Mary come to know about plantain through its relationships: where plantain lives, plantain's relationship to people, people's relationship to plantain and bugs[5]. This epistemic orientation manifests in interactions that continually foreground placed relationships.

[5] A deeper exploration into knowledge organizing mechanisms is in Paper 2: Conceptual Constellations of Spatial Indexing.

A common form of place extracted semiotic episodes in the ISTEAM walks included bringing phenomena into focus for others to examine. This is exemplified in the excerpt above when Alana has plantain in her hand and shows it to the rest of the group (line 1, opening of the semiotic episode). This is similar to what Goodwin (1999) refers to as "socially organized vision [that] requires embodied manipulation of the environment being scrutinized" (p. 1515). This social organization, however, is culturally mediated, and the re-placing subsequent epistemic actions were more characteristic of the ISTEAM walks.

As mentioned above, Medin and colleagues have found that European American youth and adults are more likely to reason taxonomically about biological phenomena. This is evident in the following excerpt from Salmon Walks in Zac (aged 9) and his friend, Missy (aged 8) are walking together with their mothers, and unprompted, Missy asks about how salmon breathe (Excerpt 4).

Excerpt 4 Salmon Walks: Place Extracted

1	Missy:	And how come, how come salmon get the air out of	***IEA – Place Extracted***
2		water? But like they don't, um, [stops] but when they go	
3		out of the water they can't breathe? It's just a whole lot	
4		more of air. Like why- what's the problem with that?	
5	Zac:	Because they live- are in- because they breathe water in	
6		through their gills. And they can only get water in	
7		through their gills, but water is mixed with air, so it also	
8		brings in the air, which lets them breathe. And then they	
9		spit out the water, through their- through… I think that's	
		the reason… [trails off]	

Missy's question to Zac about how salmon breathe comes unprompted by tool, and there is no discernible link to earlier conversations. They are on a trail in the south bluff of the ravine, far from the creek and any of the salmon, and salmon are thus considered in an abstracted form. However, while not immediately visible in the perceptual field, Missy and Zac epistemically place (Montaño Nolan, 2016; Washinawatok et al., 2017) salmon in relation to both a body of

water and in the air. Place, in an abstracted form, is relevant as a semiotic resource in sense making about both the biological and ecological attributes of salmon. However, a key distinction between this excerpt and excerpt [3] from the ISTEAM context is that there is no re-orientation to place in either the immediate perceptual field or at the level of specific placing; water and air is also talked about in the abstract sense. This pattern was consistent across the Salmon Walk context, and in looking at findings showed that there were little to no subsequent epistemic actions when the initiating action was extracted in this way. These two excerpts reflect different knowledge organizing mechanisms that are present in how participants make sense about biological kinds.

Discussion

The studies in this paper present a detailed analysis of the form and function of observations in two different contexts. Using spatial indexing as a framework to attend to the connections between observations and sense making about ecological systems, I conducted a cross-cultural and cross-context analysis of forest and stream walks in the same urban, densely forested park. There are two big findings from this analysis. First, place played a critical role in shaping how people organized their interactions in ecologically-rich environments. More specifically, both youth and adults were more likely to engage in sense making that stemmed from observations of locally salient phenomena. Second, while there were similar trends in the interactional constellations between the two contexts, there were cultural differences in how observations were organized that imply a different orientation to place. That is, Native participants in the STEAM camp were more likely to attend to phenomena relationally than the participants in the Salmon Walks.

The Role of Place in Learning

The first big finding from this paper was that place played a critical role in shaping how youth and adults organized themselves while walking in ecologically rich environments. When talking about biological or ecological phenomena, participants in both contexts were more likely to engage in sense making and interactions that were emplaced. This was evident in both the initiating epistemic actions and in the subsequent epistemic actions. The difference between place emergent and the rest of the IEAs show that attending to place, as an indexical operation, was foundational in semiotic episodes across both contexts; in other words, place drove epistemic action. Additionally, emplaced observations were also highly prevalent as a subsequent epistemic action, meaning that youth and adults continually returned to place-specific phenomena within semiotic episodes.

This finding is particularly important for a number of reasons. First, it echoes the need for theoretical and analytical methods to take seriously the role of place in learning, or what Tuck and McKenzie (2015a, b) call a *critical place inquiry*. For instance, interaction analysis, as both an analytic and methodological framework, has often considered social interactions of or between people, and sometimes people with or within an environment. These social interactions are often inherently anthropocentric. In Scollon and Scollon's (2003) theory of geosemiotics, the role of indices center on human-created sign systems *in* the world. However, this study demonstrated that interactions have meaning beyond anthropocentric orientations. By focusing on interactions that accompany sense making about ecological or biological phenomena, it was evident that participants were thinking *with* the more-than-human world (e.g. Marin and Bang, 2018; Shotter, 2006) by continually orienting and reorienting to emplaced phenomena.

This finding also speaks to the nature of observations. There have been a number of studies that suggest that what we observe is based on domain knowledge and theory, and thus mediated by knowledge structures (Eberbach and Crowley, 2009; Eberbach and Crowley, 2012; Hmelo-Silver et al., 2014; Smith and Reiser, 2005). However, this study used an interactional lens to highlight how emplaced observations, as a culturally- and contextually-mediated practice, served as particular heuristics for sense making as people walked through ecologically-rich environments (Marin and Bang, 2018; Eberbach and Crowley, 2009). In other words, observations are not just a mechanism for sense making, but as a practice, they reflect ontological underpinnings in how people orient to place. This warrants further investigation into the forms of sense making emerge and how these are mediated by, or mediate observations.

The Role of Cultural Variation in Epistemic Actions

A second major finding from this study is that although both the Salmon Walks and ISTEAM groups were more likely to have place emergent initiating epistemic actions, there was cultural variation in how participants oriented to place. I argue that the findings from this paper reflect different epistemological orientations to the natural world. A critical component of biological thinking is the construction of the human relationship with the natural world, or nature-culture relations (Medin and Bang, 2014b). Previous research has shown that Native American participants were more likely to position land as psychological close (with greater attention to context and ecological relations), and to see themselves as part of nature, than European American's with a similar level of expertise and familiarity with the context (Bang et al., 2007). Marin (2013) and Marin and Bang (2018) extended this work to look at how Native American parent-child dyads orient to place in talk-in-interaction in forest walks. They build a

methodology for studying the "pedagogy of walking", articulating how "land and water are agentic predecessors shaping the types of action that can emerge and/or be performed" (p. 113).

Building on this lineage of work, the studies in this paper demonstrated that the pedagogy of walking lends itself to observations that are emplaced, and that these emplaced observations are part of dynamic semiotic episodes that toggle between localized and abstracted forms of place. Importantly, these substrates differed across the two cultural groups. Participants in the Indigenous STEAM camp were more likely to foreground place consistently during the walks. Even if place-emergent observations did not open a semiotic episode, meaning that talk about biological and ecological phenomena did not necessarily stem from an observation localized in the surrounding environment, participants were more likely to reorient attention to place. Thus, abstracted and localized attention to place formed a dynamic and robust constellation of interactions within these semiotic episodes.

While using observations is a cornerstone of Native science, this practice is only one of a coordinated and holistic set of orientations that foster a form of reading the land (Bang and Marin, 2018; Cajete, 1999). Thinking with these two frameworks provided a lens for understanding how and why the ISTEAM participants were more likely to both have a range of epistemic actions (placed or abstract), as well as a diversity of these. And, further, it demonstrated that land was more likely to be a semiotic actor. (Marin and Bang, 2018). This warrants further investigation into the forms of sense making that emerged in these semiotic episodes, and how these were connected to place. This will be taken up in Chapter 4 (this dissertation).

Implications

Field-based science learning environments are promising sites for deepening learners' understanding about complex ecological systems because they provide opportunities to engage in practices such as observing phenomena to support or refute hypotheses as well as to build theories (Eberbach and Crowley, 2009; Smith and Reiser, 2005). The Next Generation Science Standards advocate for learning opportunities that prioritize the process of epistemic practices-focused sense making science over the acquisition of facts (NRC, 2012), and in this vein, this study heeds a call for research into effective and equitable ways to engage students in authentic science inquiry, and similarly to foster deeper understandings of the complex and rapidly shifting world in which we live. As stated above, this study demonstrates that when learning occurs in outdoor places, the natural world is not only central to sense making, but thought emerges from place. This overall finding is especially important to consider when thinking about the structure of education systems, particularly science education. The implication is that when these systems do not engage learning in places that is outside of the classroom, it shapes thinking and sensemaking in significant ways.

Chapter 4. PAPER 2: CONCEPTUAL CONSTELLATIONS OF SPATIAL INDEXING

Introduction

Understanding complex ecological systems is increasingly important in a world that is shifting at a rapid rate (Bang et al., 2015). However, the processes by which young learners come to know about complex systems, and how to teach about complexity, is still an area of inquiry. Providing field based learning experiences is a promising avenue for fostering sense making about complex ecological systems. This is in part because it provides learners with opportunities to directly engage with ecological phenomena through scientific and cultural practices of observation (Eberbach and Crowley, 2009; Bang et al., 2014; Mogk and Goodwin, 2012). There has been abundant research on the role of observations in scientific thinking, however directly exploring how observations can support or facilitate complex systems thinking is still relatively understudied (for exceptions see Hmelo-Silver, Jordan, Eberbach, Sinha, 2017; Mogk and Goodwin, 2012). This study examines the link between culture, place, and observing in field based learning settings. More specifically, I examine how sense making unfolds in interactional units of observing and attending to phenomena in the perceptual field using a framework called spatial indexing (Pugh, McGinty, and Bang, 2019).

Background Literature

Complex Systems Thinking

Complex systems refer to non-linear, decentralized interactions between multiple parts that constitute collective behavior and often lead to emergent phenomena (Davis and Sumara, 2006; Grotzer and Tutwiler, 2014; Hmelo-Silver and Pfeffer, 2004; Levy and Wilensky, 2008). More

specifically, complex ecological systems refer to causally-linked phenomena occurring within and across natural systems, such as food webs, climate change, and human-nature systems (Grotzer et al., 2013; Hmelo-Silver et al., 2017). Understanding complex phenomena requires reasoning across levels and scales (Resnick and Wilensky, 1998; Lemke, 2000), includes making connections (e.g. cause and effect) across distances and attentional frames, as well as across extended temporal frames that go beyond a focal event (Grotzer et al., 2013; Grotzer, Kamarainen, Metcalf, Tutwiler, and Dede, 2017). While it is important to understand how these systems work, teaching and learning about complex systems has been a challenge. Researchers have studied this difficulty from a variety of lenses, from differences in conceptual organization between novices and experts (Hmelo-Silver, 2004), to the socialization of children into thinking in simplistic, linear ways (e.g. Davis and Sumara, 2006; Hogan, 2002). These ideas are not mutually exclusive, and represent a myriad of angles from which to approach complex systems learning.

Knowledge Organization, Conceptual Change, and Folkbiological Reasoning

While much of this research on complex systems thinking focuses on cognitive constraints (Grotzer and Tutwiler, 2014), few of these studies have considered how cultural variation in sense making can mediate complexity thinking (for exceptions see Marin, 2013; Olson, 2013; Pugh, McGinty, Bang, 2019). Scholars are increasingly calling for research that extends beyond WEIRD (western, educated, industrialized, rich, democratic; Henrich, Heine, and Norenzayan, 2010) populations to understand the cultural and environmental factors that mediate cognition. There is consensus among various scholars that patterns of reasoning unfold through the coordination of perception, attention, and motivation (Bang et al., 2007; Davis and Sumara, 2006; Grotzer and Tutwiler, 2014; Lee, 2008), and that “human thought is enabled and

constrained by the conceptual tools that are available" (Davis and Sumara, 2006; p. 42). In other words, our attentional habits filter certain stimuli, resulting in a reliance on certain heuristics to understand how systems work and why (Grotzer and Tutwiler, 2014; Eberbach and Crowley, 2009). What we end up filtering – or in another light, what we attend to – may be influenced by our own histories, prior experiences, or beliefs, or what some have called epistemic orientations (e.g. Bang, Medin, and Atran, 2007; Marin, Medin and ojalehto, 2018).

The process by which knowledge gets organized has been taken up, in part, in conceptual change literature. This rests on the premise that conceptual organization is context-dependent and "involves a large number of diverse kinds of knowledge, organized and re-organized into complex systems" (diSessa, 1993; p. 29). In this process, learners incorporate information from a variety of sources in the perceptual field into existing knowledge structures (Danish, Enyedy, and Parnafi, 2016). Coordination Class theory (diSessa, 991; diSessa and Sherin, 1998) explains how existing knowledge structures coordinate sensory input, and through the "inferential net", incorporates it into existing knowledge structures (Danish et al., 2016). It is through this coordinated process between existing knowledge and new information that conceptual change happens.

Learning how to make sense of new information "involves knowledge of the relation between the principle and the situation" (Wagner, 2006; pp. 66). In other words, knowledge structures are not static, but rather are dynamic and organized based on context. In order to better understand these dynamic processes of learning, Brown (2014) introduces a complex systems perspective of student conceptions called dynamic emergent structures that are embedded in "affective, social, epistemological, and sociocultural dynamics" (p. 1479). Brown argues that in order to teach science concepts, students should be able to build from existing intuitive

conceptual anchors. Therefore, conceptual development, as a complex system, is nonlinear, emergent, and is embedded in social structures.

While these frameworks for understanding conceptual change highlight the contextual nature of learning, they are limited in two important ways that are of particular importance for this study. First, there is an assumption that knowledge can be broken down into pieces (e.g. diSessa, 1993). Other researchers studying scientific reasoning have argued that knowledge does not get broken down into pieces, but rather are “embedded within epistemological orientations for organizing knowledge and behavior” (Marin, Medin, and ojalehto, 2018; p. 44). Research in the folkbiological and folkecological reasoning have demonstrated that cultural worldviews influence categorical organization of biological phenomena and relationships; and reciprocally, knowledge organization influences how one sees and relates to the world through epistemological orientations (Bang et al., 2007; Medin, ojalehto, Marin, and Bang, 2013).

One framework that has been increasingly studied is what Bang and others (Bang et al., 2015; Marin, Medin, and ojalehto, 2018) call “relational epistemologies”. Drawing on Cajete (2000), relational epistemologies are "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, [everything is] connected in dynamic, interactive, and mutually reciprocal relationships" (Bang et al., 2015). This framework stems from literature in Native science and Indigenous Ways of Knowing (Cajete, 2000; Kawagley, 2006), and similarly can be used to understand the ecological forms of reasoning that emerged in Native participants in some of the folkbiological and ecological reasoning studies.

Second, much of the literature on conceptual change has positioned a particular form of expertise as the goal of learning. In other words, implicit (or often explicit), is the assumption of

a correct way of doing science. Warren, Ogonowski, and Pothier (2009) caution against the strict dichotomization of everyday versus scientific observations because it positions one as superior to the other. This is of particular importance when considering cultural variation in scientific reasoning, and the implications of this variation on both the advancement of science as a field, as well as the design of science learning environments (Atran and Medin, 2007; Bang, Warren, Rosebery, and Medin, 2012; Bang and Medin, 2010). In other words, with the acknowledgment of science (in practice and in education) as a cultural process, recognizing and making space for epistemological variations in scientific reasoning bode well for student performance and achievement, particularly for those that are underrepresented in fields of science (Bang and Medin, 2010).

Research Questions

This study examines the role of culture and context on knowledge organization about biological and ecological phenomena. I explore the sense making that occurs in two contexts, unstructured family walks during the salmon spawning season (autumn) with primarily European-American families, and an intergenerational ISTEAM (indigenous science, technology, engineering, arts, and math) camp during the summer in the same park. I ask the following research questions:

RQ 2: How do place and culture mediate sense making about complex biological and ecological phenomena?

2.1 What are the forms of sense making that emerge during forest walks, and how are these mediated by culture or place?

2.2 What is the role of observations in sense making about biological and ecological systems?

Implications from findings will articulate and expand a framework for field-based observation and attentional practices that foster land based complex ecological systems thinking.

Context and Participants

In order to examine how learning unfolds in, and is mediated by culture and place, this study spans two informal outdoor learning programs in the same urban park. Ravine Park (Figure 1) is a 200-acre densely forested city park that borders the Puget Sound. The park consists of diverse forest ecosystems, wetlands, multiple streams that merge and run into the sound, and both a rocky intertidal and sandy beach area. Within this park, I explore two informal, outdoor learning programs: An Indigenous-STEAM (science, technology, engineering, arts, and math) camp, and a Salmon Days program that educates the public about salmon in the park.

Study Site 1: I-STEAM

The data in this study is pulled from a larger Community Engaged Design Research (CEDR) project that designed and implemented expansive science practices grounded in both Indigenous ways of knowing (IWOK) and Western science (Bang and Marin, 2015)[6]. This manifested in the design of a Summer Indigenous STEAM (science, technology, engineering, arts and math; ISTEAM henceforth) program for youth that took place in large, forested parks within the city. The project was a partnership that included several organization partners, including a Native youth arts program and the University. In addition there were a range of artists, ocean scientists, parent volunteers, graduate students, and Native community members that engaged in the design of the program. The planning for the program took place during a series of design meetings that

[6] Although Native science and Western science are not mutually exclusive, each rests on particular ontological and epistemological orientations to the world, or nature-culture relations.

utilized place-designing methods (Bang et al., 2016), professional developments, and art inquiries. For example, program facilitators and designers participated in collective professional developments to prepare for the program through field days with scientists as well as storytelling workshops with a local Native artist. In addition, program facilitators walked and planned in the places we would take youth. The program was intentionally designed around the tides to highlight the integral role that land and waters play in designed learning settings.

The lands on which the camp took place are traditional Duwamish, Suquamish, and other Coast Salish Peoples' territories and have undergone dramatic transformation since European contact. A core tenet of the ISTEAM camps were to remake or build on existing relations with lands, waters, and Coast Salish communities. Indigenous pedagogies and intergenerational cultural practices were central throughout the design and implementation of the ISTEAM camp. Learning activities were designed around "walking, reading, and storying the land", which are routine practices in which individuals enact nature-culture relations that foreground relationships, roles, and reciprocity (Marin and Bang, 2018; Cajete, 1999). This included activities that centered on remaking relations with plants during scaffolded observation activities and plant relative walks. Instructors carried back-pocket guides with reminders about verbal and physical facilitation prompts to scaffold attention and observations in ways that were aligned with relational epistemologies (Cajete, 1999).

Site 2: Salmon Days

Salmon Days was an ongoing volunteer-based community program in partnership with the public utilities department, a watershed-focused nonprofit based out of the park, and the local community. The program engaged the public in place-based learning about salmon, their life cycle, habitats, and the local efforts to maintain the seasonal run. Salmon volunteers set up tents

and walked along the stream on weekends throughout the late fall during salmon spawning season. The Salmon Days program was founded to teach the community about salmon, and to further ensure efforts to protect the stream and surrounding habitat through stewardship practices. Volunteers interacted with the public, and were trained by staff from education outreach branches of the public utilities department and the parks and recreation department. Some of the volunteers were also involved in other salmon-related volunteer efforts at the park. Families frequented the park to watch the salmon run, and often interacted with the volunteers to ask questions or participate in guided walks.

The families in this study were primarily European American identifying, and the children ranged from six to thirteen years of age. The walks were unstructured, and all of the participants were recruited at the park as they walked by the volunteer tent. All of the participants were in the park specifically to see the salmon spawn, although some were also interested in additional hikes. Many of the family walks included interactions with the Salmon Days volunteers. Some families have never seen the salmon at Ravine before, and some visit the park each year during the run.

Data Corpus

Walks

Salmon Walks.

Recent research on informal learning settings highlight family discourse practices as rich sources of knowledge development (Callanan et al., 2012). Within parent-child conversations, the epistemological standpoints that parents hold regarding science, or science-related concepts, can impact how children make sense of the natural world (Luce et al., 2013; Callanan et al., 2012). In this study, I recruited families who were already in the park to wear a GoPro during their

walk. I informed them that there was no right or wrong way to walk through the park, that I was just interested in what they talked about as they walked and explored the salmon run.

Walks generally followed the creek in which salmon were running. However, some families went up a trail that traversed the south end of a ravine, leaving the creek and heading farther into the forest. Other families continued along the creek, past the point where salmon were running, although these families did not realize the salmon had turned up another stream. There were 7 walks in total over the course of two Saturdays, and video recordings of these walks ranged from 5 minutes to nearly 1 hour and 6 minutes, with an average of 40m42s. One video (Jake) was not usable because of participants' unfamiliarity with the GoPro, and thus wanting to end the walk.

The Salmon Days volunteer program was taking place at the park. Volunteer Salmon guides had a tent set up with information about salmon, including local salmon run numbers, salmon life cycle displays, and information about the park. Volunteers were also stationed at viewing points along the creek, and twice a day offered guided salmon walks (none of the families in this study participated in the guided walks while wearing cameras, and none reported doing it earlier).

ISTEAM Walks.

Walking was a key pedagogical component of the ISTEAM because it is a deeply cultural practice tied to Indigenous Ways of Knowing (Marin and Bang, 2018; Cajete, 2000). Walking was recognized as an activity for knowledge making. Ingold (2010) refers to this type of movement as *wayfaring*, in which the "concern is to seek a way through" rather than arrive at an end destination. Walks served different purposes depending on the day, location, and activity. In order to bound the data and examine the role of observations in designed walks, I selected *Plant*

Relative walks on two days of the camp, Day 2 and Day 4. These walks focused on making or remaking relationships with plants, with activities that ranged from scaffolding observations from morphological patterns of plants to growth, habitat, and relations within ecosystems. Within this data corpus, I chose walks that included both adults and children in order to examine the interplay of intergenerational interactions and place. I also chose walks that were in forested ecosystems. There were five designed (intentional) walks, and I analyzed four. One set of walks on day 1 was not considered because one of the videos (multiple cameras) was disjointed (a child wearing a POV parted ways with the group to join another for a break) or the footage took place on the beach and not during a walk. I also did not analyze whole group activities that were sedentary. In the data corpus in this study, there was 9 hours and 3 minutes of video, with an average video length of 23 minutes and 27 seconds. The children studied in this paper ranged in age from six to thirteen.

Methodological Framework

Understanding the processes and mechanisms of complex systems requires attending to phenomena with across multiple scales and levels of organization (Jacobson and Wilensky, 2006; p. 12). These same mechanisms can be found in learning settings, particularly that teach about complex systems, and thus requires an analytic lens that mirrors the complexity of the situation (Danish, 2014). In order to do this, I examine the relationship between interactions and conceptual elements to develop a theory about the nature of knowledge organization in two capacities: 1) in interactional units with land as a semiotic agent, and 2) across two cultural groups as they walk in the same urban, forested park.

This mixed-methods paper uses interaction and conversation analysis (diSessa, Levin, and Brown, 2017; Jordan and Henderson, 1995; Goodwin, 2001) to study how sense making

about biological and ecological systems unfolded in forest walks. This layers onto the analysis in Paper 1 of this dissertation (Interactional Constellations of Spatial Indexing) in which I explored the interactional nature of observations, and the relationship between place and sense making. Findings showed that place played a critical role in shaping how people observed in an ecologically-rich environment. More specifically, youth and adults engaged in sense making that stemmed from observations of locally salient phenomena, particularly in the ISTEAM context in which participants continually re-oriented to place throughout episodes of sense making. Additionally, findings showed that these observations were distributed across people, and were mediated by interactions within and among the natural world.

This study extends that research to more closely examine the forms sense making that emerged within these semiotic episodes (trajectory of sense making that was coordinated across people, place, and sometimes tools; e.g. Goodwin, 2018; Marin and Bang, 2018). This builds on sociocultural perspectives to focus on the "constellations, or ecologies, of sense-making practices and processes of interaction that people participate in, particularly in everyday contexts, and the meanings, ideas, problem solving, and forms of social life that emerge in these contexts and across development" (Bang, 2015). In other words, I study the function of observations as part of constellations of sense making.

Analytic Framework

Attentional practices mediate how individuals understand and communicate in the world (e.g. Bang and Marin, 2018; Hammer et al., 2005). The signs and mechanisms through which we communicate is called semiosis (Peirce, 1991; Scollon and Scollon, 2003). How individuals orient themselves during talk, such as what they attend to, is connected to how they talk about it, and together these constitute a "semiotic ecology" (Goodwin, 1999). Along these lines, there is

cultural variation in how we orient to the world (Marin, 2013), and how we organize knowledge (Medin et al., 2006; ojalehto and Medin, 2015). This study aimed to uncover how culture and context mediated sense making about ecological phenomena. Although I built with theories of semiotics, recognizing land as a semiotic resource in sense making is deeply rooted in Indigenous epistemologies (Marin and Bang, 2018). In response to the resounding assumption in western science that non-humans lack agency (see also Latour, 2013), Bang and Marin assert:

> "This marks a critical ontological difference in western scientific ways of knowing and IWOK [Indigenous ways of knowing]. In many IWOK (though maybe not all) humans are not the only intentional and agentic actors in the world, nor do humans occupy a privileged status that divests us of responsibility, humility, and reciprocity (Kawagley, 1993, 2006; Cajete, 2000)." (2015; p. 532)

They continue to explain how this ontological distinction permeates through dominant scientific theories and practices. Building with Linda Smith (2012) and Giddens (1984), they articulate the idea of "memory traces", entanglements of space and time in interactions that are "fused with social and ecological unfoldings of history and knowledge systems" (p. 533). In conversation with Doreen Massey's idea of places as "stories so far", this recognizes that the stories that are called forth, down the very ontological and epistemological frame, are rooted in social and cultural structures; they are not emergent in the sense of historical erasure, but rather are dependent upon these histories to determine what is possible.

Spatial indexing builds on theories of semiosis, particularly how indexing, as an interactional maneuver, can make place visible in conversation (Pugh, McGinty, and Bang, 2019). In other words, spatial indexing can be used to describe a critical component of the practice of observing, or "reading the land" (Cajete, 2000; Bang and Marin, 2017). Drawing from theories of geosemiotics (Scollon and Scollon, 2003), and distributed semiotics (Kohn, 2013), spatial indexing surfaces the entanglements of spatial, temporal, and relational dynamics

that lead to sense making about complex ecological phenomena. Thus, this framework is uniquely positioned to examine the form and function of observations in sense making about complex ecological systems.

Coding Scheme

In order to find out how place was constructed in sense making about biological and ecological phenomena, I characterized the semiotic episodes as participants walk through the forest[7] (Goodwin, 2018; Marin and Bang, 2018). I leaned on Goodwin's (2018) notion of substrates to develop an analytic framework that captured the entanglements of land, attention, and language. Goodwin (2018) explored how an indexical operation in an initial action provides the materials for subsequent action. These initial actions, marked by an utterance, are called "substrates" because they form the foundation upon which subsequent actions build. In turn, subsequent actions, including talk and other action types, are bounded by the transformation of "the very materials that composed the earlier utterance" (p. 48); these are called laminations. While these substrates and laminations can refer to a variety of human actions, I wanted to focus specifically on the role of observations in sense making. Thus, I called substrates "initiating epistemic actions" (IEAs) and laminations "subsequent epistemic actions" (SEAs).

More specifically, I identified four epistemic actions (Table 1). This process came about in two ways. First, in line with prior research in observations and attention I was interested in how land, as a semiotic actor, was positioned in sense making about ecological phenomena (Marin and Bang, 2018). Initially, I developed codes for *place emergent* (observations), and *place extracted* to dichotomize possible epistemic activities. That is, I wanted to know if

[7] This coding scheme is explained in detail in Paper 1: Interactional Constellations of Spatial Indexing

participants were observing phenomena in the local environment (such as a plant, animal, landscape, waterway, etc.), or if they were talking about phenomena that was either extracted from place (e.g. holding a berry or leaf, but out of context). After second pass through video and transcript data, I identified two other epistemic actions that were also abstracted but relevant to the local place. Epistemic actions that considered place, such as anticipating what would be seen or recalling a past event were coded as *place speculative*; when attention was focused on, or stemmed from, tools (physical tools, such plant information cards, maps, etc.) I coded as *tool*. Attending to epistemic actions along these four parameters allowed me to first make visible the substrates from which constellations of activity and sense making (Hall and Stevens, 2016).

Table 4-1 Initiating Epistemic Actions

Initiating Epistemic Actions			
Epistemic Actor	**Epistemic Action (substrate)**	**Definition**	**Example**
Child	Place Emergent	Observation that is located in or emergent from place; something in the sensory or perceptual field that is in the surrounding environment	*"Hey, it's a little mossy tree"*
Adult	Place Speculative	Anticipating what was or will be seen (or perceived) during walk (not in present moment)	*"Next time we see salmonberry just make sure we stop"*
	Tool	Reference to a material tool (such as *plant relative* information card) or ideal tool (pedagogical maneuvers)	*Material: "what is your plant relative [on card] that you are looking for?" Ideal: "Remember the story Leroy [storyteller] told us about Cedar?"*
	Place Extracted	Abstracted phenomena that is not located in place, either in the present moment or anticipatorily	*"[holding a grape in hand] this Oregon grape is super sour"*

Within this first round of coding I also attended to which participants, adult or child, opened the epistemic sequence, what I call *initiating epistemic actors* (IEAs).

In the second round of coding I identified the conceptual elements related to biological and ecological systems thinking. These conceptual elements stem from biological, ecological, and complex systems literature. There are two main categories of conceptual elements: reasoning across scales, and reasoning across levels. Each is described below.

Analysis

I present the analysis in the form of two sub-studies that aim to characterize knowledge organization and elements of complex ecological systems thinking in outdoor ecologically-rich environments. The first study focuses on scales, spatial and temporal, at which participants were reasoning about focal biological and ecological phenomena. The second study explores the levels (Lemke, 2000) at which participants were reasoning, specifically if they were attending to causal links (chaining and webbing), agent and aggregate levels, and CMP (component-mechanism-phenomena; Hmelo-Silver et al., 2017). Understanding how participants were reasoning across these two dimensions allowed me to more closely examine the constellations of sense making that unfolded during the forest walks. Findings are discussed in detail below.

Study 1: Reasoning across Scales

Reasoning across scales is both a cornerstone of complex systems, and also offer a glimpse into how knowledge is organized in talk-in-interaction (Marin, 2013; Lemke, 2000). In this study I calculated the percentage of semiotic episodes that include talk along elements of temporal and spatial scales, and then run a Chi Square Test of Independence to look for cross-context differences in the presence of codes.

Spatial Scale.

The spatial scale provides a lens into how participants were organizing attention to place. What people attend to is shaped by both epistemological orientations (Marin and Bang, 2018) and domain knowledge or experience (Eberbach and Crowley, 2009). Additionally, joint attention has been linked to knowledge development (e.g. Tomasello and Farrar, 1986; Marin, 2013). Thus, the spatial scales at which participants are observing offer insight into what they deem relevant in the semiotic episode. More specifically, this study examines if and how spatial attention is mediated by culture and context. There were four spatial codes to cover the array of spatial attention (Table 2). Locative attention was coded when participants were actually observing something in the perceptual field. Relational scale was coded when participants attended to natural kinds that were in relation to the focal phenomenon (such as nearby, adjacent, connected, etc.). Habitat scale included attention to the surrounding landscape in which the focal phenomena would grow, live, or thrive. And finally, the speculative scale refers to moments in which participants were thinking about where they might see a focal kind (e.g. a plant or animal).

Table 4-2 Codes for Spatial Scale

Spatial Scale	
Code	Examples
Locative	*There's a huckleberry right there*
Relational	*I see big leaf maple over here, so there must be salmonberry*
Habitat	*Bracken fern can grow in open, drier areas*
Speculative	*I think we might see salmon in this part of the stream*

I hypothesized that there would be contextual differences between the Salmon Walks and the ISTEAM walks. More specifically, due to the high presence of salmon in the creek, I hypothesized that much of the talk would be focused on the locative scale; for example, pointing

out salmon. Due to the relational focus of the instruction in the ISTEAM program, I hypothesized that there would be greater attention to place on the relational scale in this context.

Results.

There were a total of 298 spatial codes applied across both contexts. I conducted a Chi Square Test of Independence to calculate whether there were statistical differences in attentional frames between the two groups. Results were not statistically significant, $X^2(3, N=321) = 2.75$, $p > .05$ showing that cultural group did not play a significant role in attention to spatial scales. The four spatial codes reflect not only where in the perceptual field participants were attending, but also offered a glimpse into what participants deemed relevant in sense making.

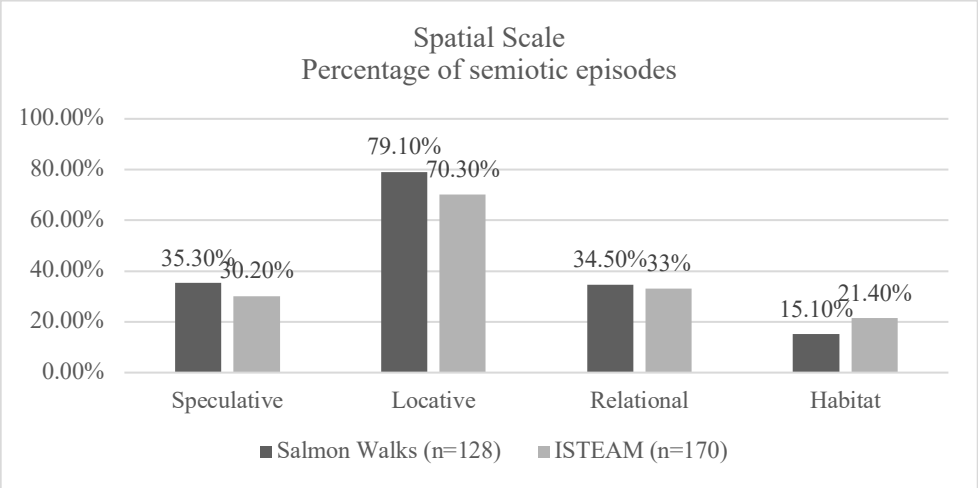


Figure 4-1 Spatial Scale: Percentage of semiotic episodes with talk that attended to phenomena on spatial scales.

While there was no significant difference in spatial scales between cultural group, there was a marked difference between the spatial scales that participants attended to in their walks. Across both Salmon Walks and ISTEAM, participants were more likely to attend to locative phenomena. This manifested in one or more participants highlighting (Goodwin, 2000)

biological or natural kinds[8] in the perceptual field – including multi-sensory attentional prompts. This suggests that placed played an important role in shaping how observations manifested during the walks.

Temporal Scale

Complex systems consist of components that interact at particular levels and have emergent properties at higher levels; there is temporal heterogeneity both within levels of socio-ecological systems, and across these levels (Lemke, 2000). Additionally, research on talk-in-interaction has demonstrated that participants frequently weave in multiple time scales in the present moment, such as local and global levels (Erickson, 2004). Being able to attend to phenomena on multiple time scales indicates an understanding of this complexity within a system. Temporal codes varied from micro-processes such as life cycles to macro-processes such as geological time. I also included codes that would reflect how participants were seeing their own histories reflected in talk, such as experiences from events prior to this walk ("experiences") to camp or walk-related phenomena. Finally, I included codes that specifically looked at natural cycles found in the ecological world, including seasonal, tidal, yearly, and rhythmic processes.

Table 4-3 Codes for Temporal Scale

Coding Examples for Temporal Scale	
Code	Example
Life Cycle	*Salmon spawning and reproduction; plant or animal growth, development*
Experience	*Connecting to something the participants has done before*
Geologic	*Glacial patterns, land movement*
History	*Social history and events*
Camp/Walk	*Referring to things that happened during the walk / camp*
Rhythmic	*Ebbs and flows(not accounted for in tidal); such as rise and fall of water levels with the rain*

[8] Kinds refer to living and nonliving elements of an ecological system. This includes plants, animals, water, rocks, people, etc.

Seasonal	*Talk about seasons, seasonal change*
Tidal	*Tides in the Puget Sound or in the ocean*
Yearly	*Event or phenomena that recurs yearly; referring to a specific year*

I hypothesized that because Salmon Walks took place during salmon spawning season there would be a lot of talk about life cycle. In the context of ISTEAM there was a focus on relational epistemologies, and thus I hypothesized that ISTEAM participants would more likely to talk about experiences, both broadly and in the camp/walk. This is also in part because families in the Salmon Walks did not have many (if any) prior experiences with either seeing salmon or the park in general.

Results.

There were 188 instances in which participants reasoned across temporal scales. A Chi Square Test of Independence showed that the percentage of talk about temporal scales was significantly different across the two cultural groups, $X^2(8, N=188) = 21.78$, $p < .05$. These findings suggest that cultural group had a significant impact on the presence of temporal scales in their sense making. Across all temporal elements, Salmon Walk families were more likely to talk about life cycle of phenomena (70.7%), while ISTEAM participants were more likely to attend to a variety of scales, particularly related to experience and seasons. In the ISTEAM context were much more likely to connect the present moment to their lived experiences, which accounted for 35% of talk in contrast to 18% of the Salmon Walk participants. This suggests a closeness to nature that has been empirically demonstrated in a number of Indigenous youth and adults in studies of folkbiological and ecological reasoning (Bang, Medin, and Atran, 2007).

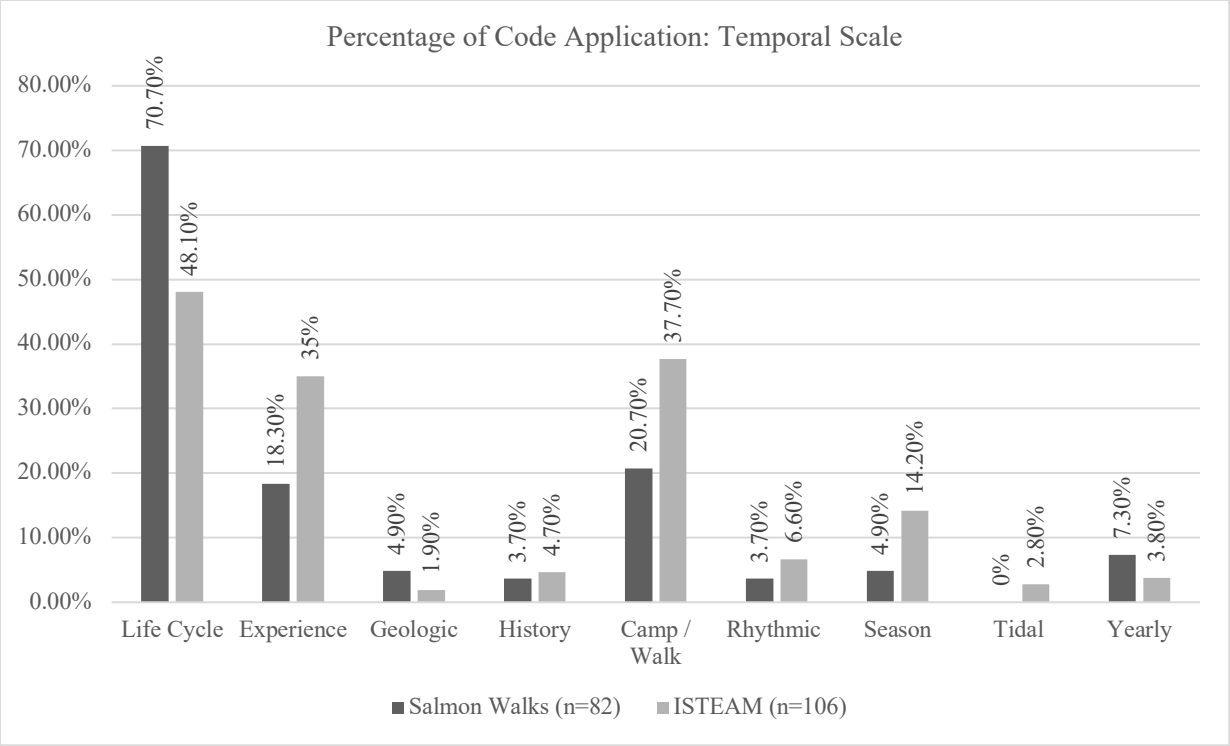


Figure 4-2 Percentage of semiotic episodes that attended to temporal scale

Discussion

Both groups incorporated dynamic spatio-temporal constellations in sense making about ecological phenomenon. For instance, the variability in talk about temporal scales within semiotic episodes reflects how participants were incorporating both global and local ecologies (Erickson, 2004), or what Goodwin (2018) calls "sedimented histories". Coupled with attention across multiple spatial scales, it is evident that place afforded opportunities to think across multiple scales.

While temporal and spatial scales do not indicate complex systems reasoning in and of themselves, they do indicate how knowledge organization mediates sense making in outdoor, ecologically-rich environments. For instance, relational constellations was evident in how participants in the ISTEAM context connected to experiences (35% for ISTEAM in contrast with

18% for Salmon Walks) and phenomena they had noticed earlier in the camp or walk (38% for ISTEAM versus 20% for Salmon Walks). The embedded nature of experiences can be described as a manifestation of nature-culture relations (Medin and Bang, 2012), demonstrating psychological closeness to nature (Bang et al., 2007) that was more prevalent in the ISTEAM context than in the salmon walks.

Study 2: Reasoning across Levels

Reasoning across levels is a critical component of complex systems thinking (Lemke, 2000; Levy and Wilensky, 2008). This includes reasoning about causal links (chaining and webbing relations), across agent-aggregate levels, and whether and how participants were attending to the CMP conceptual frame (component-mechanism-phenomenon) (Hmelo-Silver, Jordan, Eberbach, and Sinha, 2017). Findings are presented along dimensions of both knowledge organization and how that relates to systems thinking. Broadly speaking, the levels at which participants reasoned can be considered relational construals (Medin and Bang, 2014a). Understanding differences in construals reflects epistemological orientations to ecological phenomena between cultural groups, such as indigenous and western ways of perceiving the world. Construals tell us how participants view behaviors or actions of others, and how these behaviors relate to one another. This can manifest in differences in patterns of reasoning that are organized either holistically (seeing the entire system) or taxonomically (hierarchical organization of thinking) (ojalehto and Medin, 2015).

Table 4-4 Codes for Relational Construals

Coding Examples for Relational Construals		
Cognitive Dimension	Code	Examples
Causal Links	Chaining	*Cause-effect relationships, links between kinds or phenomena*

	Webbing	*Webbing or nonlinear relations between 3+ kinds*
Agent-Aggregate Level	Agent	*Reasoning at the level of the agent; e.g. bird, mushroom*
	Aggregate	*Reasoning at the level of the aggregate; e.g. forest, northwest*
	Agent to Aggregate	*Reasoning from agent level to aggregate level*
	Aggregate to Agent	*Reasoning from aggregate level to agent level*
Systems Level	Component	*Parts that make up a system*
	Mechanism	*The role, behavior, or function of parts of a system*
	Phenomena	*Patterns or problems within a system*

I hypothesized that ISTEAM participants will be more likely to attend to forms of reasoning on multiple levels and scales. This is in part based on findings presented in Chapter 3 (Interactional Constellations of Spatial Indexing), which showed that ISTEAM participants were more likely reorient to place even when the initiating epistemic action was extracted from place (for example, asking where someone found a fern in order to learn about it). Thus, I anticipate seeing a difference in place abstracted forms of reasoning. Additionally, due to the relational nature of IWOK and instruction in the camp, I also hypothesized that ISTEAM would be more likely to talk about webbing relationships. In order to examine if there were statistical cultural differences in the forms of reasoning, I conducted a Chi Square Test of Independence for each form of reasoning, and across the four initiating epistemic actions.

Component-Mechanism-Phenomenon.

Some scholars have attributed challenges with complex systems reasoning to a lack of expertise. For example, Hmelo-Silver and colleagues (2017) have developed the CMP (component-mechanism-phenomenon) conceptual representation to study if and how students are reasoning about complex phenomena particularly around ecosystem dynamics. In CMP scaffolds learners to understand the mechanisms by which components interact within certain phenomenon. This follows the Structure-Behavior-Function (SBF) framework, based on the premise that novices tend to focus on components or mechanisms, but have difficulty attending

to the interactions and dynamic processes of phenomena. In other words, students tend to reason about simple, centralized explanations that focus on structures, while experts are able to attend to decentralized, functional, and emergent processes (Hmelo-Silver and Pfeffer, 2004; Hmelo-Silver, Liu, Gray and Jordan, 2015; Grotzer, Kamarainen, Tutwiler, Metcalf, and Dede, 2013).

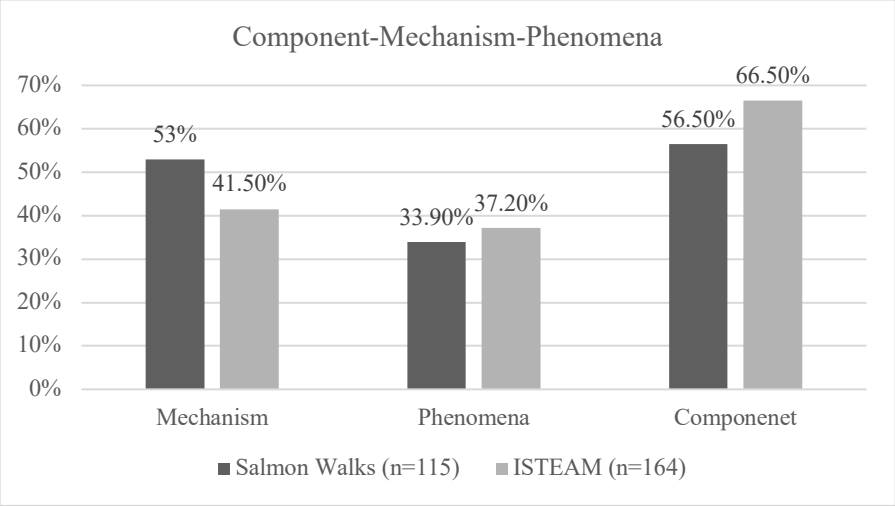


Figure 4-3 Percentage of semiotic episodes that attended phenomena across CMP Scales

Results.

There was no statistical difference between the Salmon Walk and ISTEAM groups, but we do see that across both cultural groups participants were reasoning across CMP scales. In other words, participants were complexly reasoning across multiple levels of a system, and the form of this looked remarkably similar across both contexts. This suggests that while cultural group may not play a significant role, place does.

Causal Links

Understanding complex phenomena requires reasoning across levels and scales (Resnick and Wilensky, 1998; Lemke, 2000; Grotzer et al., 2017). This includes making connections across distances and attentional frames, as well as across extended temporal frames that go beyond a

focal event, and requires attending to the causal links between components of a system (Grotzer et al., 2013; Grotzer et al., 2017). Previous research has shown that novices tend to focus on linear, unidirectional (from A to B only) cause and effect relationships, while experts are able to reason about webbing relationships with secondary, tertiary and more links (Hmelo-Silver, Jordan, Eberbach, and Sinha, 2017). Therefore, in this analysis, I attend to if and when participants are talking about causal links during the forest walks. In order to do this, I coded each for the presence of chaining (connecting two or more components in a causal relationship) and webbing (connecting three or more components in non-linear ways) within each semiotic episode. I think calculated the percentage of the code application within each IEA, and ran Chi Square Test of Independence for each IEA to see if context played a significant role in shaping talk.

Results.

Chi Square Test of Independence showed that across Salmon Walks and ISTEAM there was a significant difference in the presence of chaining relationships when the initiating epistemic action was place speculative $X^2(1, N=160) = 9.7, p < .05$. As a reminder, abstract speculative was coded as an IEA whenever participants were talking about anticipating or recalling biological or ecological phenomenon. Additionally, in this initiating epistemic action ISTEAM participants were also significantly more likely to talk reason about webbing relationships $X^2(1, N=77) = 10.9, p < .05$. This suggests that when ISTEAM participants opened a semiotic episode in an anticipatory or reflective manner, they were more likely to talk about cause and effect relationships among two or more kinds.

Agent-Aggregate Reasoning

Reasoning across agent and aggregate levels of a system is a critical element of

complexity thinking. That is because complex systems consist of elements (agents) whose behaviors interact to form emergent properties that manifest that manifest in emergent phenomena at the level of the group (aggregate), and the emergent phenomena do not retain the properties of the agents (Levy and Wilensky, 2008; Wilensky and Resnick, 1999). Some have argued that reasoning at the aggregate level is common in traditional science (Resnick and Wilenksy, 1998) but that children developmentally reason at the agent level first (Wilensky, 2006). While others have seen the difference in agent and aggregate levels as ontological in nature (e.g. Chi, 2005). Still others have claimed that coordinating across the levels of a system individuals can reason in the form of "Agent-Aggregate Complementarity (Levy and Wilensky, 2008). In these studies there has been little to no consideration of how cultural variability plays a critical role in knowledge organization. This study examines the forms of reasoning across agent and aggregate scales to see if context facilitates talk in this way.

Results.

There were significant difference across a number of elements of agent-aggregate reasoning (Table 6). First, context had a significant impact on sense making at the level of agent, agent-to-aggregate, and aggregate-to-agent levels. Second, these significant differences for agent and aggregate-to-agent were when the initiating epistemic action was abstract speculative, and also abstract tool for agent level. In other words, when a participant opened a semiotic episode in an anticipatory or reflective way (e.g. "I wonder if we will see salmonberry on this trail"), the instructors and Native youth in the ISTEAM context were significantly more likely to reason about agent or aggregate-to-agent level phenomenon. And ISTEAM participants were also more likely to reason at the level of the agent if abstract tool was the IEA, which was not the case for

the Salmon Walks. If the IEA was place emergent, such as an observation that stemmed from place, ISTEAM participants were more likely to reason from the agent-to-aggregate.

Table 4-5 Chi Square Test of Independence for Agent-Aggregate Level reasoning for each IEA

Agent-Aggregate Reasoning across Initiating Epistemic Actions

	Salmon Walks	ISTEAM	χ^2(df)	*p value*	*Significant*
Agent					
Place Emergent	53	70	1.6	0.88360063	
Place Speculative	10	24	13.6	0.01936563	**
Tool	8	22	13	0.01755922	**
Place Extractive	5	9	3.5	0.26174125	
Aggregate					
Place Emergent	24	31	1.3	0.85717702	
Place Speculative	5	13	7.8	0.06575287	
Tool	5	7	1.6	0.64398306	
Place Extractive	1	8	2.2	0.39420695	
Agent to Aggregate					
Place Emergent	13	25	6.3	0.30487732	
Place Speculative	1	8	6.9	0.02137986	**
Tool	3	2	1.2	0.60164297	
Place Extractive	1	2	0.6	0.67328998	
Aggregate to Agent					
Place Emergent	0	13	11	0.00196287	***
Place Speculative	0	3	3	0.08661588	
Tool	1	2	0.9	0.60313038	
Place Extractive	0	2	0.9	0.43857803	

This toggling is visible in the following clip from the ISTEAM context. During this walk a number of students and an elder, Mary, are looking in the creek for fish. The following excerpt is a clip from a longer semiotic episode that starts with an abstract speculative question from one of the students, Camila, asking another student, Malik, where he is going, and Mary asks if he is

looking for more fish.

1 Mary: Are we looking for more fish?
2 Camila: Yeah.
3 Runa: I saw some fish over there.
4 River: You know the really deep part of the river way back there? I think the
5 salmon people live there, pretty sure.

In this snippet of talk, the group moves from a speculation about finding fish to toggling across spatial and temporal scales. When Mary asks if they are looking for more fish, Runa points upstream to where they were a few minutes ago; in this move she not only connects to the biological kind (fish), but locates fish both in a place ("over there") and in a previous experience at the level of the camp/walk. River, another student, layers onto this (e.g. Goodwin, 2013) and specifies that the fish were in the "really deep part of the river"; this move not only confirms that the fish were in the creek, but locates them in a habitat. And finally, when he adds "I think the salmon people live there", he is signaling an epistemological resource in thinking with Indigenous ways of knowing (Marin and Bang, 2018). This small excerpt, reflective of a number of semiotic episodes throughout the camp, reflects that not only are youth and adults sense making with elements akin to complexity, but that they are epistemically grounded in relational ways of knowing. Further, it also demonstrates that sense making is distributed across people and place.

Discussion

There were significant differences across some aspects of sense making across the two contexts. First, while there were no significant differences in Component-Mechanism-Phenomena framework, both groups were making sense of ecological phenomena at a systems level. This suggests that when in ecologically-rich environments, participants were able to reason about complex ecological systems. However, there were cultural differences among the scales at which

participants were sense making. For instance, the Native participants in ISTEAM were more likely to make causal links at the level of both chaining (connecting two or more phenomena) and webbing (connecting three or more phenomena in a web-like way). Most notably, these significant differences were both present in the place speculative initiating epistemic action. In fact, it was in this IEA that much of the agent-aggregate level differences were seen as well. For instance, this was the case when reasoning at the level of the agent and reasoning from agent to aggregate. However, there was also a significant difference between Salmon Walks and ISTEAM in the place emergent IEAs for agent and aggregate-to-agent level reasoning.

While we cannot infer causation from these results, they demonstrate that culturally-mediated knowledge organization has a significant impact on how people make sense of ecological phenomena when they are in ecologically-rich settings. In other words, these findings show how sense making about complex systems unfolded in activity. More specifically, cultural differences were present in place emergent and place speculative substrates, suggesting that the ways in which participants are orienting to land is culturally different.

Conclusions

This study was premised on the idea that providing young learners with opportunities for field based learning experiences is a promising avenue for teaching about complex ecological systems. Much of the research on complex systems thinking has focused on cognitive processes of learning that have rarely taken place into consideration. Additionally, there is a need for more research into cross-cultural variation in complexity thinking. This study examined knowledge organization about ecological systems by studying how learning unfolded in place and activity. The findings in this paper demonstrate how sense making about biological and ecological phenomena was tied to both activity and culture. This was reflected in the forms of sense making

that emerged in semiotic episodes among distributed actors within a shared sense-making system. There were two big findings from this study. First, sense making across scales and at the level of systems was present across both cultural groups. Second, cultural differences in knowledge organization were present when observations were emplaced or were speculative about place.

In the first finding, there was variability in the scales and levels at which participants were reasoning across both groups. For instance, both the Salmon Walks and the ISTEAM participants attended to phenomena across multiple spatial and temporal scales, and they were reasoning about components, mechanisms, and phenomena in systems. However, there were significant differences in how the participants were reasoning across temporal scales, with greater attention to experiences in the ISTEAM group. This suggested psychological closeness, a construct that has been articulated in cross-cultural research. However, this study extended previous research by specifically locating these differences in place and interaction. In particular, there were significant cross-cultural differences in whether and how the youth and adults were reasoning across agent and aggregate level scales and causal links. This was evident when participants were attending to place (place emergent and place speculative). That is, place and culture were important factors in the ability to reason about complex systems. Thus conceptual constellations were rich with knowledge organized across dynamic and varying kinds and that forms of reasoning that cross many levels.

Implications

This analysis surfaced the emergent and grounded forms of sense making that were present as participants moved through space. The findings push the field to take more seriously the interplay between culture and place in knowledge organization, particularly around complex

ecological systems thinking. This warrants further investigation into how the design of the learning environment mediates sense making in field based settings. For example, relational observation practices were reinforced in the ISTEAM walks; instructors prompted sense making across spatial and temporal scales and learners were encouraged to continually reorient to place. Instructors also made space and encouraged foregrounding Indigenous Ways of Knowing. The findings in this study demonstrate that when learners are afforded these opportunities, complex forms of sense making emerge.

Chapter 5. PAPER 3: MEDIATIONAL CONSTELLATIONS OF SPATIAL INDEXING

Nature-culture relations are embedded in the design and implementation of field based science learning (Bang and Medin, 2010; Bang, Warren, Rosebery, and Medin, 2012). This manifests in physical artifacts, discourse, attentional prompts, and questions asked (e.g. Cole, 1996); in some cases this can lead to reimagining the possibilities for creating equitable field based (outdoor) science learning environments, yet all too often leads to gatekeeping about what counts as knowing something (Bang and Medin, 2010; Bang et al., 2012). How these learning environments are structured and the types of sense making they afford is the focus of this paper. More specifically, this paper explores the "mediational constellations" of sense making about biological and ecological systems as youth and adults go on forest walks. By closely examining the interplay of the tools, place, and people, and the underlying ontological and epistemological orientations that guide them, this work aims to contribute to the literature on designing and implementing outdoor, ecology-focused learning.

When it comes to teaching and learning about ecological phenomena, outdoor learning experiences can provide critical opportunities to engage in inquiry and exploration (Mogk and Goodwin, 2012). Authentic engagement in science practices is a shift that is reflected in the Next Generation Science Standards (NRC, 2012), and at the same time, provides opportunities for contextualized learning that can support deeper understanding of relationships and interactions within systems (see Paper 2, this dissertation). The design of field based learning experiences has often been taken up in the domain of environmental education. Environmental education has spanned locally and globally, from conservation education (Leopold, 1949) to international recognition of the need for greater environmental awareness (Tblisi Declaration, 1977).

However, there has been a divide in the purpose of EE, namely between knowing about the environment and caring about the earth (Chawla, 2006; Gruenewald, 2003; Orr, 1992). While these two are not mutually exclusive (and this is not an exhaustive list of the endeavors of EE), this illuminates how any manifestation of EE is ontologically, epistemologically, and axiologically grounded in a foundational relationship to the natural world, what Bang and colleagues call nature-culture relations (Bang et al., 2012; Bang and Marin, 2015). And making this orientation visible is the first step in designing and implementing ethical and just outdoor learning experiences.

As with all education, field based learning opportunities often reflect hegemonic and settled structures that are predicated on the erasure of Indigenous peoples whose stories, present day relations, and future possibilities are embedded (Bang et al., 2014; Tuck and Yang, 2012). Bang and colleagues emphasize that "the constructions of land, implicitly or explicitly as no longer Indigenous, are foundationally implicated in teaching and learning about the natural world, whether that be in science education, place-based education or environmental education" (Bang et al., 2014; p. 39). Thus, the types of learning that are possible are bounded within these cultural-historical systems that mediate how people see the world.

Returning now to the design of material and symbolic tools. The design and structure of learning environments that reflect and are open to epistemic heterogeneity (Rosebery, Ogonowski, DiSchino, and Warren, 2010) are critical for creating ethical and just classrooms[9]. Therefore, in both researching and imagining place-centered learning environments, arguably one must first consider the multiplicity of relationships and histories that comprise a place as "stories so far" (Massey, 2005). The purpose of this paper is to examine how place is constructed

[9] I use "classrooms" broadly to indicate formal or informal learning environments.

in two outdoor learning environments by examining both material and symbolic tools in interaction with people, place, and sense making.

Theoretical Framework

There have been a number of frameworks that attend to interactions between materials and people in learning. One of the most pervasive in sociocultural theories of learning is activity theory. Activity theory can be traced back to Vygotsky, who articulated a theory of learning and development that considers the role of cultural artifacts as mediators in human cognition and actions (Vygotsky, 1978; Engeström, 2001). In the second generation of activity theory, Leont'ev (1981) expanded on this model by broadening the unit of analysis beyond the individual learner to account for collective activity. Engeström (2001) then built out third generation activity theory, following the lines of Cole (1988) to study how multiple activity systems interact with one another to produce expansive learning opportunities. While these theories have considered the role of humans and artifacts, there was little consideration of how culture mediates these interactions. Cultural historical activity theory (CHAT), further expanded this framework to recognize that "learning ecologies are co-created and grounded in the cultural historical practices of the communities involved" (Gutiérrez and Vossoughi, 2010; p. 100), and that culture mediates interactions among humans and nonhumans (Gutiérrez, Morales, and Martinez, 2009). Within this framework, artifacts are recognized as both material and ideal (or symbolic), and creating a theory of learning requires researchers to attend arrangements of learning on social, spatial, and temporal scales (Cole et al., 2015; Gutiérrez et al., 2009).

However, in conversation with a critical place inquiry (Tuck and McKenzie, 2015b) this study also makes visible a sociomaterial orientation on learning in which the "environment, other animals, objects and artefacts are treated as integral to the enactment of human existence and

social life rather than as simply background context or tools" (Fenwick and Edwards, 2013). In this vein, a sociomaterial orientation foregrounds subject-subject relationships between humans and more-than-humans (Bang et al., 2014), or what Shotter (2006) calls "withness-thinking", by understanding that knowledge is relationally embedded in constellations of materials and interactions (Fenwick et al., 2012; Tuck and McKenzie, 2015b). Therefore, taking a sociomaterial orientation to CHAT, I ask the following research questions:

1. What is the role of designed materials (physical tools and instructional prompts) in sense making about ecological phenomena during forest walks?
2. How does this look different across cultural groups?

Context

In order to examine how learning unfolds in, and is mediated by culture and place, this cross-site case study (Borman, Clarke, Cotner, and Lee, 2006) spans two informal outdoor learning programs in the same urban park that is the traditional lands and waters of the Coast Salish peoples. Under the jurisdiction of the city's parks and recreation department, this park is bounded in a 200-acre densely forested area that borders the Salish Sea. The park consists of diverse forest ecosystems, wetlands, multiple streams that merge and run into the sound, and both a rocky intertidal and sandy beach area. This area is also home to traditional fishing grounds for Duwamish, Suquamish and other Coast Salish peoples. Within this park, I explore two informal, outdoor learning programs: An Indigenous-STEAM (science, technology, engineering, arts, and math) camp, and a Salmon Days program that educates the public about salmon in the park.

Study Site 1: I-STEAM

The data in this study is pulled from a larger Community Engaged Design Research (CEDR) project that designed and implemented expansive science practices grounded in both Indigenous ways of knowing (IWOK) and Western science (Bang and Marin, 2015)[10]. This manifested in the design of a Summer Indigenous STEAM (science, technology, engineering, arts and math; ISTEAM henceforth) program for youth that took place in large, forested parks within the city. The project was a partnership that included several organization partners, including a Native youth arts program and the University. In addition, there were a range of artists, ocean scientists, parent volunteers, graduate students, and Native community members that engaged in the design of the program. The planning for the program took place during a series of design meetings that utilized place-designing methods (Bang et al. 2016), professional developments, and art inquiries. For example, program facilitators and designers participated in collective professional developments to prepare for the program through field days with scientists as well as storytelling workshops with a local Native artist. In addition, program facilitators walked and planned in the places we would take youth. The program was intentionally designed around the tides to highlight the integral role that land and waters play in designed learning settings.

The lands on which the camp took place are traditional Duwamish, Suquamish, and other Coast Salish Peoples' territories, and have undergone dramatic transformation since European contact. A core tenet of the ISTEAM camps were to foreground relationships with lands, waters, and Coast Salish communities. Indigenous pedagogies and intergenerational cultural practices were central throughout the design and implementation of the ISTEAM camp. Learning

[10] Although Native science and Western science are not mutually exclusive, each rest on particular ontological and epistemological orientations to the world, or nature-culture relations.

activities were designed around “walking, reading, and storying the land”, which are routine practices in which individuals enact nature-culture relations that foreground relationships, roles, and reciprocity (Bang et al., 2014; Cajete, 1999; Marin and Bang, 2018; Smith, 2012). This included activities that centered on remaking relations with plants during scaffolded observation activities and plant relative walks. Instructors carried back-pocket guides with reminders about verbal and physical facilitation prompts to scaffold attention and observations in ways that were aligned with relational epistemologies (Bang et al., 2014; Cajete, 1999; Pugh et al., 2019).

Site 2: Salmon Days

Salmon Days is an ongoing volunteer-based community program in partnership with the public utilities department, a watershed-focused nonprofit based out of the park, and the local community. The program engaged the public in place-based learning about salmon, their life cycle, habitats, and the local efforts to maintain the seasonal run. Salmon volunteers set up tents and walk along the stream on weekends throughout the late fall during salmon spawning season. The Salmon Days program was founded to teach the community about salmon, and to further ensure efforts to protect the stream and surrounding habitat through stewardship practices. Volunteers interact with the public, and are trained by staff from education outreach branches of the public utilities department and the parks and recreation department. Some of the volunteers are also involved in other salmon-related volunteer efforts at the park. Families frequent the park to watch the salmon run, and often interact with the volunteers to ask questions or participate in a guided walk.

The families in this study are primarily European American identifying, and the children ranged from six to thirteen years of age. The walks were unstructured, and all of the participants were recruited at the park as they walked by the volunteer tent. All of the participants were in the

park specifically to see the salmon spawn, although some were also interested in additional hikes. Many of the family walks included interactions with the Salmon Days volunteers. Some families have never seen the salmon at Ravine before, and some visit the park each year during the run.

Studying family sense making in nonformal environments makes visible parent-child knowledge development (Luce et al., 2013). It also provides a lens for studying how home practices can speak with the design of traditional science instruction (Bell, Tzou, Bricker, and Baines, 2012). This is particularly important when considering a call for creating learning environments that embrace epistemic heterogeneity (Rosebery et al., 2012; Warren, Ogonowski, and Pothier, 2009).

Methods

This cross-site case study (Borman, Clarke, Cotner, and Lee, 2006) explores how place, tools, and people interact to make sense of ecological systems during forest walks. I use knowledge and interaction analysis (diSessa, Levin, and Brown, 2016; Goodwin, 2001; Jordan and Henderson, 1995) to study how sense making unfolds over time and place.

Data Corpus

The data corpus for this study consists of audio and video recordings that follow participants in both contexts as they go for forest and stream walks. I used a modified version of the Jefferson transcription system[11] (Jefferson, 2004). More specifically, I chose focal moments in which participants were interacting with the tools during their walks. For both ISTEAM and

[11] Transcription symbols: ((denotes descriptions of context or activity)) = refers to latched speech and (.) refers to micropause of insignificant amount of time.

Salmon Walks there were GoPro™ cameras worn with a chest harness to capture point-of-view. Youth took turns wearing these cameras in ISTEAM, and if there were multiple youth in a family in the Salmon Walks, one opted to wear the camera. In addition to these recordings, data also takes the form of field notes from the Salmon Walks volunteer training, as well as material tools for the Salmon Band Scavenger Hunt. For ISTEAM, the data corpus also included field notes from design meetings, and material tools related to instructional prompts for scaffolding attention (for the adult instructors), observational tools (for youth), and plant ID cards (for both youth and adults to use individually or in small groups). Tool details can be found in Appendix D.

Participants

ISTEAM

In the ISTEAM context, I follow two youth, Alana and Dalia, as they look for their "plant relative" bracken fern over the course of the camp. Other focal participants include fellow youth and instructors that they interacted with while they were trying to learn about and identify bracken fern.

Alana. Alana is Cherokee and Yaqui and was 11 years old at the time of the camp. She lived in Texas but was visiting family in the pacific northwest for the summer. She self-identified as someone who liked science, but was unfamiliar with the flora and fauna of the pacific northwest and was interested in learning more. Alana did not know many of the other youth before coming to ISTEAM, and in addition to learning about the landscape she was also navigating social relationships throughout the camp.

Dalia, Sophia, Jimmy, and Noah: Dalia, Chippewa and Colville, and Noah, Zacatecas, were both 10 years old at the time of the camp. They had been coming to ISTEAM since 2014

and were familiar many of the instructors and the structure of the camp. Sophia, 13, and Jimmy, 10, are siblings and are Kiowa, Creek, and Cherokee. They had been coming to ISTEAM since 2015 (this was their third year), however the year of this camp they were only able to come for two days. Their mother was also an instructor at the camp in previous years and was an environmental educator as well.

Priya (researcher). I was a designer and instructor at the ISTEAM camp. I am Indian-American and had been part of the ISTEAM camps in the northwest since they began in 2014. I am trained as an environmental educator and took part in the design and implementation of the tools. I am not Indigenous and over the years had been navigating ontological and epistemological differences between my culture and family and the pedagogical orientations in the camp. While I am experienced in teaching and learning about plants, I had initially approached nature-culture relations from a western epistemological frame (e.g. Bang and Medin, 2010; Hammer, Elby, Scherr, and Redish, 2004). This manifested in instructional habits and discourse, such as using "species" instead of "relatives" or "relations" when referring to plants, or prompting observations without first thinking with stories. Through the iterative process of design work (Wang and Hannafin, 2005), I began to navigate epistemological frames while teaching and learning in places (Bang and Medin, 2010). The current year of the camp in this (2017), was my fourth year in this program.

Salmon Walks

Pratt Family. In the Salmon Walks context, I follow the Pratt family as they come across two Salmon Boxes laid out on the trail during a Salmon Scavenger Hunt. They self-identified as "Caucasian". Tommy, 7 years old at the time of the walk, wore a GoPro mounted by a chest harness; other family members were his older sister Ayla (did not specify age, around 10 years

old), and his mother and father. Their father frequently talked about how they were new to the Pacific Northwest and was eager to learn more about the salmon and the landscape.

Analytic Framework

In order to understand the dynamic and interactional nature of learning in the outdoors, this paper utilizes a microethnographic approach (Gee, 1996) to analyze instantiations of tool engagement during forest walks. For ISTEAM this analysis followed two participants, Alana and Dalia, as they look for their plant relative bracken fern; data was chosen when participants were actively looking for bracken fern, and thus spanned 2 walks over 2 days. Salmon Stewards data focuses on how one family took up the Scavenger Hunt tool during their walk.

Using both knowledge and interaction analysis (e.g. diSessa, Levin, and Brown, 2016) I attend to moment-by-moment participant interactions with each other, artifacts, and instructional design (Gee and Green, 1998) to understand the mediational constellations of sense making. More specifically, I take a micro-longitudinal and micro-latitudinal approach to characterize how tools mediated sense making over time and place (DeLiema, Lee, Danish, Enyedy, and Brown, 2016). I focus on two dimensions of sense making to guide the analysis: (1) the role of designed tools (physical tools and instructional prompts in sense making, and (2) how the use of tools varied across cultural groups. In thinking about how outdoor learning environments can foster land-based pedagogies, these dimensions offer insight into the sociomaterial constellations that are mediated by tools.

Unit of Analysis: Spatial Indexing

I utilize spatial indexing as the unit of analysis to surface the constellations of artifacts, people, and places. Spatial indexing is a framework for studying observations in a way that

attends to the temporal, spatial and relational entanglements (Pugh, McGinty, and Bang, 2019); or what Cajete (2000) describes as "reading the land" (Bang and Marin, 2017; Marin and Bang, 2018). Drawing from theories of geosemiotics (Scollon and Scollon, 2003), and distributed semiotics (Kohn, 2013), spatial indexing manifests in the form of a semiotic indicator (an index) that is grounded in place. Therefore, spatial indexing is uniquely positioned to make visible the constellations of place and materials, as well as forms of reasoning across spatial and temporal scales.

Analysis

Case Study 1: Looking for Bracken Fern

Plant Relatives was an activity arc that took place over the course of the camp. It was deeply rooted in scaffolding observations using epistemological orientations from both Native science practices (Barnhardt and Kawagley, 2005; Cajete, 2000) and Western science practices (e.g. NRC, 2012). Material tools included *plant ID cards, plant relative observation tool*, and ideational tools (e.g. Cole, 1996) such as Native stories shared by S'klallam storyteller Donny, as well as "back pocket" observation prompts that instructors carried with them as a reminder to scaffold attention across multiple temporal, spatial, and relational scales. The Plant Relatives activity arc had stemmed from previous Community Engaged Design Research in Chicago (Bang et al., 2015); in this camp, the activity undergone many iterations over the years. These iterations were towards designing tools and scaffolds that fostered relational epistemologies, and included more explicit attention to plant relationships, habitat, and human-nature relations across space (multiple habitats) and over time (throughout the camp and connecting to home and cultural practices).

Part 1: Remaking Plant Relations

On day 1, instructors and the camp elder introduced the idea of foregrounding and remaking plant relatives throughout the week (e.g. Bang et al., 2014). This was coupled with a plant relatives template (Appendix A) as an attentional and observation scaffold. This plant template was intentionally designed to prompt youth to attend to morphological features of a plant, as well as relationships to other living and nonliving kinds within a particular habitat. On the second day of camp, there was a "plant relatives walk" in which each youth chose (or were given) a plant relative to make relations with over the course of the week. These tools and activities prompted the youth to attend to phenomena in multiple places in order to scaffold relational- and systems-level reasoning that is foundational to both Native and Western science (e.g. Cajete, 1999; Hmelo-Silver and Pfeffer, 2004; Hmelo-Silver, Jordan, Eberbach, and Sinha, 2017). The goal was not to only have specialized knowledge and relationships with one plant, but to understand agent-aggregate levels of a system (e.g. Levy and Wilensky, 2008) to show that plant fit into a larger community (system, to put another way), as well as how the system(s) it was in affected the plant.

Excerpt 1: Reading the Card

All of the youth in the camp received a plant relative card and began their walk in small groups of 4-5 students with an adult instructor. This first excerpt focuses on Dalia, who had bracken fern. She read some of the information about bracken fern before beginning the walk.

1	Dalia:	This is bracken fern ((showing fern to camera)), and it
2		grows near horsetail, and ((reading card)) "as the ground
3		continues to warm it quickly unfurls the stems and leaves
4		reach out into the summer sun, it can grow up to 9 feet tall
5		and the triangular shape takes up a lot of space. The leaves
6		are triangle shaped and are composed of 10 pairs of leaflets"

The information Dalia read from the card described bracken fern relationships to other plants (lines 1-2), the sun (line 3), and the warming ground (lines 2-4). It also described plant morphological features (lines 5-6) and growth patterns (line 4). Thus, the card "placed" bracken fern in a complex ecological system. Moreover, the information on the plant relative card was "semiotically charged" and "incorporate(d) ways of knowing and acting upon the world that have been inherited from predecessors" (Goodwin, 2013; p. 1). This semiotically charged tool held relationships to land that were ontologically grounded in both Native and Western Science.

Part 2: Searching for Bracken Fern

Alana and Dalia were in separate groups, and as Alana began her plant relatives walk she was searching for bracken fern along the trail. As in the excerpt above, Alana was also using the tool to guide her search.

Excerpt 2: Ferns on the trail

1	Alana	Ferns! ((turns to face large fern on side of trail))	
2		Will this…((turns fern frond over to look at underside)) No.	
3		((looks at another fern farther along the trail))	

Alana was not familiar with bracken fern, but was using morphological information, such as the presence of spores on certain ferns, from the plant ID card to guide her investigation as she walks

along the trail. As Alana walked over to three different ferns to look closely at the underside of the frond, she was using plant structures (e.g. no spores) as a heuristic, or what Goodwin (2013) calls a "substrate" her search for bracken fern. A substrate refers to materials -such as tools or talk, or things in the surrounding environment - that get acted upon as participants make meaning in collective action (Goodwin 2012), or what I call semiotic episodes.

Excerpt 3: Bracken fern grows near horsetail

As Alana walked along the path, she ran into Dalia. Dalia believed she had found bracken fern and shared some of the relational information that guided her search. Recalling what she shared with the camera in excerpt 1, Dalia explained that she had found the fern growing near horsetail.

4 5	Dalia	I found bracken fern ((showing Alana fern in her hand)). It grows near horsetail.	
7	Alana	This isn't Bracken Fern.	
8	Dalia	Yeah it is	
9 10	Alana	That's not bracken fern. ((turns towards plants and points to a fern)). Is that where you got it?	
12 13 14 15	Dalia	No I got it over there ((points up the trail)). I found it growing near horsetail. And this ((reaches for fern)) has the spores on it	
16 17	Alana	Oh it does? I thought that was the back ((continue walking up trail))	
18 19 20		((stops to look at fern on side of trail, turns over frond)) Then how come we didn't find ours near horsetail?	
21 22 23 24	Dalia	Cause you weren't by a horsetail. ((Look to side of the trail, pauses)) Oh there's more horsetail down there. That's where the Bracken Fern is	

25 26	Alana	((Alana starts walks down side trail towards stream, stops to check the underside of a fern))	
28 29 30	Alana	((stops near stream bank, reaches for a fern growing next to horsetail)) I found our fern!	
31	Dalia	I found a bunch more! ((calling to Alana from farther up the trail))	
32 33 34	Alana	So did I! ((walks up trail towards Dalia with fern in her hand)) (.) This was just on the ground.	

Alana and Dalia were toggling along spatial scales as they attended to phenomena in the perceptual field that were both locative and relational (Paper 2: Conceptual Constellations of Spatial Indexing). The substrate (plant ID card) included relational information about bracken fern, and Dalia used this information to guide her search. The meeting of Alana and Dalia on the trail introduced two new layers of substrates: Dalia, as a knowledgeable other, and ferns, as living members of the ecological landscape. Additionally, it becomes evident that even the role of the plant ID card shifted; although the use of the plant card as a substrate is the same in both settings, it scaffolded attention in different ways. Because a substrate is semiotically charged (Goodwin, 2013), the ways they were taken up reflects how the actor made meaning from it, and how that was aligned with an epistemic frame. While Alana used this card to attend to morphological features of bracken fern, Dalia used it to attend to relationships. This difference could be attributed to the fact that Dalia was in her fourth year of the ISTEAM camp and had been participating in plant relative activities over the years. Over the years she had been making

(or remaking) relations with plant relatives in across places. This suggests that the pedagogical orientation of the camp was accomplishing its goals of fostering relational epistemologies.

When Alana and Dalia met on the trail, their actions became enmeshed. Dalia explained that she found bracken fern “over there” (line 12) “growing near horsetail” (line 13). This action does a few things. First, Dalia indexes (“over there”) where she had seen bracken fern. This indexing called a prior experience, a relational one, into the current observation. The second thing this action does is introduce a new substrate, land (in the form of the surrounding, contextual environment), to Alana. Land, therefore, becomes a “lamination” (Goodwin, 2012), in the shared semiotic space among Alana, Dalia, and the physical tools. This lamination drove subsequent action for Alana (see Paper 1, this dissertation) to reorient to place, and Alana walked to the stream to find bracken fern.

Excerpt 4: Reorienting to Place

Alana continued to walk up the trail with the piece of fern that she had found on the ground near horsetail, and on the stream bank. She showed the fern frond to one of the adults, Priya, who was farther up the trail.

1	Priya:	You found bracken Fern?
2	Alana:	Yeah.
3	Priya:	You're sure it's Bracken?
4	Alana:	Yeah. Cause it doesn’t have the spores and it's by=
5	Noah:	= It doesn’t have the orange stuff on it.
6	Alana:	That's because it's Bracken Fern, Bracken Fern doesn't
7		have spores.

When Priya asked Alana if she was sure that she was indeed holding bracken fern, Alana responded referenced the morphological information about bracken fern (“it doesn’t have spores”) found on the plant ID card. This move reflected how strong the heuristic for attending to plant structure was in Alana’s biological knowledge organization (ojalehto and Medin, 2015).

Priya then asked where Alana found the fern in a subsequent epistemic move that, like Dalia, incorporated place in the semiotic field.

1	Priya:	Where did you find it? ((turning to Alana, asking about
2		bracken fern))
3	Alana:	Right there. It's like right back there ((pointing off trail)). It
4		grows by horsetail.
5	Priya:	Actually this is lady fern ((looking down at fern by
6		stream)). A different kind of fern.
7	Alana:	This? ((holding fern she had picked))
8	Priya:	I'm pretty sure. But I can't tell with just one piece.

In this pivot, Priya asked Alana where the fern was found, thus layering attention to habitat as another substrate. Fostering attentional practices towards relationships and habitat were part of both the design of tools and the teacher scaffolds, and thus were semiotically charged as symbolic tools (Cole, 1996). Embedded in this attentional prompt were orientations to land that foregrounded place as a relevant semiotic agent (Marin and Bang, 2018). Thus, not only did habitat become part of the conceptual constellation (Paper 2, this dissertation), but it added to the growing sociomaterial constellation that was distributed across people and place.

When Priya and Alana looked near the stream for bracken fern, they once again returned to the fern frond that Alana was holding.

1	Priya:	What's the pattern in the fern that you're holding?
2	Alana:	Okay this? Okay so this is bracken fern, that's what it is. I'm
3		pretty sure that's what it is.
4	Priya:	So was it, so look, was it a single stock that goes like this
5		((gesturing in upward motion to mimic a stalk))? And then
6		goes like this? ((gesturing tapered shape))
7	Alana:	Yeah.
8	Priya:	Or did it go like this and then have another branch here and
9		another branch here, each of them? ((gesturing branching
10		out of fern fronds))
11	Alana:	I don't know because it was just laying on the ground.
12	Priya:	Oh okay. Because they ((bracken fern)) look very similar to
13		lady fern, that's the reason why I ask. Lady ferns love to
14		

15 grow by stream banks. This is a lady fern right here ((points to fern growing by stream)).

Throughout this excerpt, Alana and Priya were toggling among habitat, relationships, and morphological orientations to come to know the fern Alana was holding. Priya asked Alana what the fern looked like by describing two similar types of ferns – a bracken fern and a lady fern. This method of comparing is a practice common in biological observations (Eberbach and Crowley, 2009), and was frequently used throughout the camp when students and instructors were seeking more information about plants. This comparison continued in the following excerpt.

1	Alana:	That's not what this is ((frond in hand)).
2	Priya:	That's different?
3	Alana:	It is.
4	Priya:	What's different about it?
5	Alana:	These are more clumped together than those. ((looking at
6		leaflets on frond))
7	Priya:	Would that be an age thing?
8	Alana:	Possibly.
9	Priya:	So let's see, these look ... They do have a similar pattern.
10	Alana:	This is the tip, maybe we can find out by the tip.
11	Priya:	Of alternating and then each of these branches off, kind of
12		alternating, right? It goes like one, and then one. And then
13		one, and then one. And they have little-
14	Alana:	Oh these are like right next to each other.
15	Priya:	But they also alternate. See what I mean? That's a young
16		one.
17	Alana:	These are the ... That's what this is.
18	Priya:	Okay. Cool let's see if we can find more.

Priya and Alana zoomed in to examine the patterns of leaflets on the frond, and their comparison still did not yield a definitive answer, and Priya says “let’s see if we can find more” (Line 14). Through the laminations of designed material tools and prompts to make land visible, Alana and Priya were constructing a rich constellation of sense making about both the fern Alana is

holding, and bracken fern, which they have yet to find. This sociomaterial constellation not only guided their thinking, but their movement through, and attention to, place.

Part 3: Continuing the Search on Day 4

Excerpt 5: We found bracken fern!

Day four of the camp included a long hike along the North Bluff trail. This trail went up along a ravine, densely forested with Douglas firs, maples, salmonberry among many others. Along trail, Priya noticed, for the first time in the camp, a bracken fern growing along the side of the trail. Priya and the youth began to observe the plant structures, relationships and habitat.

1	Priya:	Okay let's take a second, because this is the first bracken fern I've
2		seen. How about you?
3	Jimmy:	I don't even know what bracken fern is.
4	Alana:	It grows straight up ((holding and reading from plant relative card))
5	Priya:	Where are we?
6	Noah:	Ravine Park.
7	Jimmy:	We're in a place.
8	Sophia:	Under... we're around a lot of shrubbery.
9	Jimmy:	Is this Seattle?
10	Priya:	Shrubbery.
11	Jimmy:	Shrubbery, mate!
12	Noah:	We're in Seattle.
13	Sophia:	Ah there's like a few trees.
14	Noah:	We're in Seattle.
15	Jimmy:	There's like four trees.
16	Priya:	A few trees. So we're noting the relatives. What about the shape of
17		the land here?
18	Jimmy:	It's very...
19	Noah:	Hillside.
20	Priya:	Hillside...
21	Alana:	((reading plant card)) It says all over the world ((inaudible))
22	Priya:	Okay, but we're noticing. You're using that, let's use our
23		observations, just like Donny said in his story.

In this excerpt, there was an entanglement of many substrates and laminations, some of these carried over from earlier in the camp, and others from earlier in the walk. However, Priya then introduced another substrate to this episode, story. She reminded the group to “use our

observations, just like Donny said in his story" (lines 22-23). Throughout the hike that day, this group had been thinking with one story that Donny had shared earlier in the day that taught the students about how gifts from plant and land relations were made visible through observations of patterns. Thus, throughout this walk the group had been referencing and thinking with that story as they looked for patterns and their plant relatives. Re-storying the land was designed as a "time-space framing [to] counter… settler-colonial time-space structuration" (Bang and Marin, 2015), and the adults and elder continually made these visible throughout the camp.

Additionally, in this excerpt (5) the distributed nature of learning is also visible. Students and the instructor are engaged in continuous laminations, building on one another's prior utterances and orientations, including zooming out to ask if they were in Seattle (lines 9 and 12), noticing that there was a lot of shrubbery (lines 8, 10, and 11), and noticing that there were a lot of trees (lines 13, 15, 16). This reflects how meaning making unfolded in both individual and collective action, and "significance [was] built through and experienced in temporal bursts of sense-making, often in coordination with others, often left hanging in the realms of ambiguity" (Ochs, 2012; p. 144). Moreover, the substrates with which the youth and adult were using to build co-operative action – that is, collective sense making – incorporated the more-than-human world, in a form of "withness-thinking" (Shotter, 2006) that acknowledged land as a semiotic actor (Marin and Bang, 2018) and part of the mediational constellations of sense making.

Discussion: Mediational Constellations in ISTEAM

Mediational constellations of ecological sense making included a variety of attentional practices coupled with sociomaterial tools such as plant cards and instructional prompts; these, in turn, were associated with orientations to land that positioned the more-than-human world as a relevant semiotic actor within these conceptual constellations (Bang and Marin, 2018). The Plant

Relatives arc of the camp was designed to foster deep relationships with plant relatives throughout the week. “Getting to know” plant relatives epistemically positioned the more-than-human as relations, and learning manifested in “reading and storying the land” (Marin and Bang, 2018). For example, had this activity been decontextualized, Alana’s inquiry may have stopped at the first fern she saw without spores. Instead, through both material and dialogic scaffolds, place was indexed and incorporated into the semiotic field.

Making place visible and part of the mediational constellation contextualized sense making about biological and ecological phenomena. Many of the youth were continuously attending to relationships when looking for, or observing, their plant relatives. This was evident in Dalia’s connection to horsetail, and was also evident in the way Sophia, another student, attended to the “shrubbery” that was surrounding bracken fern when they did find it (excerpt 5, line 8). The attentional prompts were designed in a way that foregrounded Native science practices of observing (e.g. Bang and Marin, 2015; Brayboy and Castagno, 2008; Cajete, 1999). More specifically, by re-orienting to place, the physical and instructional tools resisted reductive and decontextualized form of observing that are typical in science classrooms, such as using plant morphology as the main method of coming to “know” bracken fern (e.g. Eberbach and Crowley, 2009). In fact, what was evident was that the youth in the camp were sense making over time and place (Figure 1). In the map, we can see where sense making about bracken fern happened during the walks. This manifested in moments of spatial indexing in which sense making was coupled with observations and spanning spatial, temporal, and/or relational scales. In other words, sense making was distributed, emplaced, and was narrated through relationships and stories, and was thus steeped in land-based pedagogies (Bang et al., 2014).

Figure 5-1 Places where Alana was looking for bracken fern.

Case Study 2: Salmon Scavenger Hunt

Salmon Walks: Scavenger Hunt

The following case study followed one family as they walked trails during an event called "Salmon Celebration". This community event was held on one Saturday in November and was hosted by the public utilities department and various volunteer-run organizations. One of the educational programs put on by the utilities and parks department was an activity called the Salmon Bracelet Scavenger Hunt (SPU, 2013). Boxes, or "treasure chests" were set up throughout the trails surrounding the creeks where salmon run. Families were given a scavenger hunt sheet at the long field (X marked spot) with a map of the trails with the locations of the treasure chests. When children answered trivia questions correctly, they took a bead, located in each box, to add to a salmon bracelet. Participants were given a map with the location of each box (Appendix B). The goal was to find all 9 of the treasure chests and complete the salmon bracelet. Each box had 3 levels of answers and students were tasked with writing answers to all 3 in order to receive a bead.

Part 1: Where in the watershed?

Tommy, his sister Ayla, and their parents walked for nearly an hour exploring the trails and walking along the stream. Their walk was just under a mile. As mentioned above, the family was relatively new to the Pacific Northwest and this was their first time seeing the salmon run in the park. As they walked up one of the trails that climbed the south side of the ravine, they found a box on the side of the trail.

Excerpt 6: Where are we?

1	Mom:	Oh, is that a box, or a question for us?
2	Tommy:	Lemme look
3	Ayla:	It is ((walk up to scavenger hunt box on log))
4	Mom:	Blue. It stands for, a watershed
5		((referencing scavenger hunt sheet)).
6		"When defined as any area of land
7		where water drains in a specific creek,
8		lake et cetera. Alright, pretend you're a
9		drop of rain. Fall from the sky and land
10		right to where you're standing. What
11		lake would you roll into?"
12	Dad:	Hmmmm.
13	Ayla:	What lake ((inaudible))

In this excerpt, the Pratt family finds the scavenger hunt box on the side of a trail, far from the creek where they started. The box had been intentionally placed in that location because it was on a hillside, and water drained into the creek where the salmon were running. As a substrate, this box was held multiple semiotic layers. First, the location of the box was, in itself, an serving an indexical function – to prompt attention to the hillside (Goodwin, 2013; Scollon and Scollon, 2003). Second, the description of a watershed in the box laminated another semiotic field into this constellation – namely the idea of a watershed. Finally, through this new framework that emerged from "properties of action and tool organization" (Goodwin, 2013; p. 12), there was a question about rainfall (lines 9-11), asking participants to imagine which lake they would roll into if they were a rainfall. The Pratt family does not initially answer the question.

Excerpt 7: “Where will our water go?”

14	Mom:	((reading card)) “True or false? A
15		raindrop falls on your home would fall on
16		the same large body of water as one that
17		goes on your school”
18		((family talking, inaudible))
19	Mom:	Alright so.
20	Ayla:	Level 1=
21	Mom:	= Water will- where will our water go?
22		This creek?=
23	Ayla:	= it will go here, if it drops here where
24		what lake will it go into?
25	Mom:	Oh what lake will it roll into?
26	Dad:	Um, what is it, Lake Washington right
27		here?
28	Mom:	Um, blue. ((picking out a bead for the
29		bracelet; referencing map and scavenger
30		hunt))

When the Mom reads the next question (lines 14-17), two new semiotic fields are introduced, the home and school. However, without knowledge of where they were in this location, these elements did not help with sense making. It is important to note that there was no lake nearby. They are located in a park in which water drains to a creek, and then down to the Puget Sound. In their overview of the role of observations in scientific reasoning, Smith and Reiser (2005) note that “without understanding the nature of and strategies for conducting observational investigations, students may only attend to features made explicit by teachers or other experts” (p. 318). Since there was no teacher in this scenario, this observational scaffold may have been useful to someone with more knowledge about the landscape, or more familiarity with where they were in relation to lakes and the sea. In this case, the same mediational tools would have played a different role in scaffolding attention in different groups.

Excerpt 8: Stages of the salmon life cycle

The Pratt family continued their walk down the trail and made their way to the next scavenger hunt box. This box as located on a section of the trail that is along the stream where salmon were visible. They began to read the next set of questions in the box.

1	Dad:	Alright sweetie read it to us, we'll see what we gotta do
2	Mom:	((reading from box, inaudible)) “Fill in the- salmon live in the fresh
3		water when they are babies and the ‘blank’ water when they are
4		adults”
5	Ayla:	Salt
6	Tommy:	True
7	Mom:	You say salt water too? ((reads next question)) "There are six stages
8		in a salmon's life cycle. Adult is the fifth stage. Can you name the
9		other 5 in order?"
10	Ayla:	Ahhh
11	Dad:	Ah we saw them on our ((inaudible)) too!
12	Mom:	On the what?
13	Dad:	On the - it was on that stand of all the eggs
14	Ayla:	Ugh! I didn't - I didn't read it!
15	Dad:	So one of them is fry, when they're little. Little teeny guys
16		((family starts walking up the trail away from the stream))
17	Mom:	Smolts or something?
18	Dad:	Look it up?
19	Mom:	Yeah we should look it up
20	Dad:	What was the question? 5 stages of the salmon?
21	Mom:	Uh huh what are the other 4? I have spinning game in my classroom
22		of this. But I haven't played it. I just put it out for my kids. It has the
23		stages of salmon.
24	Dad:	((asking Siri on smartphone)) What are the 5 stages of a salmon?
25	Siri:	((inaudible))
26	Mom:	If they had QR codes on there we would just QR it
27	Dad:	I know that'd be awesome right?

In this scavenger hunt box, the prompt question first asked the type of water that salmon live in during the adult stage of their life. The box was positioned along a freshwater stream with adult salmon running, although the answer in this case was salt water. Both Ayla and her brother Tommy were able to answer this question, likely in part because they had some domain knowledge about fresh and saltwater, or about where salmon live. In the next question about the stages of the salmon life cycle (lines 7-9), however, the family cannot remember the stages. Both

parents attempted to bring in other semiotic fields to help answer this question. The Mom referenced the "spinning game" in her classroom (line 21), and the Dad recalled the information tent that showed the stages of a life cycle (lines 11-13) that was currently set up in the field. Eventually, the Dad used digital technology (smartphone) to look up information about the salmon life cycle, a substrate that is increasingly the focus of much research on technologies in the learning sciences (e.g. Taylor, 2017).

Figure 5-2 Places where the Pratt family stopped at a Scavenger Hunt Box

Discussion: Mediational Constellations in Salmon Scavenger Hunt

In the Salmon Walks, finding a box was part of a scavenger hunt that was designed to piece together information about salmon habitat, behaviors, and relationships. Similar to the ISTEAM context, these elements were present in the designed scaffold of the tools. The nature of the questions prompted thinking across spatial and temporal scales, such as watersheds (excerpt 6), ocean and fresh waters (excerpt 8), and life cycles (excerpt 8). However, while the design of material tools thinking across scales, there were no accompanying scaffolds that asked participants to directly attend to localized place. Since the Pratt family had little prior knowledge

about the place they were in (and the tools inherently required this understanding) indexing phenomena in the local environment (excerpt 7, lines 21-26) did not help them answer the question. The design of the attentional scaffolds in the tools, combined with a lack of place-specific knowledge, led to a form of sense making that was abstracted and decontextualized. What emerged in excerpt 8, then, was a constellation of mediational tools that spanned digital technologies[12], prior experiences at work and on the walk, that "would never have met without [the family] redistributing their traits in new combinations" (Latour, 1995; p. 154). In other words, the substrates that the Pratt family pulled into the semiotic field did not necessarily laminate on one another to produce the co-operative action of answering trivia questions (Goodwin, 2012), but rather ended up arranged in a constellation of distributed materials. What emerged, then, were "knots" of sense making that stayed in one place (located around the box), but did not carry through the localized place, as was evident in the ISTEAM excerpts.

General Discussion

The mediational constellations were vastly different across the Salmon Scavenger Hunt and the ISTEAM context. The physical tools played a critical role not only in the forms of sense making that emerged, but also in how observations were scaffolded and how participants oriented to place. Looking across the two contexts, the moments of spatial indexing, when participants were prompted to observe and think across spatial, temporal, or relational scales, emerged in what could be described as "knots" (Massey, 2005). However, the nature of these knots were quite different. The ISTEAM knots were dynamic, interconnected, spanned time and place, and positioned land as a semiotic actor within the mediational constellation. These were moments in

[12] While studying the use of digital technology is a rapidly growing field of inquiry (e.g. Taylor, 2017; Taylor and Hall, 2013), I do not take this up in this study. However, inquiries into the entanglements of digital technologies, interaction, and complex ecological systems would be an exciting endeavor.

which various scales and semiotic fields were enmeshed and, in some cases, laminated in ways that produced co-operative action (Goodwin, 2013) and place-embedded forms of sense making. Sense making was thus distributed across the landscape. While the Salmon Scavenger hunt attempted to do this in design, the attentional scaffolds did not help the Pratt family make these connections. This is in part because the scavenger hunt consisted of known-answer questions, which did prompt further investigation to gather evidence and thus narrowed the possibility for personally meaningful or place-embedded forms of sense making (Reiser et al., 2001). Presenting the mediational constellations across these two settings is not designed to describe right and wrong ways of instruction, but rather draw attention to affordances and constraints of these tools in field based science learning.

Implications for Field Based Learning

There is increasing evidence that meaningful science learning happens in field based sites (Mogk and Goodwin, 2012; Windschitl, 2017). However, how these learning environments are constructed, including the design of instructional tools, plays significant role in the learning opportunities that unfold. Implications from this study suggest that when questions prompt thinking across spatial, temporal, and relational scales, but do not consider the emplaced nature of these interactions, then they are not enough to foster deep pedagogical engagement with the ecological systems thinking. Instead, this study demonstrated that when these inquiries are coupled with observational prompts that orient to place, *and* foster withness-thinking (Shotter, 2006), deeper forms of sense making unfold. Moreover, these forms of sense making are distributed in co-operative ways across people, place, and tools.

Chapter 6. GENERAL DISCUSSION

In order to design transformative and equitable field based science learning environments, we need to better understand how learning happens when outdoors. This, in part, stems from theories of learning that recognize scientific cognition as embodied, interactional, and embedded in the world (Hutchins and Renner, 2012). This also recognizes and builds from the idea that field based learning is foundational to many sciences including ecosystems science, geoscience, and biology, because it "provide[s] the opportunity to study phenomena in open, unconstrained, dynamic, and complex systems" (Mogk and Goodwin, 2012; p. 135). Importantly, field based learning environments can also provide opportunities to engage in both deeply cultural and scientific practices such as observation (Correa-Chávez and Rogoff, 2009; Marin and Bang, 2018; Eberbach and Crowley, 2009).

This dissertation explored the forms of sense making that emerged in an outdoor, forested environment in order to understand how learning about ecological systems unfolds in situated activity. I examined the constellations of interactions, practices, and mediational tools as youth and adults went on forest walks. More specifically, I looked at the role of culture and place by studying the similarities and differences in learning across two contexts: an informal Indigenous STEAM (science technology, engineering, arts, and math) camp with youth and adults, and nonformal Salmon Walks with primarily European-American. To do this I asked: How do place, culture, and cognition mediate sense making about complex ecological systems? To answer this, I examined three subsequent research questions and layered lines of analysis to characterize the form, function, and mediation of spatial indexing across two learning settings. These were:

1. Interactional constellations of spatial indexing:

1.1. What are the forms of observations in sense making about ecological phenomena during forest walks? How are observations positioned or utilized within semiotic episodes?

1.2. How do cultural and place mediate the practice of observing in biological and ecological sense making?

2. Conceptual constellations of spatial indexing:

2.1. What are the forms of sense making that emerge during forest walks, and how are these mediated by culture or place?

2.2. What is the role of observations in sense making about biological and ecological systems?

3. Mediational constellations of spatial indexing:

3.1. What is the role of designed materials (physical tools and instructional prompts) in sense making about ecological phenomena during forest walks?

3.2. How does this look different across cultural groups?

General Findings

Findings from these studies argue that when learners are in ecologically-rich learning environments, place drives sense making. Additionally, place-embedded sense making is also culturally-variant and is mediated by the design of tools. Finally, these findings demonstrate that place-embedded learning can foster complex ecological systems thinking, which is imperative in a world that is undergoing rapid ecological shifts caused by anthropogenic factors. Thus, there were three big findings from this dissertation:

1. place played a critical role in shaping sense making about ecological phenomena across both cultural contexts,

2. culture played a role in shaping knowledge organization in place, and thus drove sense making that emerged in different forms, and
3. mediational tools either scaffolded or detracted from place-embedded, complex forms of sense making when outdoors.

Spatial Indexing: Observations, culture, and complexity

In order to study how learning unfolded in place, I developed and examined the framework of *spatial indexing* as a cognitive activity of observing and sense making about ecological phenomena while in outdoor learning contexts. Spatial indexing allowed me to identify moments in which observations were intertwined with sense making across temporal, spatial, or relational scales. Importantly, this framework provided a lens to more deeply examine observations as a cognitive and cultural activity.

There has been a lot of research about the role of observations in scientific reasoning (e.g. Hmelo-Silver, Jordan, Eberbach, and Sinha, 2014; Eberbach and Crowley, 2009; Smith and Reiser, 2005). Observations have often been considered in service of other scientific practices, such as data collection and explanations (Grotzer et al, 2017; Mogk and Goodwin, 2012). This dissertation was after the cognitive processes of noticing and how cultural and place-embedded practices mediated the sense making that emerged. What I found was that across contexts, place actually drove epistemic action, and thus learning. In other words, while many have considered observation to be mediated by theory or domain knowledge, this dissertation highlighted that place and culture are important factors in how observations unfold and connect to sense making.

When talking about biological or ecological phenomena, participants in both contexts were more likely to orient to observations that were emplaced. This was evident in both the initiating epistemic actions and in the subsequent epistemic actions. This difference place

emergent and the rest of the IEAs show that attending to place, as an indexical operation, was foundational in semiotic episodes across both contexts; in other words, place drove epistemic action. Additionally, place was also highly prevalent as a subsequent epistemic action, meaning that youth and adults continually returned to place observations within semiotic episodes.

This finding also argues that while observations are both an everyday and discipline-specific practice, the two are not necessarily mutually exclusive. In fact, while both cultural groups were engaging in complex (and complex-emergent) forms of sense making about ecological phenomena, cultural practices and epistemic orientations were woven throughout the interactions. This point is particularly salient because for a long time, science (as a discipline) was considered an acultural endeavor; however, sociocultural theories of learning have made visible that all learning is cultural. More specifically, the Next Generation Science Standards specifically draw attention to this: "All science learning can be understood as a cultural accomplishment… What counts as learning and what types of knowledge are seen as important are closely tied to a community's values and what is useful in that community context" (NRC, 2012; pp. 283-284). The axiological positionings in science education expect learners, either explicitly or implicitly, to either draw on their varied cultural repertoires of practice (Gutiérrez and Rogoff, 2003), or to compartmentalize them in order to participate in normative modes of instruction learning (e.g. Bang and Medin, 2010). The findings in Chapter 4, for example, showed that walking in ecologically-rich environments allowed children and adults to engage in complex forms of sense making; however, a closer look at the discourse and attention reflected cultural ways of thinking and knowing that were embedded in the forms of sense making that emerged.

The role of place and culture in sense making about ecological phenomena

Place played a critical role in shaping how interaction was organized in ecologically-rich environments. When studying interactions, both youth and adults were more likely to engage in sense making that stemmed from observations of locally salient phenomena. However, while there were similar trends in the interactional constellations between the two contexts, there were cultural differences in how observations were organized that imply a different orientation to place. That is, Native participants in the STEAM camp were more likely to attend to phenomena relationally than the participants in the Salmon Walks. This was evident in how Native participants were more likely to reorient to place regardless of the initiating epistemic action (Paper 1). In other words, place was consistently a semiotic actor (Marin and Bang, 2018) in sense making about ecological and biological phenomena.

This also was evident in conceptual organization across both contexts[13]. Across both contexts, participants were reasoning across components, mechanisms, and phenomena (CMP), a critical part of complex systems reasoning (Hmelo-Silver et al., 2017). However, statistical analyses demonstrated how culture was a significant factor in whether participants reasoned about causal links (e.g. Grotzer et al., 2013) or agent-aggregate levels (e.g. Levy and Wilensky, 2008). More specifically, the Native participants in ISTEAM were more likely to reason about agent and aggregate phenomena when the grounding epistemic action was emplaced (stemmed from place) or was place speculative (was rooted in an anticipation, or reflection, about the place they were in). Finally, there were significant statistical differences between cultural groups in the temporal scales that were attended to in sense making. For instance, the instructors and Native

[13] It is important to note that when I talk about conceptual organization, I am thinking of knowledge as distributed among people and context. In other words sense making happened in groups.

youth in ISTEAM were more likely to connect phenomena to prior experiences (such as family or walk experiences), while the Salmon families were more likely to reason about life cycles of biological kinds. This suggests a difference in knowledge organization between the ISTEAM and Salmon Walks participants. More specifically, that Native participants were more likely to position ecological phenomena as psychologically close (e.g. Bang et al., 2007). Whereas the families in the Salmon Walks were more likely to reason about the life cycles of biological phenomena during their walks.

Finally, in the third paper examined how tools – both material and instructional – mediated sense making. This paper demonstrated that even when material tools prompted attention to place, place-emergent forms of "reading the land" emerged in the ISTEAM context with both instructional scaffolds and pedagogical orientations that foregrounded relational epistemologies stemming from Indigenous Ways of Knowing (Bang et al, 2015; Cajete, 1999). Overall, this led to emplaced sense making that was distributed across time and place, that continually referenced land as a relevant semiotic actor (Marin and Bang, 2018).

These differences in knowledge organization both reflect and extend prior research. For instance, while there has been increasing research demonstrating cultural differences in cognition, this has often been studied at the level of the individual (e.g. Atran and Medin, 2004; ojalehto and Medin, 2015; Nisbett et al., 2001). The studies in this dissertation demonstrated that emplaced, complex forms of thinking were distributed across people, place, and material tools, thus in constellations of learning (Gutiérrez and Rogoff, 2003). Moreover, they were situated in co-operative actions that recycled and built on the semiotic tools made available (Goodwin, 2013; Goodwin, 2018), and unfolded in ways that demonstrated cultural variation, an area of

inquiry that has received little attention (for exceptions see Marin, 2013; Bang and Marin, 2015; Marin and Bang, 2018).

Implications

Providing opportunities for equitable, place emergent, field based learning

While there is a wide range of literature on the benefits of outdoor learning (Williams and Dixon, 2013), classroom teachers typically have little experience with taking kids outside (Dillon et al, 2006). The findings in this dissertation makes an interactional and conceptual argument for why place-embedded learning about science is important. Place, put simply, can be defined as "the nexus of culture and the environment" (Gruenwald, 2008), and creating learning opportunities that foreground place allow learners to make personally and culturally meaningful connections to what they are studying (e.g. Bang et al., 2017; Bricker and Bell, 2013; Tan and Calabrese Barton, 2012). Additionally, in thinking about connections between ecological systems and human populations, it is well-known that certain communities are disproportionately affected by the impacts of climate change. This also means that many of these communities, including Indigenous peoples, have been adapting to ecological and social changes and have systems of knowledges and practices that reflect these experiences (Whyte, 2013).

As demonstrated in this dissertation, when youth and adults were in ecologically-rich outdoor environments, place was central in sense making. Additionally, place-emergent and place-focused epistemic actions, or forms of reasoning, were linked with more talk about complex ecological phenomena. These findings suggest that outdoor learning opportunities are important for teaching and learning about complex ecological systems. More specifically, there is a need for learning environments that allow youth to drive exploration through active inquiry that stems from place. While much of the literature on observations has talked about the

importance of how domain knowledge and theory scaffold observations, this dissertation suggests that there is also a need for more place-emergent scaffolding, and that this scaffolding can surface and make space for epistemic heterogeneity. This can be fostered with attentional prompts that ask students to attend to place in ways that foreground relationships across time and place, which can support complexity thinking in science. For instance, asking students to explore phenomena in multiple places and over time not only reflects authentic science practices, but can lead to more complex and engaging forms of reasoning.

Indigenous Ways of Knowing and Native Science

> "Ultimately, science is a storytelling for understanding of the natural world. Indigenous science is also a process of understanding, a way of coming to know rightful relationships to the natural world that yields life." (Cajete, 2000, p. 80).

The notion of foregrounding relationships is a cornerstone of Native Science and many Indigenous Ways of Knowing[14] (Barhardt and Kawagley, 2005; Cajete, 2000), and drives observation in important ways. When thinking about designing for observations, it is important to consider that not only are observations a scientific practice, but also reflect particular cultural orientations (e.g. Correa-Chávez, Rogoff, and Mejía Arauz, 2005; Marin, 2013; Rogoff, 2014) that open or close possibilities for engaging Indigenous youth in equitable and just ways. For example, "unlike Western Science, Native Science does not attempt to generalize observations to universal laws or to combine observations in order to make predictions about nature" (Brayboy and Castagno, 2008; p. 13). Brayboy and Castagno point to a difference in practices that ultimately reflect a particular orientation to understanding the world. For instance, observations

[14] However, I echo Brayboy and Castagno (2008) to offer a disclaimer that this analysis does not intend to essentialize all Indigenous ways of knowing, but rather to illuminate and extend the research that has demonstrated practice-oriented and epistemological differences between cultural communities (e.g. Bang, Medin, and Atran, 2007).

are often used in western science as a means to draw generalized conclusions, a form of inductive reasoning that permeates much of the sciences and science education. This form of reasoning is epistemically predicated on reducing phenomena down to parts in order to understand the whole. While this method has merit and has contributed to the advancement of many scientific theories, it does not, as a standalone, provide a comprehensive understanding of subjects-in-the-world, or what Shotter (2006) calls "withness-thinking". The manifestation of relational epistemologies in interactions and in the design of pedagogical tools demonstrated forms of reasoning that not only reflected complexity thinking, but systems thinking in ways that were meaningful.

This dissertation, therefore, makes the case that field based learning environments can create more equitable and personally-consequential (Bricker and Bell, 2013) learning experiences for youth, and thus have implications for designing with and for Indigenous communities towards decolonization and cultural resurgence (Bang et al, 2015; Simpson, 2014; Wildcat et al, 2014). For instance, by designing with Indigenous pedagogies of walking (Marin, 2013), and foregrounding relational epistemologies (Cajete, 2000), this dissertation demonstrated the ISTEAM was accomplishing what land-based pedagogies. Bang and colleagues articulate this in their perspective on place based education:

> "For us science education, place-based education, and environmental education are critical sites of struggle because they typically reify the epistemic, ontological, and axiological issues that have shaped Indigenous histories (Castagno and Brayboy 2008). More hopefully, we also see them as sites of potential transformings—forming a nexus between epistemologies and ontologies of land and indigenous futurity. In our view, realizing this transformative potential will require engaging with land-based perspectives and desettling (Bang et al. 2012) dynamics of settler colonialism that remain quietly buried in educational environments that engage learning about, with and in the Land and all of its dwellers. (Bang et al., 2014, p. 39)

Thus, taking seriously how place is constructed, the temporal and spatial scales that are attended to, can either open or constrain possibilities for learning.

Theoretically, this dissertation extended the literature on how observations play an important role in sense making about complex ecological systems. This is particularly relevant to the design and implementation of science learning programs which want to incorporate observations in investigations, but have yet to fully explore the theoretically- and culturally-driven depths of observational practices.

Limitations

The studies in this dissertation took the form of a layered analysis to study interactional, conceptual, and mediational constellations of sense making across two walking contexts in the same park. However, it is important to consider how the structure of the walks and the time of year may also play a critical role in the forms of reasoning that emerged. This dissertation, of course, does not look at two similarly-structured programs; there are numerous pedagogical differences. First, the two contexts occurred at different times of the year; Salmon Walks were in the late fall and the ISTEAM camp was in the summer. It is possible that seasons had an effect on sense making or attention. Second, the Salmon Walks explored parent-child sense making in unstructured stream walks, while the ISTEAM walks were part of a larger outdoor camp with some participants that had been attending for consecutive summers. Thus the findings in this study do not generalize to European Americans and Indigenous peoples writ large. Rather, they extended the literature on cultural variation, and call for more research into how place and culture shape knowledge organization.

Future Research

As mentioned above, the two contexts took place in different seasons. Future studies could examine if and how seasons play a role in the interactional and conceptual nature of sense making. For instance, Tuck and McKenzie (2014) talk about how relationships to harvest and food, what they call "eating the landscape" (e.g. Salmón, 2012), reflect an ontological orientation to place. Harvesting berries for foods and plants for medicine was threaded throughout the ISTEAM camp. Looking at this over seasons, or looking at how eating relationships are similar or different across cultural groups in the same season, offer exciting areas of inquiry.

Another area of inquiry could be to look at how sense making unfolded over space and time by looking at consecutive semiotic episodes (e.g. Appendix F). Analyzing walks in this way would provide a deeper understanding of the micro-longitudinal and micro-latitudinal (DeLiema, Lee, Danish, Enyedy, and Brown, 2016) processes of learning as participants navigate the trail. More specifically, this would allow the researcher to trace if and how sense making was threaded across the landscape. Additional work on these sense making processes would not only contribute to interactional and conceptual theories of learning, but would also have implications for the design of field based learning environments.

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APPENDIX A

ISTEAM Walk Details

IS1a- Beach to Field: Wetlands.	This walk follows four children and two adults as they make their way back to the camp base in the Long Meadow. This walk starts out on the beach as the group passes by the culverts which connect Cascading Creek to the Puget Sound. Before the seawall and railroad tracks were built this area was once rich estuarian zone that is now mostly sand with eel grass beds a few yards off shore. The group stops to talk about what an estuary, a place where fresh and salty water "mingle". They perform a "Salty Fresh" dance before continuing on their way over the railroad trestle. From here, Ron splits from the group and Maya and the four students walk through the wetlands to get back to camp.
IS1b- Beach to Field: Road.	This walk followed a group of six children, two adults, and an infant carried by one of the adults. While walk *IS1a* walked through the wetlands, this group walked on a trail along the road. They stopped to pick thimbleberries along the way.
IS2 - Imprint Pond:	This *Plant Relatives* walk departs from the camp base in the Long Meadow to the Imprint Pond. The Imprint Pond is a small pool where juvenile salmon are raised and released as fry (a 3-5 week process) in the winter to early spring. Juvenile salmon follow leave the imprint pond and follow Swift Creek, eventually meeting up with Cascading Creek and down to the Puget Sound. In the fall, adult spawning salmon will make their way back up this stream. This walk follows Swift Creek up to the Pond.
IS3 - Wetland Exploration:	Although initially part of the larger North Bluff Hike (IS4), this segment follows two groups that branch off from the whole group before a bathroom break and arriving at the North Bluff trailhead. These groups walk downstream along Cascading Creek, through the wetlands, and eventually make their way to meet up with the rest of the group. There are six adults and nine children; of the six adults, one (Luis) is holding the mobile camera and doing data collection, and two (Sam and Anna) are visitors from a University course run by Minna and Oscar and they were not part of the design of the camp.
IS4 North Bluff Hike:	The entire camp participated in the North Bluff *Plant Relatives* hike. The location of this hike was intentional because some of the instructors had seen a plant, stinging nettle, along the trail in previous walks; the group was intending to harvest nettle to make tea. Every group started the walk from western portion of park, following a trail along the northern part of ravine and eventually ending at the imprint ponds. The trail winds through a forest dominated by Douglas firs, Western Redcedars, Bigleaf Maples, huckleberries, salmonberries, thimbleberries and some nettle scattered along the trail, among other flora commonly found in this environment. The trail consists of a series of inclines and declines, although generally the trail slowly ascends.

APPENDIX B

Initiating Epistemic Action

	Total IEA	Place Emergent + Speculative	Place Emergent + Tool	Place Speculative + Tool	Tool + Place Extracted	Place Emergent + Extracted
Salmon Walks:	161	4	7	4	0	0
ISTEAM:	203	12	5	4	1	1

APPENDIX C

Chi Square Test of Independence

Causal Links across Initiating Epistemic Actions

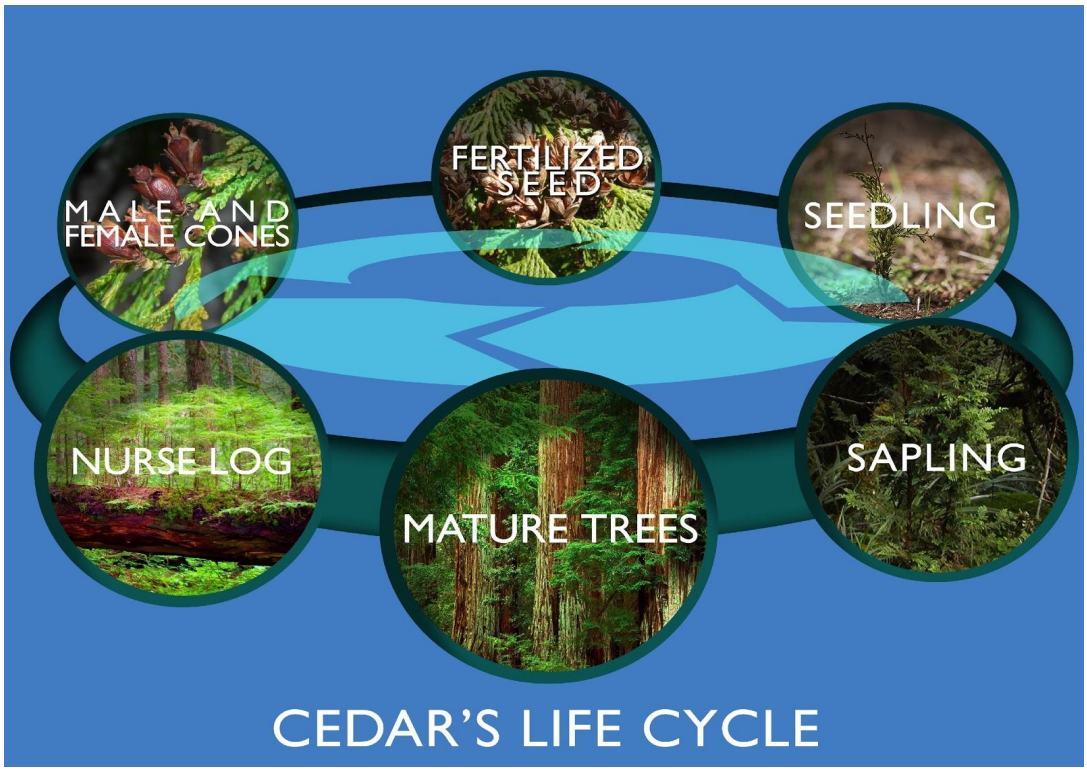
	Salmon Walks	ISTEAM	χ^2(df)	*p value*	*Significant*
Chaining					
Place Emergent	30	47	5.4	0.53715232	
Abstract Speculative	7	17	9.7	0.04673662	**
Abstract Tool	13	28	8.8	0.34780332	
Place Extractive	4	14	0.3	0.93141372	
Webbing					
Place Emergent	13	28	8.8	0.16451043	
Abstract Speculative	1	12	10.9	0.00259314	**
Abstract Tool	10	6	4.5	0.25680986	
Place Extractive	0	7	3.2	0.14729914	

Component-Mechanism-Phenomena across Initiating Epistemic Actions				
Component				
Place Emergent	50	73	4.4	0.68849911
Abstract Speculative	12	23	10.6	0.07252165
Abstract Tool	12	21	7.9	0.16882841
Place Extractive	2	12	2.5	0.43496716
Mechanism				
Place Emergent	43	43	13	0.15588152
Abstract Speculative	9	16	6.7	0.17820115
Abstract Tool	11	11	0.7	0.87569084
Place Extractive	5	8	4	0.18798576
Phenomenon				
Place Emergent	33	43	1.5	0.86219789

Abstract Speculative	5	11	5.8	0.1450961
Abstract Tool	6	7	0.6	0.8750459
Place Extractive	1	10	3.1	0.2709124 3

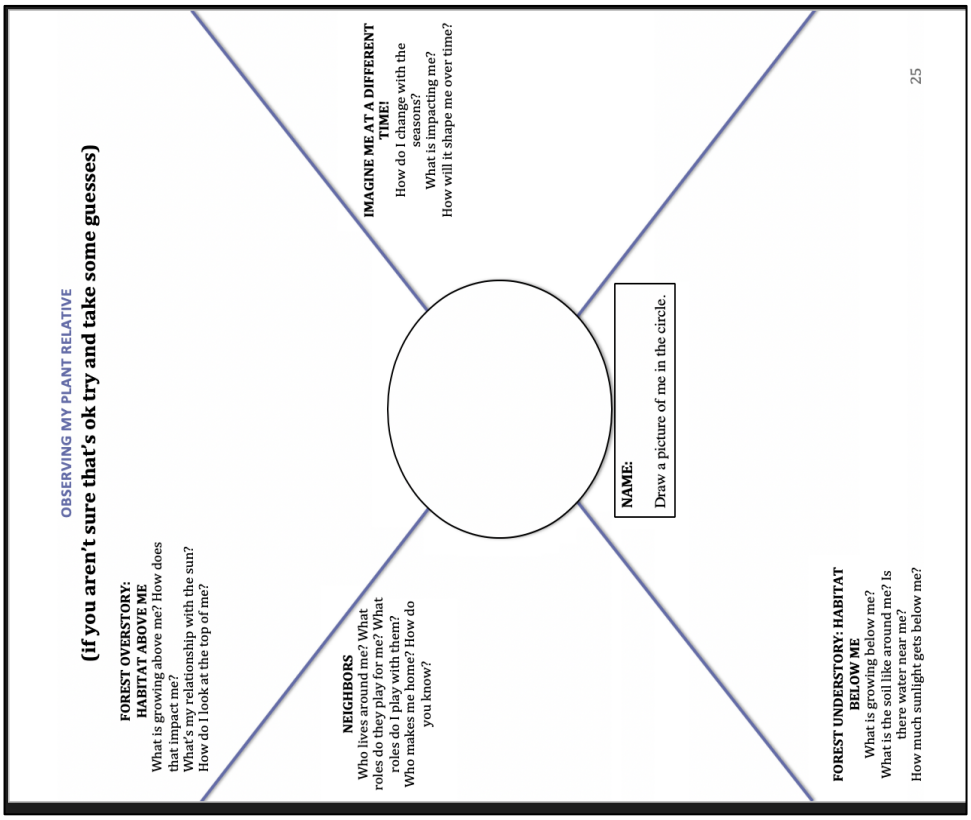
APPENDIX D

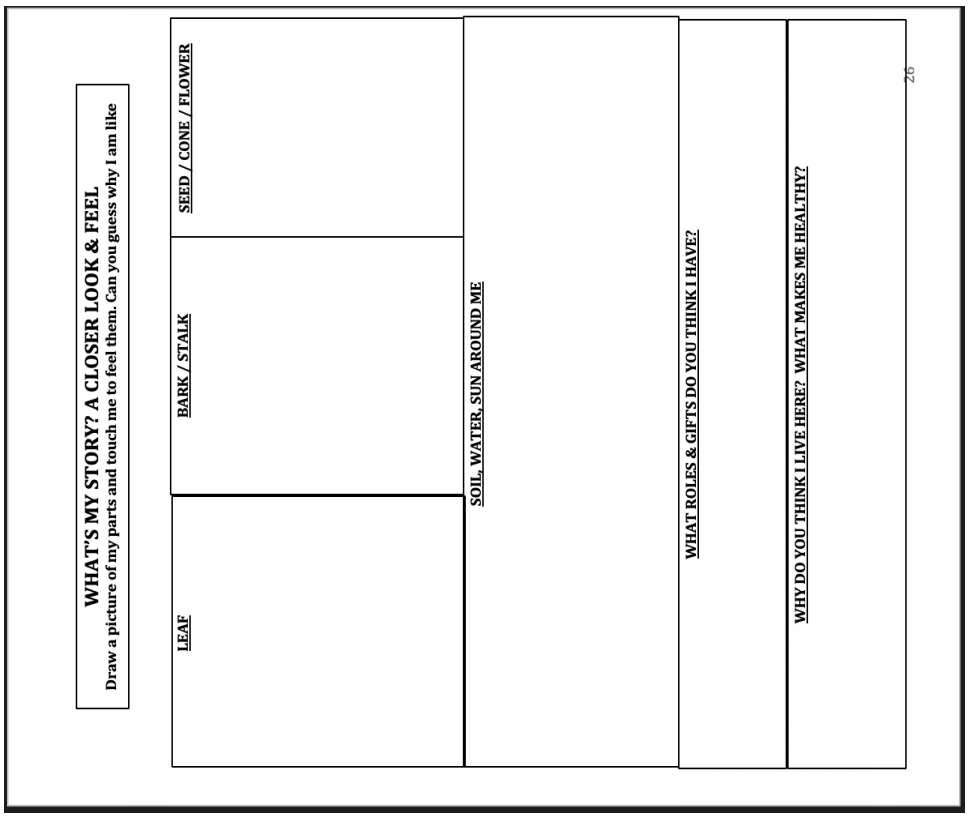
ISTEAM Tools: Plant Relatives in Relations


MALE AND FEMALE CONES
FERTILIZED SEED
SEEDLING
NURSE LOG
MATURE TREES
SAPLING
CEDAR'S LIFE CYCLE

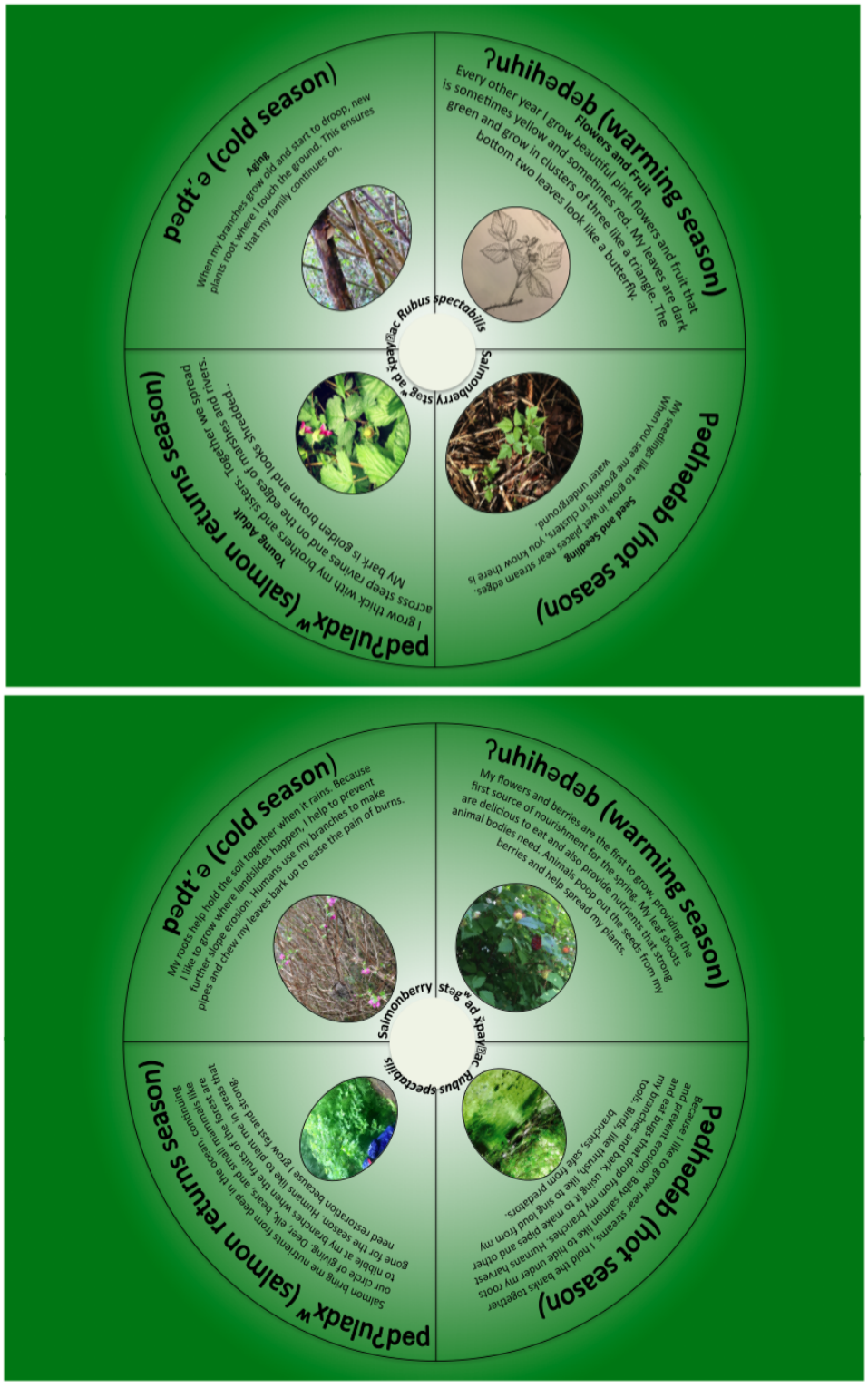

PROTECTS SALMON HABITAT BY PROVIDING SHADE TO COOL WATER
OLDER TREES CREATE DENS FOR BLACK BEAR
PEOPLE USE CEDAR AS SHELTER, MEDICINE, CLOTHING, BASKETRY, CANOES, TOOLS AND ART.
WHEN SALMON DIE THEY BECOME FOOD FOR CEDAR
FORESTS BECOME HOME FOR SPOTTED OWL
FALLEN CEDAR BECOME NURSERIES FOR NEW PLANTS
SHELTERS BIRDS AND SQUIRRELS
CEDAR IN THE WEB OF LIFE

Plant Relatives Observation Scaffold





Plant Relatives ID Card



APPENDIX E

Scavenger Hunt Map with locations of each trivia box

APPENDIX F

Further inquiry into micro-longitudinal and micro-latitudinal sense making across time and place in forest walks.

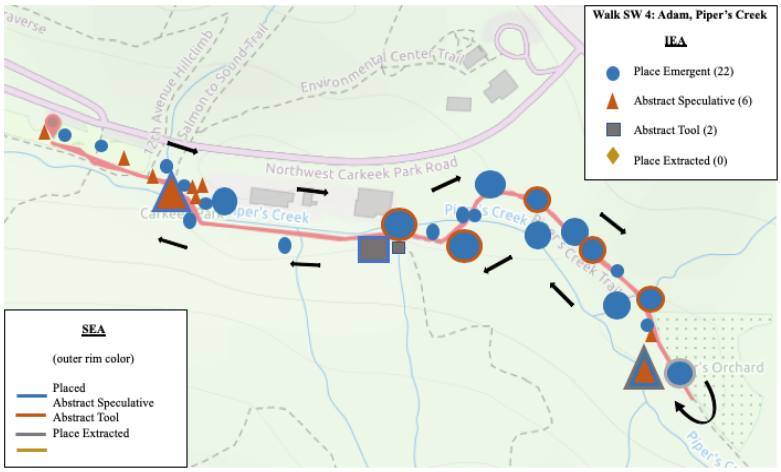


Figure 0-1 Salmon Walk: Anderson Family

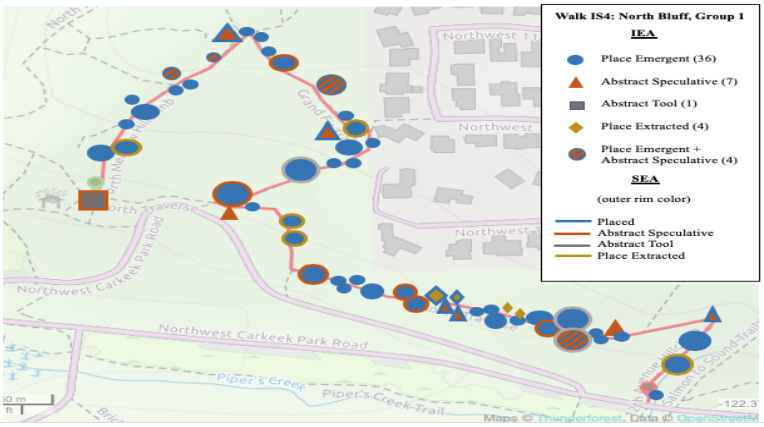


Figure 0-2 ISTEAM Walk: North Bluff Trail

VITA

Priya Pugh has worked with children for over 20 years, and has been an environmental educator for nearly 10 years. In this role, she has designed, implemented, and researched outdoor learning for youth and adults. Priya's research focuses on the intersection of place, culture, and cognition. Primary research methods include Community Engaged Design Research, Participatory Design Research. She also engages in mixed-methods analytic styles, including interaction and conversation analysis.