Pugh, P., McGinty, M., & Bang. M. (2019). Relational Epistemologies in Land Based Learning Environments: Reasoning about Ecological Systems and Spatial Indexing in Motion. Culture Studies in Science Education, 2(14), 425-448.

Relational epistemologies in land based learning environments: Reasoning about ecological systems and spatial indexing in motion

ABSTRACT

Social and cultural practices in learning settings are sites for leveraging and/or re-mediating sustainable and just conceptions of nature-culture relations to meet changing environmental demands of 21st century. In this study, we take a microethnographic (Gee and Green, 1998) approach to examine sense-making among three youth while engaged in a walking activity in which they were asked to embody a plant during a summer land-based educational program focused on supporting Native youth to engage in cultural practices of reading the land. We found that the micro-practice of spatial indexing dynamically mediated sense-making about ecological systems.

The 21st century marks a critical time in human history. A time which demands that the social structures of human communities be re-mediated towards more sustainable and just assemblages and forms of life that know and take seriously complex socio-ecological systems. While the complexity of the task before us is stunning, we suggest a, if not the, pivotal dimension of this change rests on the remaking of nature-culture relations (e.g., Tallbear 2011; Latour 1991) even, or perhaps particularly, in urban places. Human-nature relations are enacted in human activity and reflect implicit and explicit epistemic, ontological, and axiological dimensions and commitments

that vary across cultural communities. In this sense human-nature relations are intertwined in cultural practices, wherein culture is understood as the constellation of historically, contextually, and sociomaterially mediated practices that are distributed across persons, tools, and places (Nasir et al. 2006; Rogoff 2003).

Although the study of human cognition about the natural world is a robust area of scholarship, the field has been dominated by western notions of human-nature relations (ojahleto and Medin 2015). In addition, scholarship focused on learning and teaching has overwhelmingly been conducted in human-saturated environments where the natural world has been minimized or rendered nearly invisible except through human-made artifacts (e.g., computers, books) (Bang, Faber, Gurneau, Marin, and Soto 2016). The relatively narrow spaces in which careful study of learning has occurred with respect to human-nature relations has not only constrained what we know about human learning in, with, and about the natural world, it has also limited how we have imagined, designed and enacted learning and making relationships with the natural world in educational settings (Bang 2016). Expanding the possible forms of nature-culture relations in learning environments are necessary to better engage young people in learning about complex socio-ecological systems responsive to 21st century demands in just and sustainable ways. For Indigenous peoples, expanding nature-culture relations in learning environments is also central to re-mediating education from its historical intentions of eradicating Indigenous knowledge systems - that is Indigenous nature-culture relations - what some scholars have called forms of onto-epistemic violence (Burkhart 2004; Marker 2006) to spaces which can contribute to Indigenous resurgence and wellbeing (e.g. Simpson 2014). Central to this endeavor is carefully considering the ways in which culture, identity and epistemic activity are conceptualized and designed for in learning environments.

Culture, Identity and Relational Epistemologies

In the field of science education scholars are increasingly recognizing the role of culture, identity, and power in science education (Brown et al. 2016; Rosebery, Warren, and Tucker-Raymond 2016) and how these dimensions are intertwined and reflected in epistemic orientations and activity (Bang and Medin 2010). A significant body of work in science education has focused on the Nature of Science (NOS) and epistemic orientations with respect to science learning and teaching (e.g. for review see Lederman 2007). While scholars are increasingly recognizing that NOS is socially and culturally embedded, there is significant work to unearth careful and detailed specifics of these dimensions. Further NOS has yet to adequately excavate the ways in which it has relied on the hierarchical ordering of epistemic orientations that are deeply saturated in the unfolding histories of nations that reflect racism, sexism, and coloniality (e.g. Grosfoguel 2012; 2013). Often when scholars have engaged in understanding students' and teachers' NOS or epistemic orientations that are distinct from western science they have done so with the goal of replacing, changing, or facilitating their participation in dominant paradigms instead of working to develop learning environments that engage epistemic heterogeneity (Rosebery et al. 2010).

In efforts to contribute to foundational knowledge about human learning and development and work towards more equitable learning environments for Indigenous youth, families, and communities, we and other scholars (e.g., Jensen, Scheller, and Wind 2015) have been studying *relational epistemologies* and more broadly Indigenous knowledge systems (e.g., Brayboy and Castagno 2008; Cajete 1999; Medin and Bang 2014). Relational epistemologies can be summarized as 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.

In order to better understand the enactment of relational epistemologies in non-human-centered places, we have focused this study on intergenerational cultural practices of *walking, reading, and storying the land* and the ways in which knowledge and sense-making unfold in such cultural practices (Marin and Bang 2018; Marin 2013). Walking, reading, and storying the land are routine practices in which individuals make and enact human-nature relations and apprentice children into epistemic, ontological, and axiological stances in human-nature relations. From this orientation we have been designing learning environments that engage pedagogies emergent from both these practices and decoloniality (e.g., Bang, Curley, Kessel, Marin, Suzukovich III, and Strack 2014).

Recently Ananda Marin and Megan Bang (2018) argued that these practices involve the coordination of attention and observation between humans and more-than-human kinds for the purposes of identifying and naming kinds, generating explanations, and finding evidence to create a story about the perceptual field (see also Massey 2005; Ingold 2000). While scholars increasingly are recognizing that a central task in learning involves the coordination of perception, attention, and motivation in movement (e.g., Grotzer and Tutwiler 2014; Taylor and Hall, 2013), an important distinction in our work rests on the ontological claim that land itself, though never fixed and always becoming, is a relevant semiotic field in meaning making (Bang and Marin 2018). Relatedly, we also conjecture that more-than-human life has significantly larger and more important roles in learning and development than typically conceived, particularly with respect to relational epistemologies (Bang and Marin, 2015). This stance marks a distinct departure from much of the foundational study in human learning and in educational research and is deeply

informed by the community-based work with Indigenous communities we have engaged in, as well as Indigenous scholarship more broadly (e.g. Barnhardt and Kawagley 1998; Deloria 1991).

In our work we have been particularly interested in how relational epistemologies and cultural frameworks about human-nature relations may be impacting complex socio-ecological systems reasoning. We suggest that relational epistemologies in motion, or on the move (see Headrick-Taylor 2017), are an important area of study, and can afford new understandings about how the process of sense-making works in the practice of walking, reading, and storying the land. While other forms of land based practices are also rich areas of study, we suggest walking, reading, and storying the land is a fundamental human activity that all people likely engage in to some extent. In this paper, we argue that *spatial indexing* is a key aspect of sense-making in that is emphasized in walking - or mobile - forms of learning. While we think this is true for all learners, we especially think this is important for Indigenous learners. As efforts towards Indigenous resurgence and forms of land based education continue to grow (e.g. Calderon 2014; Tuck and McKenzie 2014) our understandings of how learning works in these contexts can also grow ensuring that they become ever more effective. Further, cultural variables in conceptual and epistemic ecologies shape possible forms of spatial indexing that have affordances or constraints for reasoning about complex socio-ecological systems.

Indexing: Spatial, Temporal, and Relational

We propose a framework of *spatial indexing* to describe a critical component of the practice of reading the land. Spatial indexing broadly refers to any time we notice something in our spatial field and it alludes to something else on temporally, spatially, or relationally dynamic scales. Drawing from theories of geosemiotics (Scollon and Scollon, 2003), and distributed semiotics, we

surface the entanglements of spatial, temporal, and relational dynamics that lead to sense making about complex ecological phenomena. Although engaging in very different approaches, both Ron Scollon and Susie Wong Scollon (2003) and Eduarado Kohn (2013) elaborate on Charles Peirce's 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 in-placed 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 is primarily focused on indexicality, referring to how the meaning of a sign depends on its placement of 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 we find the contextual nature of indexicality useful in that it draws explicit attention to place, the construct of *spatial indexing* goes beyond the placed social semiotic world to incorporate temporal and relational dynamics of the natural semiotic world. Here we follow the lines of anthropologist Kohn (2013, p.7), who articulates an "anthropology beyond the human" 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 we need a framework for understanding humans in relation with other life-forms. While this may seem like a radical proposition, a semiotic systems framework that recognizes communication beyond the human is fairly intuitive. Animals and other forms of life communicate with one another, most often engaging in semiotics that are outside of human comprehension. However, as Kohn (2013, p.9) argues, "it is through our partially shared semiotic propensities that

multi-species relations are possible, and also analytically comprehensible". For example, a group of leaves moving together might be a sign that either the wind is blowing, that something is physically moving the branch that all the leaves are connected to, or that some other possible event is occurring. While there is important debate about the claim that only humans engage in symbolic signs, in this paper we do not take this up but focus on how indexing occurs and its impact on epistemic activity. Indexing, therefore, semiotically grounds us, connecting us within a semiotic world at this intersection of humans and other life forms. Spatial indexing, more specifically, is a framework that locates our observations, or particular attentional practices, in place, time, and relations with others.

We are particularly interested in the ways that spatial, temporal, and relational intertwining occurs in indexing, and the related potential affordances for sense-making. These three forms of indexing are interrelated and often occur together. However, we mark their differences to understand how the initial framing of articulated perceptions impact subsequent sense-making - as Goodwin suggests, it sets the ground for the types of epistemic actions that can follow (Goodwin 2013). Spatial indexing can be defined in its most abstract as a form of meaning making in which a phenomenon that is spatially present (located in the perceptual field) is immediately discursively connected, via sense making, to a different phenomenon that is not explicitly present. This associated sense making *indexes* phenomena on either a different locative, temporal, or relational scale. While indexing is a routine practice in human sense-making that varies across social communities (Scollon and Scollon 2003), contexts (Goodwin 2007), and activity systems, in this paper we are interested in moments of spatial indexing in which complex socio-ecological reasoning unfolds.

Additionally, articulating and developing the framework of spatial indexing allows us to understand how people orient to place while in motion. We suggest that epistemic orientations and mobility consequentially shaped the semiotic frame in which people understand and communicate in the world. Mobility attunes attention to space in particular ways if only for navigational purposes (e.g. Goodwin 2000). However, Indigenous scholars have argued that places shape activity and meaning - or are pedagogical - even when they operate implicitly below a conscious level (Kawagley 1995). Given spatial indexing is a human phenomenon, in our work we have been particularly interested in epistemic orientations may produce variability in spatial indexing and sense-making. For example, we hypothesize, that when individuals are sense making via a relational epistemology they may attend to relational dynamisms and perpetual becomings; they would be able to read the land to attend to the dynamic and changing narratives of interacting elements of an ecosystem, or as Greg Cajete (2000 p. 182) puts it, to encounter and describe a "place… as a reflection of a creative living force".

In this article, we are interested in how epistemic orientations, particularly relational epistemologies, shape how youth engage in meaning-making, and more specifically how they are spatial indexing, as they move through an ecosystem. This study focuses on data from one activity during a week-long STEAM program serving 40 urban Native American youth in 1st through 12th grade in a large northwestern city. Our study was guided by the following questions:

- What forms of reasoning were Native youth engaged in during moments of noticing / spatial indexing about ecological phenomena?

- How did youth engage in practices of reading and storying the land? More specifically, how did land shape youth's epistemic activity while walking?

- Given the first two questions, how/were Indigenous identities and relational epistemologies manifesting in their sense-making?

Project Overview and Study Context

This study is part of an iterative community-engaged design project which involved community members, researchers, and graduate students to design and implement land-based learning programs that facilitate and support Indigenous ways of knowing and western science. The program was committed to employing and reinforcing relational epistemologies (Bang and Medin, 2010). This particular program focused on interrelations among forest and ocean ecosystems, particularly through waterways, with the kinds of impacts change climate change and ocean acidification is having on these systems.

A foundational activity in the program was remaking plant and animal relatives, by which we mean youth learned about culturally salient plant and animals as well as the cultural practices, histories and stories about them. For example, youth learned about and developed relationships with stinging nettle. They learned about the biology of the plant, its relationships to forests, and to other animals. They also learned stories about how nettle has helped Native people, and the culinary and medicinal uses of nettle, as well as the tools (e.g. cordage) and other materials made with nettle. Youth also harvested nettle and engaged in some of these activities directly. A similar framework was followed for learning about oceans and tidal pools in particular, however in the tidal pools we were more focused on the role of water (including its pH levels and temperature) in relation to the organisms we were learning about as well as variations between rocky tidal zones, mudflats, and eelgrass beds and the range of life afforded in each, as well as the impacts of ocean acidification. Further, the program engaged youth in creating artistic responses to and with all their experiences in learning about and making relationships with land, water, and all of their dwellers.

The program was implemented in three consecutive summers, with 2 weeks of camp during years 1 and 2, and 1 week during year 3 at a local community center located in an urban park with thickly forested lands as well as ocean shoreline. The project was a partnership that included several organization partners, including Red Eagle Soaring, a Native youth arts program, Sealaska, 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. 2016), 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. Importantly, program facilitators walked and planned in the places we would take youth.

The program was designed to focus on nature-culture relations and learning about complex ecological systems through relational epistemologies and mobile pedagogies of walking, talking, and storying the land. The framing question for the camp was: *How can we live in respectful, reciprocal, and responsible relations with our lands and waters?* Responding to this question requires knowing lands and waters well and having rich relations with lands and waters, and all that dwells in them. Further we were especially interested in youth learning this in the context of climate change. We developed a series of pedagogical orientations and practices that were designed to privilege particular semiotic landscapes and guided our programming in several key ways. First, we utilized *Indigenous storytelling* as the introduction to our inquiries and relied on asking kids to produce stories of phenomena in a range of ways. For example, on some occasions we had youth imagine the possible stories of the things they were observing came to be. Another

example is that we had youth collect a range of observations in tidal pools and asked students to create a story that accounted for the data they observed.

The youth also engaged in a series of embodied imagining activities in which they were asked to become characters and enact stories of their own, following specific prompts or criterion. This embodied activity was an important hybrid activity with another crucial part of our pedagogy in which we positioned youth to constantly be observing and exploring phenomena from multiple perspectives - what we call *perspective taking* (e.g. Medin and Bang, 2014a). Multiple perspectives were instantiated through taking on perspectives of others entities, or *kinds* (e.g. birds, plants, animals, etc.) but it also included taking on perspectives of processes and of space/time relations. Perspective taking and thinking across levels spatially and temporally was a focal pedagogical practice to support both relational epistemologies and complex systems thinking (Cajete 1999; Wilensky and Resnick 1999). Further this practice reflects a critical understanding of the importance of space time configurations. As Smith (2012) argues "different orientations towards time and space, different positionings within time and space, and different systems of language for making space and time 'real' underpin notions of past and present, of place, and of relationships to the land." We worked to carefully design at the intersections of these ways of understanding the importance and shape of perspective taking in order to develop learning that supported complex socio-ecological systems learning from Indigenous ways of knowing and being.

Storying and perspective taking were also embedded in our material tools. For example, when youth were engaged in observation and data collection around focal plants, the material tools always scaffolded students to collect data from multiple perspectives (e.g. what liked to eat it; how does it get energy), to observe at different levels (e.g. leaf veins, leaf, branches, whole plant), across space (e.g. what lived near the plant and were there others like it), and over time

(e.g. what it would it look like in different seasons) Further we developed material tools that reflected systems and inter-species relations; for example for focal plants we developed infographics we called webs of life (see figure 1). While neither of these tools is particularly remarkable on their own we draw these out to demonstrate that we worked to integrate and scaffold markers of relational complex socio-ecological systems thinking across the program.

[Insert Figure 1]

In addition, perspective taking often emphasized the recognition of reciprocal relations between entities. Reciprocal relations is a key dimension of relational epistemologies and Indigenous knowledge systems that orient people to search for and expect interactional relationships in sense-making (e.g., Cajete 1999). Another key pedagogical commitment and practice relevant for this study was the focus on *field based science practices in inter-generational arrangements*. Our inquiries into forest and ocean ecosystems occurred *in place*, with additional curriculum that synthesized connections among them. This also required us to do a fair amount of walking routinely. These walks became pedagogical opportunities to both scaffold youth into an activity (e.g., on the way to the beach) or to be reflective and synthesizing times (e.g., on the way back from the beach). Thus an emergent pedagogical practice of *walking activities* also became a key place of design and relationship making. Over the course of the week we had 6 major walking activities that were configured in triads or in small groups. The walking activities fell into two broad categories: facilitated close observing or imaginative embodied perspective taking. This study focuses on an embodied imagining walking activity and the forms of sense-making that were enacted by youth.

Methods

This case study stems from a larger community-engaged design research project in which youth programs were developed in response to a call for more expansive science education that were rooted in Indigenous ways of knowing (IWOK) but also engaged Indigenous youth in Western science. The work partnered with a range of researchers, community members, and families in the both the design and implementation of the program. Participants in this study include students (campers), ranging from six to sixteen years old, as well as adult instructors, some of whom were also co-designers and researchers of the program.

Data

The data corpus for this project consists of audio recordings, video recordings, and field notes (or minutes). Data collection began with the first design meetings, and continued through professional development sessions, pre- and post-interviews, and implementation. During implementation in the field, we had multiple instruments recording-- stationary video cameras, mobile video cameras, instructors and students wearing audio recorders, and point-of-view cameras worn by students. We recorded 25 design meetings and 8 professional development sessions, collected 46 hours of implementation data in three different ecosystems, conducted 14 pre-interviews and 21 post-interviews, and gathered student work from all three ecosystems. This study analyzes one walk in which participants engaged in a synthesizing role play activity.

Overview of the walking activity "Role-play a plant relative". The walking activity focused on having youth role-play a plant relative that we had been learning about during the program. The goal of the walk was to continue to foster youth making stronger relationships with the focal plant life as well as to explore the interactions and relationships with those plants in ecosystems. The walk started at the cultural center and ended at the beach and was about 1 mile and took

approximately 20 minutes. Youth were arranged in groups of three and they were asked to take the perspective of a plant and during the walk become that plant. The small groups were instructed to explore which plant they would embody, and what their roles and relations were to one another and within the larger ecosystem, including relations with other entities. Using a mobile video camera, handled by a researcher, this walk follows a triad, Nicholas, Damien, and Myles, for a duration of twenty minutes. This walk meandered through multiple ecosystems- a paved road lined with blackberries and trees, a forested gravel trail, an open meadow, and finally another forested trail that was steep, shaded, and moist. (see Figure 2). We used criterion sampling to select this video for analysis because it captured a walk without direct mediation from adults in the moment. In addition, this walk had minimal directions or forms of accountability for youth, thus sense-making in this space was especially youth-driven.

[Insert Figure 2: Map]

[Caption: *Aerial view of the park. Red lines trace the walk from the classroom (circle) to the beach (x).*]

The group of focus: Nicholas, Damien, and Myles. We focus our analysis on one walk that included Nicholas, Damien, and Myles, three boys walking and role-playing together. All three boys are Native youth and enjoy role-playing and computer games. At 12, Damien is the oldest and is Kiowa, Creek, and Cherokee, while Nicholas, Anishinaabe and Dine, is 11 and Myles, Anishinaabe and Metis, is 8 years old. This is Nicholas' second year at the camp, and both Damien and Nicholas are knowledgeable about plants and the local ecosystem, having spent time at the park where the camp took place with their families. Sometimes the students were separated into groups by age, which placed Myles into a different group, but when the groups were integrated, Myles sought out Damien and Nicholas.

Analysis

As with any complex system, understanding the processes and mechanisms requires attending to phenomena that have "multiple causes and consequences, and where order and structure coexist at many different scales of time, space, and organization" (Jacobson and Wilensky 2006; p. 12). Therefore, understanding the multifaceted and integrated nature of learning settings (and particularly ones that aim to teach about complex socio-ecological phenomena) requires an analytic lens that mirrors the complexity of the situation. In this study, we take a microethnographic approach (Bang et al., 2015) of a semi-structured walk, and analyzed the data using both knowledge analysis and interaction analysis (e.g. diSessa, Levin, and Brown 2016). Microethnographies allow the researcher to examine the interplay among moment-by-moment participant interactions with each other, with artifacts, and with the academic tasks, which are reciprocally mediated by, and mediating, the social construction and dynamics of the activity (Gee and Green 1998). More specifically, we take a microlongitudinal and microlatudinal approach to characterize how sense-making evolves over time and reiteration (longitudinal), as well as in moments of interaction across settings or in movement during the walk (latitudinal) (DeLiema, Lee, Danish, Enyedy, and Brown 2016). To do this, we utilized interaction analysis to examine the ways in which mobility and the physical world mediated the conversation through *spatial indexing*.

In addition to interaction analysis we use conversation analysis to trace articulated prominent conceptual themes that arise throughout the walk (Goodwin 2000b), and the ways in which the land and specific characteristics of the land shape the boys' sense-making. This analytical approach allowed us to examine how language and place afforded particular forms of sense-making about socio-ecological phenomena. To conduct our analysis we viewed data multiple

times, including audio and video, identifying salient interactions and conceptual threads in which participant talk hovered around ecological phenomena. We translated the audio using a modified version of the Jefferson transcription system (Sacks, Schegloff, and Jefferson 1974). Our analysis of conceptual threads focused both on ecological knowledge (specifically ecological relations) as well as conceptual dynamics that were markers of complex systems thinking by attending to the focal kinds that were talked about, as well as the relations among these kinds. We focus on three important conceptual themes that function as indices for understanding or negotiating complex ecological relations. These themes are 1) taking the perspective of plants, 2) reasoning between agent-aggregate levels, and 3) discussion of keystone species and their relations. We argue that these forms of reasoning were constructed in a dialogic environment that included the physical world (e.g., plants along the trail) in which spatial indexing was central and produced, in a form of reading the land (Cajete 2000).

Using knowledge and interaction analysis, we are able to not only attend to the dialogue that took place among the three participants, but also to the ways in which the phenomena in the perceptual field mediated conversation and sense-making. Spatial cues and *indices* manifested both explicitly, with the use of highlighting phenomena in the visual field (Goodwin, 1994), as well as implicitly, such as using the forest inhabitants as parameters for choosing a plant to embody. In the following analysis, we will trace the conceptual themes that emerged among Damian, Nicholas, and Myles chronologically in the walk. Concurrently, we will articulate how spatial indexing is broadly present in observations, but also illuminate the more nuanced forms of complex ecological reasoning that emerge in association with certain observations.

Walking, Reading, and Storying the Land

In order to trace conceptual themes across the walk, we analytically traced youth as they walked, read, and storied the land. We marked moments when the participants referenced *natural kinds* (e.g. plant, animal, etc.), and the subsequent conversations that took place. This allows us to trace conversation that centered on ecological phenomena. Throughout the walk, we found that Nicholas, Damian, and Myles often notice or reference a natural kind in their visual field 9 times in 20 minutes of video clips. Some of these noticings were prompted by conversation, other noticings drove the subsequent conversation. In particular, we are interested in the epistemic navigation in sense making, and have pulled out three themes that were present in the data: perspective taking, agent-aggregate reasoning, and keystone species.

Perspective Taking

Perspective taking was a deliberately designed pedagogical practice informed by research on culture and cognition and complex systems reasoning. Growing research with Indigenous people has demonstrated that they are more likely to engage in perspective taking when reasoning than non-Indigenous peoples (Dehghani, Bang, Medin, Marin, Leddon and Waxman 2013; Unsworth 2008). Relatedly, perspective taking seems to support reasoning about complex systems because of the attention to dynamic and relational aspects of a system (Olsen 2013; Levy and Wilensky 1999). Throughout the program, and in this activity specifically, youth engage in perspective taking both spontaneously and through facilitation. During this particular walk not only were youth engaged in perspective taking, but more specifically, embodied perspective taking. We argue that taking the perspective of plants and animals is a form of relational thinking and is an indicator of reading the land.

Excerpt 1: Blackberries Taking Over. The first excerpt (Figure 3) takes place near the beginning of the walk, which begins on a paved road lined with different coniferous and deciduous trees,

smaller shrubs, ferns, and blackberries. The three boys, Nicholas, Damien, and Myles are walking together in a loosely formed triad, with movement across the width of the road as well as weaving in and out of other groups. They begin by talking about different plants and their characteristics, some of which are both in visual range, as well as plants they have studied, embodied, or learned about in prior activities. In the beginning of the video, Myles, the youngest at 8 years old, points and says, "blackberry" as he looks over to the plants on the side of the road. As the group continues to talk about choosing plants to embody, Myles says he wants to "be" a blackberry. Myles embodies blackberry, and enacts blackberry's behaviors and relations to others. It may be important to note that Himalayan blackberries, a species not native to the Pacific Northwest, are notorious for taking over landscapes, which often results in the pushing out of native flora. By pointing out blackberry along the side of the trail, Myles is incorporating an observation into his ongoing sense making about which plant to embody. We argue that this is a form of spatial indexing in a broad sense; an observation, noticing, and joint attention are incorporated into a form of sense making about ecological phenomena.

[Insert Figure 3: "Blackberries Taking Over"]
[Insert Table 1]

As Myles is yelling, he runs through other groups with his arms out, catching up with his group. In this excerpt, Myles not only engages in embodied perspective taking as instructed (not any given youth would follow the activities' instructions) but he does so in a way that accomplishes a minimal task, catching up. For example, he could have said to his group "wait up" and run over to them. Instead he both verbally and physically enacts blackberry's behavior and narrates blackberry's impact on others. This form of embodied perspective taking was routine in the boys' walk in the program more broadly. We suggest that routine perspective taking fosters relational

thinking and may encourage thinking in more dynamic, rather than linear, causal webs over time, although this may be dependent upon which conceptual ecology is active. This form of embodiment is also indicative of a psychological closeness that has been associated with greater attention to context and therefore a more relational understanding of ecological systems (Medin and Bang 2014b). While maintaining this embodiment. Myles toggles between thinking about blackberries as an aggregate ("us blackberries") to speaking as an individual plant and thus his individual actions. We argue that this nuanced attention to, and perspective taking in, agent and aggregate levels of a system is another indicator of understanding complex and dynamic interactions (Jacobson and Wilensky 2006). We continue to see this throughout the walk.

Agent-Aggregate Reasoning

A significant indicator of complex systems thinking is the ability to toggle between agent and aggregate levels of a system (Levy and Wilensky 2008). In the context of this study, agent-aggregate refers to the differences in behavior and properties of an individual (for example, one car) from that of a group (for example, traffic). While some have argued that "novices" are unable to attend to this dynamicity, we found that the participants in this walk navigated multiple levels of an ecosystem that are aligned with agent and aggregate constructs as they reasoned about plant relationships.

Excerpt 2: Guardians of the Forest. In the excerpt below (2) Myles and the group expand their focus from blackberry and begin to focus on a new plant while exploring the roles that plants play in an ecosystem. The excerpt begins by Nicholas establishing a standpoint for the boys' imagining by articulating that they are "guardians of the forest." Damien elaborates on this by describing

components of the forest, plants that would count as guardians ("nettle, blackberry*"*); throughout, Myles calls out the plants he would like to be.

[Insert Table 2]

While there is toggling between agent and aggregate levels of the forest ecosystem in this exchange, it is important to note that is distributed *across* the three boys (e.g. Hutchins, 1991; Salomon, 1997). In the first two utterances in the excerpt we suggest that Nicholas and Damien are thinking at aggregate levels as types of forests and referencing the agent-level components of the system; they are toggling between these levels. Following Dylan's turn to the agentic level of plants at the end of line 2 Myles proposes to become a new individual plant, "a nettle." The following turns indicate three levels of sense making as the activity unfolds. On the one hand, Nicholas and Myles are negotiating which plant to embody based on parameters of the designed activity: pick a plant to embody, presumably one that you have not embodied before. On the other hand, Damien returns to the parameters of what Nicholas called the "guardians of the forest" (line 1). And finally, there is a shift from "guardians of the forest" to become synonymous with "keystone species". In this we see Damien and Nicholas collaboratively toggle between the agent and aggregate levels beginning to explore the roles and relations of plants to one another and to the forest ecosystem. Following the lines of Sharona Levy and Uri Wilensky (2008) "analyzing processes within and among these levels offers a deeper understanding of the systemic nature of the complex phenomenon at hand" (p. 37). Additionally, while toggling between the agent and aggregate level the youth enact a relational understanding of both the roles (keystone species) *and* responsibilities (guardians of the forest) of the agents within the system.

Keystone Species

Keystone species is a biological term used to refer to a species that plays a (sometimes disproportionately) large role within an ecosystem based on the number of assemblages of other elements of the system (Paine 1995). Although a topic of debate in some scientific communities, we apply a culturally inflected meaning of the term, by focusing on assemblages, or relations, within a system. In the following excerpts, Nicholas, Damien, and Myles are negotiating which plants to embody by narrowing their choices down to "keystone species." Importantly, they are also expanding their conceptual ecology to not only be exploring discrete plants but to also focus on the plants' behaviors, functions, and processes with the ecosystem (e.g. structure-behavior-function theory, Hmelo-Silver, Marathe, and Liu 2007). Further, the concept of keystone species becomes specifically culturally inflected in the following two excerpts.

Excerpt 3: Who Counts as a Keystone Species? Early on in the walk, and threaded throughout, Damien, Nicholas and Myles are talking about which trees are keystone species, and what qualifies them as such. Indexing on both spatial and relational scales, Myles points up to a maple and asks if he can "be that tree… be a maple". The observation and joint attention to a tree alludes indexes the behaviors and relationships of maples as keystone species: they "give maple" and oxygen and take in carbon dioxide. We argue that this is a more nuanced form of spatial indexing, because the spatial index both draws joint attention to an object (Marin 2013), and also alludes to behaviors or functions outside of the immediate perceptual field.

At this point in the walk, the boys have now turned off the paved road and onto the gravel trail which leads through a dense forest. As the boys continue along the path, Myles wrestles with the concept of keystone species. He names plants ("grasses? trees?"), asking his group mates if they count as keystone species. Myles and Damien shift the focus from specific types of plants to describing the functions and roles in the forest.

[Insert Figure 4: Keystone Species]

[Insert Table 3]

In trying to understand what would count as a keystone species, Myles gives an explanation that attends to the function of a plant, oxygen and carbon dioxide exchange through "breathing" (excerpt 3, line 1). Damien fine tunes this explanation by noting that function alone does not define a keystone species, their relation within an ecosystem also needs to be factored in, such as *not all trees, "some trees can be invasive"*. Again, the toggling between agent and aggregate levels of a system is distributed across the boys as they are engaged in sense-making. The spatial index, pointing to a maple tree, semiotically grounds Myles as he tries to make sense of what differentiates a keystone species from an invasive. While both pines and maples are part of the carbon dioxide-oxygen cycle, he is able to locate the maple *in place*, and he knows that maples are unique in that "they can give maple" [syrup]; this may indicate that he believes this does not make maple an invasive species, but rather sees it as belonging in *this* ecosystem. Additionally, we suggest that because Myles is Anishinaabe and Metis, and maple trees and maple sugaring are an important part of Anishinaabe culture, it shapes his nuanced attention to the important roles maples play both social and ecological systems. Importantly, Myles seems to hold that keystone species play important roles where they are in giving relations with others, which we will visit in the next excerpt.

Excerpt 4: Stinging Nettle as a Keystone Species. We see the boys continue to negotiate keystone species as they incorporate another plant into their sense making, stinging nettle. Here a similar conceptual dynamic plays out. In the following excerpt (split in two) the concept of

"keystone species" becomes the conceptual focus that allows for dynamic sense-making about plants that have relations not only among humans and the plants, but also within a larger system.

Figure 5: Stinging Nettle Keystone

Excerpt 4.1

[Insert Table 4]

[Insert Figure 6: Nettle Cordage]

Excerpt 4.2

[Insert Table 5]

Defining keystone species as having a protecting function began with talk about "guardians of the forest" (excerpt 2), and is returned to when Damien says that nettle "protect[s] the forest" (excerpt 4.2, line 4). However, in excerpts 3 and 4 there is also an important shift from the function of the plant in the forest, to what it gives, what bethany ojalehto and Douglas Medin (2015) refer to as *helping* relationships. For example, Myles says that maple trees "give maple" (excerpt 3), and Nicholas says that nettles give cordage, medicine, and take care of the forest (excerpt 4.2, line 5). In other words, stinging nettle and maple tree hold open the space for debating about the criterion of keystone species. ojalehto and Medin found that Indigenous peoples were more likely to focus on how different species in an ecosystem engaged in behaviors that helped the health of an ecosystem, even if they were indirect helping relations. The focusing on helping relations in this sense are a part of Indigenous knowledge systems and ways of knowing that emphasize reciprocal relations. From this perspective, we suggest the boys' exploration of the concept of keystone species is taking on inflections of relational epistemologies by articulating giving relationships.

Excerpt 5: Horsetails Give Medicine. We see this again in the following excerpt (5); where after talking about nettle as a keystone species, the group comes to a place in the forest with a large

groundcover of horsetail (a plant). Nicholas *highlights* (Goodwin 2000b) horsetail on the side of the trail, and we see Damien look down, Myles (not pictured) following suit shortly after.

[Figure 7: Horsetails Medicine]

[Insert table 6]

With joint attention on horsetail, Damien playfully gestures to Nicholas and Myles to "be useless horsetail". Simultaneously Myles and Nicholas respond to this. In a distinct spatial index, Myles explicitly attends to the stillness of horsetail, reiterating that they are "useless" because they "just hang around". Nicholas, on the other hand, slightly offended by the dismissal of horsetail, again attends to the giving relationships that horsetail has with others (medicine, food). Horsetail is a plant that many tribal communities have had long relationships with for culinary and medicinal purposes. Nicholas' observation is a form of spatial indexing because it semiotically indicates the apparent immobility of the plant and therefore uselessness, yet also relationally indexes the relationships between horsetails and humans. It is also an interface between the immediate goals of the activity (embodying a plant), and the cultural experiences that shape how Nicholas perceives nettle, as a significant medicine and food for people.

Spatial and Relational Epistemologies

We argue that instances of spatial indexing can be indicative of particular epistemic or ontological frameworks, and therefore we see individuals and or collective groups navigating these frameworks. Throughout the walk Myles, Nicholas, and Damien have used the concept of keystone species as a conceptual index with which they have played out spatially and temporally variant practices. For example, as mentioned earlier, we see a shift in defining keystone species as "guardians", to later focusing on the helping and reciprocal relations they have with others. In

other words, the group has attended to the dynamic roles and relations among plants, humans, and larger ecosystem levels, in culturally specific and nuanced ways. Additionally, we have seen spatial and temporal toggling as the boys negotiate agent and aggregate scales in which ecological phenomena such as life cycles and relationships take place.

Excerpt 6: Growing a Plum Tree. Towards the end of the walk, we see Myles synthesize these ideas, and specifically take up the notion of "giving", to finally negotiate yet another plant to embody, a plum tree. Twelve minutes into the walk the group leaves the forested trail, walks through a meadow for a couple hundred yards, and then re-enters a forested section on a set of steep stairs going down. At this point in the walk, Myles, Nicholas, and Damien have continued to talk about trees, have intermingled with other groups, and have had a chance to talk briefly with an instructor. As the re-enter the forest, Myles states that he (still) wants to be a tree and negotiates with Nicholas and Damien which tree to embody.

Deciding which tree to embody is now mediated by attending to the land (who lives here), as well as the relational gifts. In this case, a plum tree "give[s] food", as Nicholas points out (excerpt 6, line 2). Myles appears to make a lateral shift to another food-giving tree, a mango tree, and Damien re-places his attention by pointing out that "we don't have mango trees. I guess we have plum trees. That's good" (excerpt 6, line 4). We interpret Damien to mean that mango trees do not grow where they are and hesitantly agreeing that Myles could be a plum tree because it is local.

[Insert Figure 8: Plum Tree]

[Insert table 7]

This explanation both explicitly attends to the surrounding environment, as well as implicitly upholds the self-created rule in the activity that they need to pick plants that are in this ecosystem.

In other words, land itself mediates ideas the constructs of the activity. Once this is established, Myles finally embodies a plant as he continues to walk down the trail.

Temporal toggling

Excerpt 7: Plums Produce Food. Fully attending to the possibilities of phenomena (i.e. indexing) requires that phenomena are not held in place temporally nor spatially. Toggling is a way of managing the fluidity of multiple possibilities. Myles toggles between the perspectives of a human and a plum tree in embodiment. The group as a whole engages in temporal toggling, shifting from a plum tree life-cycle frame (the time it takes for a plum tree to mature and produce plums), to the time frame of the world they are walking in.

[Insert Figure 9: Plums Produce Food]

[Insert Table 8]

As this group re-enters the forest and begins their descent down a set of steep stairs, Myles, who is behind the others, has now become a plum tree. Myles and his group are working through the tensions of walking the land in the perspective of another plant. However, these moments of tension opened a space for the youth to reason across multiple time scales, while simultaneously attending to the perspectives, life cycles, behaviors, and relational roles of the focal plants. In line 3 (Excerpt 7) Myles asks the others if he is "producing plums" where he walks, which shows a nuanced understanding of plum trees as providing food (plums) as well as reflecting an orientation to the trees growth and life cycle; furthermore, this is coupled with his experience of walking (as a human). This launches into a temporally dynamic interpretation from Damien and Nicholas of fruiting plum trees. Together they toggle, conceptually, between the life cycle on an annual /

seasonal scale, and simultaneously on a walk-level scale. This move to conceptualize the behaviors of a plum tree across multiple time scales is indicative of a complex and dynamic understanding of the life cycle of plum trees; plum trees only grow fruits when they are mature (not as young trees), and they only do it seasonally. Weaving multiple time scales indicates an ability to reason beyond what is immediately presented, and instead towards nonlinear and interactive relationships (e.g. Grotzer and Tutwiler 2014).

Discussion

The dynamic and unfolding process of *reading the land* involves the coordination of attention and observation between humans and more-than-human kinds (Bang and Marin 2017), in which human-nature relations are enacted as reflections of both culture and historical experiences, as well as the moment-to-moment interactions in place. By tracing both conversation and interactions, we have been able to follow conceptual and mobile assemblages to characterize the boys' sense-making about humans and more than humans throughout this walk. In particular, the concept of keystone species has served as a conceptual pivot for personal and dialogic negotiation of the roles, relations, and gifts of plants both in the perceptual field and out. Ultimately, however, the practice of reading the land has both constrained and afforded parameters for participation in the *activity*, in this case embodying a plant during the walk.

As we look micro-longitudinally and -latitudinally across the walk, we argue that the assemblages unfolding are enactments of emergent complex ecological systems thinking that reflects relational epistemologies and is intertwined with markers of identity for the boys. The markers of emergent complex ecological systems thinking are demonstrated in three themes: perspective taking, reasoning about agent-aggregate relationships, attending to keystone species.

Furthermore, these conceptual practices unfold in mobility and are mediated by interactions with one another as well as with place (Marin 2013). Through the processes of walking and talking the land, youth were engaging in relational epistemologies by the way they were focusing on the reciprocal relationships that plants have while they negotiated criterion for keystone species. As mentioned earlier, youth were encouraged to use observations and explore phenomena from multiple perspectives. Spatial indexing propelled their continual conceptual navigation in the practice of walking and talking the land; we argue that this is one way in which coordination of attention (Marin 2013) is spontaneously orchestrated. Further, we suggest that spatial indexing may be a more prevalent form of cognitive activity for peoples whose knowledge systems are explicitly land- and water-focused or when activities and practices highlight land and waters more explicitly and do not construct them as stagnant backdrops to human activity (Bang, Medin, and Atran 2007). In this specific case we see the forms of reasoning evident in discourse and patterns of interaction reflective of Indigenous knowledge systems as they may manifest in youth. More specifically, the boys' negotiation of relations among natural kinds – including humans and their focus on helping functions when reasoning about relations among kinds in a given ecosystem – was central to their sense-making and is similar to findings in other Indigenous communities.

Further Research

This framework warrants further investigation for three reasons (among many). First, there is a significant lack of diversity in STEM-related fields, and understanding the how reasoning takes place in out-of-school settings can bear importance on how we structure classrooms. Second, understanding complex systems is increasingly important in the face of larger issues such as climate change and largely communicating about climate change has not been particularly

effective in fueling research efforts on the science of science communication. Finally, the use of observations in this unstructured, outdoor setting has implications for the design of learning spaces. For example, the highlighting of observations in the moment, and the ability to reason about them indexically, speak to the affordances of outdoor learning settings. While these settings are emerging in the form of environmental learning centers, it can also be fostered in school outdoor spaces, such as gardens. Shifts towards engaging youth in field based science courses and forms of practice are necessary to engage youth in the full spectrum of scientific practices. In addition, engaging in field based practices may help to rupture the school-community divide that many non-dominant youth experience wherein school is distinct and separate from community and family life (Mack et al. 2012). However, more detailed design and research of field based learning environments with k-12 students is needed to fully realize how processes of walking and talking the land can be scaffolded to support science education that prepares youth for 21st century demands. Importantly however utilizing these pedagogies will require educators and scholars to engage with communities and families from different paradigms – such as partnerships governed by recognition and refusal of historically saturate power dynamics in design and decision making as well as implementation. Further, engaging pedagogies of walking and talking the land will need to carefully consider the forms of power and narratives that are engaged as relationships and reasoning about land. More specifically, these pedagogies will need to refuse Indigenous erasure and neutral constructions of land or they will simply replicate normative and oppressive paradigms.

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This material is based upon work supported by the National Science Foundation under Grant Nos. DRL 1712796, DRL 1713368, and DRL 1946478.

Figures

Figure 1

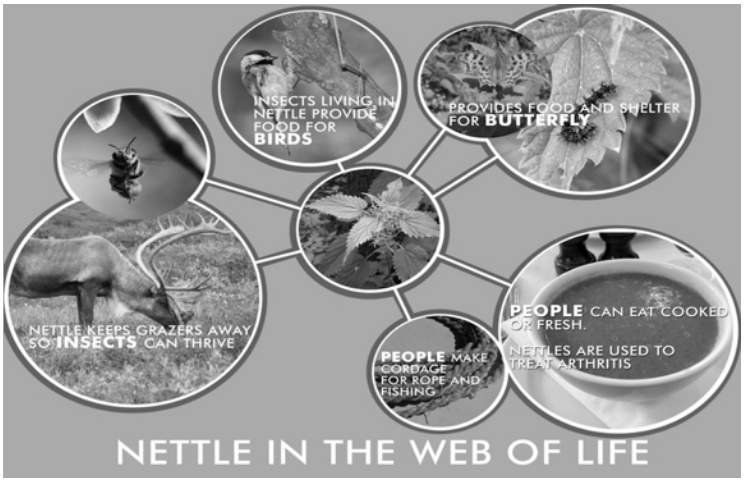

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Tables

Table 1

Myles:	Yeah but us blackberries taking over. Ya ya ya! I'm taking over you! *(waving arms at group)* I'm taking you over! *(running through group)* I'm devouring you!

Table 2

1	Nicholas	We are the guardians of the forest
2	Damien	We can just be a type of like, um forest. One nettle (.) blackberry bushes are another one –
3	Myles	- Okay I'm gonna be a nettle!
4	Nicholas	No you have to be something different.
5	Myles	Blackbe:rry
6	Nicholas	No not that you've already been that one
7	Myles	Why?
8	Nicholas	Because you've already been a blackberry –
9	Damien	You can have two people. Like, one person's nettle
10	Nicholas	We're keystone species so you have to –
11	Myles	Okay, what are keystone species?

Table 3

1	Myles	…so pine trees – so trees are keystone species. And they breathe in carbon dioxide and they breathe out…
2	Damien	Kind of. Certain trees are. Some trees can be invasive. Some trees can just be there because of that –
3	Myles	Can I be:: (.) Can I be that tree with the (*pointing up*) – can I be a maple tree? (.) Cause maple trees can give maple and they breathe in carbon dioxide and they breathe out (.) oxygen.

Table 4

1	Damien	I wanna be – I shall be the stinging nettle!
2	Myles	Ah haha! But that's not a keystone species.
3	Nicholas	*(slows down, turns around to face Myles)* Yes it is. *(turns back to face trail)*

Table 5

4	Damian	*(group continues walking)* Well they're – well yeah they kind of are, they protect the forest -
5	Nicholas	- Yeah and they give people string to make cordage (.) and they give people medicine, and they give people stuff, and they take care of the forest-
6	Damian	- and they help like so many people
7	Nicholas	Yeah. They most definitely are (.) a (.) keystone spe-ya [species]
8	Damian	- Ya ha -
9	Nicholas	- ya ha ha -
10	Damien	Also they make – they make sure that you look around (.) instead of stepping everywhere (.) so that you don't get stu::ng for 5 hours.

Table 6

1	Nicholas	Oh. Horsetail. Look at the horsetail *(pointing down to the right)* our job is to look for these -
2	Damien	*(looks down at horsetail)* - Okay, you'll be a useless horsetail *(gestures towards Myles and Nicholas)*
3	Myles	Yeah -
4	Nicholas	– horsetails are very good! –
5	Myles	- Horsetails are useless (*inaudible*) I mean look they just hang around and stay still.
6	Nicholas	No! It is *ve*ry good for medicine, and very yummy. And –
7	Damien	- yum yum yum yum –
8	Nicholas	Super good for medicine.

Table 7

1	Myles	I'm going to be a plum tree. Plum tree.
2	Nicholas	They give food.
3	Myles	Mango tree. Mango tree. I'm gonna be a mango tree
4	Damien	We don't have mango trees. I guess we have plum trees. That's good.
5	Myles	I'm going to be a plum tree. Plum tree.

Table 8

1	Myles	(*yelling after group*) Ah, PLUM TREES WEREN'T MADE TO DO THIS! Right? (1s) (*now talking to himself*) Plum trees were not made to do this. They are not made to do this. They're made to produce food. (1s) (running after group) You take plum trees so seriously! (2s) Good humans (*talking to group mates*) (.) stop this. (2s) Um guys, you know that plum trees weren't made to do this! I produce food wherever I walk.
2	Nicholas	(*continuing to walk with Damien*) Hurry up!
3	Myles	Okay, am I producing other plum trees wherever I walk?
4	Damien	No. You produce a month of the year. *(continuing to walk)*
5	Myles	Oh. Here's a plum. I'm starting to grow some! (3s) Okay, when am I going to be a big grown up?
6	Damien	in 10 years!
7	Nicholas	5 minutes.
8	Myles	5 minutes.