

*Research Article***Nature–Culture Constructs in Science Learning: Human/Non-Human Agency and Intentionality**Megan Bang¹ and Ananda Marin²¹*Learning Sciences and Human Development, University of Washington, Seattle, Washington*²*Department of Psychology, Northwestern University, Evanston, Illinois**Received 5 November 2014; Accepted 15 January 2015*

Abstract: The field of science education has struggled to create robust, meaningful forms of education that effectively engage students from historically non-dominant communities and women. This paper argues that a primary issue underlying this on-going struggle pivots on constructions of nature–culture relations. We take up structuration theory (Giddens, 1984. *The constitution of society: Outline of the theory of structuration*. Berkeley and Los Angeles, CA: University of California Press.) and decolonizing methodologies (Smith, 2012. *Decolonizing methodologies research and Indigenous peoples* (2nd. ed.). London: Zed Books.) to reflect on the *structural principles* of the *settled expectations of nature–culture relations*. We suggest that taken together both Giddens’ and Smith’s respective discussions of time-space relations provide a powerful framing for nature–culture relations. Carefully examining shifts in the temporal and spatial scales during moments of talk and action in out-of-school science activities may help to increase the field’s understanding of divergences, convergences, and productive generativity between Western science and Indigenous ways of knowing to create transformative science learning. Drawing on our work in community-based design research and studies of everyday parent–child interactions, we begin to describe emergent structural principles that may unsettle normative time-space and nature–culture relations. In addition, we describe specific practices and pedagogical forms that expand views of human and non-human agency, as well as present and possible socio-ecological futures. © 2015 Wiley Periodicals, Inc. *J Res Sci Teach* 52:530–544, 2015

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The field of science education has struggled to create robust, meaningful forms of education that effectively and equitably engage students from historically non-dominant communities and women. In this paper we argue that a primary issue underlying this on-going struggle pivots on constructions of nature–culture relations. To achieve equity in the emerging era of science education (i.e., Next Generation Science Standards) we suggest we will need to simultaneously attend to: (1) underlying theories of learning and development that structure inequity and (2) expansive views of nature-culture relations, and related possible socio-ecological futures, that drive education. In this paper, we work to make visible some dynamics of nature-culture relations that are firmly embedded in most learning environments and structure how children and teachers imagine, know, study, and make meaning of the relations between the natural world (e.g., organisms and phenomena of all kinds as well as their interrelationships) and cultural forms of life (e.g., ways of thinking and acting that organize human communities). We present findings from a

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community based design research project with an urban Indigenous community that attended to the proposed simultaneity and resulted in improved learning for Indigenous youth.

In our work we focus centrally on the relations between the natural world and cultural worlds (typically meaning human worlds) – what others in allied fields (cultural anthropology, philosophy of science, and Indigenous studies) have called the nature-culture boundary and what we call nature-culture relations. Nature-culture relations as a linked construct arguably grounds much of human activity and figures centrally in core ontological, epistemological, and axiological frameworks across social and scientific domains. Dominant constructs of nature-culture relations have typically positioned humans as distinct from and a part from the natural world. However, recent scholarship has focused on removing and transforming this bordered construction towards a view of intertwined nature-culture relations (e.g. Latour, 2013). The reflexive turn from bordered nature-culture constructs in broader social spheres is significant. However, the genealogy of intertwined reciprocal nature-culture relations and subsequent implications for subject-object constructions is rooted in Indigenous communities and our knowledge systems across the globe since time immemorial (e.g., Cajete, 2000; Deloria, 1979; Kawagley, 1990, 2006).

In our view science education is a key site in which *nature–culture relations* are defined, enacted, brought-to-life, expanded, narrowed and legislated. The manifestations of nature-culture relations, from the very constructions of subject matter, to focal content, to the configurations of practice, engaged in science learning environments are often deeply unreflective of the most pressing scientific questions – rather they focus on “settled” phenomena as well as “settled” perspectives and relations to phenomena. Further science classrooms can distance students from the lived socio-scientific challenges their communities face and often fail to position youth as contributors and participants in the pursuit of possible and desperately needed solutions. For example, students have limited opportunities to deeply become involved with cutting edge science such as exploring microbial life and human health, or monarch migrations and planting practices, or agriculture adaptations and food security. We suggest, that *settled expectations of nature–culture relations* (Bang, Warren, Rosebery, & Medin, 2013) in science learning tends to *structure* learning in ways that restrict experienced and possible forms of agency, identities, and relations. While we think this is true and relevant for all learners, we have been focused specifically on Indigenous students and communities.

In our research we work to excavate key sites in STEM education in which settled expectations are reproduced and can be transformed towards expansive learning (Engeström, 2001). In the learning environments collaboratively built with communities, we have worked at intentionally transforming normative “boundaries of reality” in science education through engaging Indigenous ways of knowing (IWOK) (Deloria, 1979) – an approach we call desettling wherein the “de” is intended to mark a decolonizing orientation to unsettling science. In this article, we engage structuration theory (Giddens, 1984) and decolonizing methodologies (Smith, 2012) to reflect on the structural principles of nature-culture relations that have surfaced in our work. More specifically, we work to explore the ways in which conceptions of time-space ontologies and, subsequent forms of agency, are foundational dimensions that shape nature-culture constructions. In our view, time-space ontologies significantly impact the boundaries of possible constructions of nature-cultural relations instantiated in practice. While settled expectations of nature-culture relations act as restrictive structural principles in unfolding activity, we suggest critical engagement with cultural practices and pedagogical forms can cultivate expansive forms of time-space ontologies and thus expand nature-culture relations in learning. As we will show, we find these emergent forms of activity reflect temporal and spatial synchronicity that can transform nature-culture relations in ways that enable simultaneous heterogeneity of practices, processes and the construction of new relations that deepen science learning (Massey, 2005).

Settled Expectations of Nature-Culture in Science Learning Environments

Settled Expectations or “the set of assumptions, privileges, and benefits that accompany the status of being white...that whites have come to expect and rely on” (Harris, 1995, p. 277) across the many contexts of daily life, also shape nature-culture relations and science learning environments. Building on the foundational work of Harris, Bang et al. (2012) argue that settled expectations of nature-culture relations are rooted in historically structured racial hierarchies in which the privileges of whiteness are recursively mobilized. We extend this to suggest that the settled expectations of racial hierarchies are predicated on settler-colonialism and are encoded and facilitated in learning environments. The fundamental tenant of settler-colonial societies is the acquisition of land as property, followed by the establishment of settler lifeways as the normative benchmark from which to measure development. These are accomplished through: (1) erasure of Indigenous presence, (2) staged inheritance of indigeneity by Whites (Reardon & Tallbear, 2012) and (3) erasure of African descendants humanity through the structuration of slavery and resultant reduction to and control of black bodies (Wolfe, 2006). Scholars have argued that pervasive inductions of Indigenous absence from land is a critical aspect of establishing constructions of uninhabited land and settler normativity (Veracini, 2011). The maintenance of settler normativity requires the structuration of time-space relations in ways that make the inseparable dynamics of acquisition of land, indigenous erasure, and the domination of black people appear as an inevitable, unconnected, and natural course of development rather than socio-politically engineered to support and foster white entitlement and privilege.

We, building with others, suggest that the foundational ontological, epistemological, and axiological assumption of these settled relations is premised on the idea that nature and culture are separate and distinct realms (e.g., Cajete, 2000; Kawagley, 1993; Latour, 2013). This foundational premise manifests in orientations and reasoning in a multiplicity of ways, including but not limited to a view that humans are distanced or apart from the natural world. The human separated view results in asymmetrical forms of reasoning and assumptions about human entitlements to and extractions from the natural world. While attention to environmental ethics continues to increase and challenge the legitimacy of human domination and entitlement to the natural world, as Latour (2013) articulates, there still remains a persistent orientation that non-humans are without agency and intent, thus making such domination more palatable. This marks a critical ontological difference in western scientific ways of knowing and IWOK. 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). These conceptual dynamics are at minimum reflected in curricular constructions, representations of phenomena, and modes of inquiry/pedagogies typically employed in learning environments. For example, most representations of ecosystems fail to include humans, but even when humans are present, they often reflect frames of extraction or pollution which are manifestations of dominant nature-culture relations of human domination and entitlement (Medin & Bang, 2014). We suggest that these constructions of nature-culture relations are linked to settler-colonialism and give rise to specific and pervasive time-space ontologies.

Settled Expectations, Time-Space Ontologies, and Structural Principles

Despite the growing awareness for the need to change socio-ecological systems, making serious shifts has been slow. We suggest that underlying theories and practices of teaching and learning are complicit in this stagnation because they have not excavated the persistent

orientations in moment-to-moment interaction that reproduce normative perspectives of nature-culture relations and consequently minimize transformative possibilities. Giddens (1984) writes:

social systems, as reproduced social practices, do not have ‘structures’ but rather exhibit ‘structural properties’ and that structure exists, as time-space presence, only in its instantiations in such practices and as memory traces orienting the conduct of knowledgeable human agents. . . . The most deeply embedded structural properties, implicated in the reproduction of societal totalities, I call structural principles. (p. 17).

Building with Giddens, we suggest dominant nature-cultural relations are a kind of structural principle that shape time-space presence and are reflected in forms of “memory traces.” These time-space presences influence both individual conduct and the reproduction of specific forms of practices. In this sense, time-space relations are not simply abstract forms in the present; they are fused with social and ecological unfoldings of history and knowledge systems. Reflecting on time-space relations from Indigenous perspectives, Linda Smith (2012) writes:

Different orientations towards time and space, different positioning 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. . . . What has come to count as history in contemporary society is a contentious issue for many indigenous communities because it is not only the story of domination; it is also a story which assumes that there was a ‘point in time’ which was ‘prehistoric’ . . . Traditional indigenous knowledge ceased, in this view, when it came into contact with ‘modern’ societies, that is the West. (p. 113).

In our work, the combined perspectives of Smith and Giddens provides a generative theoretical framing for nature-culture relations in teaching and learning. Time-space relations structure conduct, practice and interaction, both across historical time (Bourdieu, 1977; Smith, 2012) and in the moment-to-moment unfolding of interaction (Goffman, 1974). The ordering of time-space relations foregrounds particular memory traces which play forward in on-going activities. These moments can be significant instances in which inequities are reproduced and enclose space (Massey, 2005) and as such are in need of “relentless critical awareness” with respect to how time-space relations are constructed (Mignolo, 2007). As Smith points out, time-space positionings between the West and Indigenous communities have often served hegemonic ends for peoples and for land. Here Smith excavates the way in which the settled expectations of time orientations (past and present) are often instantiated towards normative nature-culture relations and position indigenous peoples and ways of knowing out of contemporary space.

We suggest these constructions can—and often do – contribute to the reproduction of inequitable outcomes for Indigenous youth in science education. A key way settled expectations ~~emphasize~~ does this is ~~by~~ imbue with consequence the divergences between ways of knowing (Aikenhead, 1996; Barnhardt & Kawagley, 2005; Chinn, 2007) typically, as Smith suggests, by messaging that Indigenous knowledge has ceased. This erasure restricts the intellectual, expressive and agentic forms of meaning making based in IWOK – thus, they function in science education as a form of epistemic and ontological control. Previous work has explored how these kinds of positionings work against student interest, motivation, and disciplinary identity (e.g. Nasir, 2011; Kane, 2012; Stevens et al. 2008) and project futures defined by Indigenous absence.

Reflecting on the work of both Giddens and Smith, we explore how new possibilities for learning are enabled when typically silenced memory traces in activity are reoriented in time-space synchronicity with expansive forms of nature-culture relations. We argue that community-based design research, as well as studies of everyday learning interactions, may be

ways to disrupt settled expectations, recognize Indigenous presence and futures and enable robust exploration of possible socio-ecological futures.

Community-Based Design Research. Informed by decolonizing methodologies (Smith, 1999) we retooled design-based research methodologies to engage a broad range of community members as the key decisions makers in the design and enactment of a variety of science-learning environments. This resulted in the implementation of youth and family programs in Chicago. The design teams (comprised of elders, parents, youth, teachers, professional scientists, as well as research staff developed from within community) engaged in critically reflective activities to explore relations between western science and IWOK. In creating learning environments, we purposefully labored to resist and transform settled nature–culture relations. We sought to create opportunities for learning where multiple forms of agency and identities in relation to the natural world were possible. A core stance that continually arose as we designed for and enacted science activities was that nature and culture are intertwined and fluid, thus facilitating and encoding orientations in which humans are a part of the natural world, rather than positioned on the outside (Medin & Bang, 2014). We developed a view of human meaning making as fundamentally heterogeneous and multi-voiced (Rosebery et. al., 2010), both within and between socially and historically constituted communities and ways of knowing. The focus on heterogeneity also reflects Kawagley’s (1993) proposition for finding both the convergences and divergences of IWOK and western science ways of knowing. The design team was deeply committed to relational epistemologies-teaching youth all things are related, connected in dynamic, interactive, and mutually reciprocal relationships (Barnhardt & Kawagley, 2005; Brayboy & Castagno, 2008; Cajete, 2000; Kawagley, 1993). Our learning environments reflected these commitments, for example, plants and other animals are “relatives” and connected to human life (Cajete, 2000). Further, our learning environments reflected pedagogical perspectives of knowing and coming to know, through building relationships with places by walking and reading the land—or what we call land-based pedagogies, even in urban places (see Bang et al., 2014; Friedel, 2009; Marin & Bang, submitted; Simpson, 2014). The team saw these stances as firmly emergent from IWOK and in expansive relationships with western science.

Studies of Learning in Everyday Contexts. In addition to design research, we are also interested in fundamental questions about culture, cognition and development, and have sought to more deeply understand the intellectual generativity (as opposed to deficits) and implicit pedagogies mobilized within everyday practices (Warren et al. 2005; Barton, Tan, & Rivet, 2008; Gonzalez et al., 1995; Gutiérrez, Baquedano-López, & Tejada, 1999; Lee, 2010; Varelas et al., 2010). For example, our research teams have studied outdoor practices of fishing, hunting, harvesting and gardening, among others. Building on the findings from these studies, as well as insights generated from our design research, we have shifted our focus away from topically named practices to the configurations of key processes in outdoor practices. These studies have focused on the position and role of the natural world in practices, the physical organization and dynamics in practice and the attentional patterns and semiotic practices that unfold in such practices (for example see Marin, 2013).

To better understand how transformative learning emerged in both the designed environments and family practices, and given our unsettling orientation, in this paper we ask the following research questions: (1) *What cultural practices and pedagogical forms offer opportunities for unsettling normative structural principles shaping time-space and nature–culture relations?* By using the term pedagogical forms we intentionally point to the concept of cultural forms (e.g., Saxe & Esmonde, 2005) suggesting that in interactions, pedagogical forms (questions, directives,

etc.) are used to accomplish particular goals. These forms play a key role in shaping cultural practices. (2) Which time-space relations and nature-culture relations (e.g., forms of human and non-human agency) emerge through the use of such forms? Here, we begin to articulate and illustrate these practices and forms to explore the opportunities for meaning making and agency that are opened.

Methods

The data presented in this paper comes from a larger body of research that began more than a decade ago and was inspired by Indigenous elders walking the perimeter of the Great Lakes to bring awareness to the declining health of the lakes and the earth at large. Compelled in part by the message of the walks, community members came together to develop innovative science learning environments for Native youth, families, and community living in Chicago. A strategic collaboration formally took shape between the American Indian Center (AIC), a community-based non-profit, the Menominee Language and Culture Commission and two research institutions, and was supported by multi-year grants. A major goal of this collaboration was to increase participation in the sciences among Native youth and families.

Data Sources and Participants

“Classroom” Data. Our design research occurred in iterative annual cycles. We began with summer programs focused on middle school age Indigenous children and then expanded to full year programs and monthly family science days. The number of middle school students participating in the program varied but hovered around 25. The majority of students participating were Native American, and many were low-income as indicated on their program registration forms. Most youth attended Chicago Public Schools. We primarily video recorded both the design process and implementation of the designed learning environments, however, we also audio recorded or took field notes where appropriate. For the purposes of this paper, we analyzed implementation data (video and transcripts) drawn from the second round of design during a six-week summer program implemented at the AIC. The implementation data consisted of 2–6 hours of daily video over ten days of enactment.

“Everyday practices” data. We also studied joint meaning making in everyday parent child interactions particularly in practices reflective of the practices in our learning environments. The data in this paper comes from a series of forest walk studies among urban, Native American families in which a caregiver was asked to go on a forest walk with their child. Caregivers were primarily parents and children were between the ages 4 to 8 years old and 10 to 12 years old. The majority of walks were dyadic (focal child and caregiver), however, sometimes more family members were present. In the first series, three Native American families were asked to go on multiple (between 4 and 6) walks (see Marin, 2013). In the second series, 25 Native American families (13 with children in the first age group and 12 with children from the second age group) went on a single walk in an urban forest preserve. In this paper we present a case study of one family’s forest walks. The Meadows family participated in the science education programs we designed. In this paper, we focus on discourse from the family’s second and third walk, both of which occurred in late September during the afternoon. Each walk lasted from 30 minutes to 1 hour. The family recorded themselves using small wearable cameras (see <http://www.vio-pov.com>).

Analysis. After initial steps in data processing (logging and tagging), we repeatedly viewed video and read transcripts that represented rich cases in relation to our research questions. We focused on the cultural forms and practices that students, teachers, and the case study parent routinely used during face-to-face interactions (i.e. interactional practices) that students, teachers, and the case study parent routinely used during face-to-face interactions to highlight and jointly notice time-space and nature-culture relations. Some scholars have discussed this in terms of disciplining perception (Stevens & Hall, 1998). This analytic focus on the routine interactional practices of noticing helped us to identify constructions, meanings and relations to the natural world, ascriptions of agency and intentionality, and the possible identities resourced in moments of learning (what Derry et al. (2010) called “events” in video data).

Through this process, we identified three cultural practices that families and teachers used to construct meaning and were key sites of desettling nature–culture expectations including: (1) instructional launches, (2) naming practices, and (3) walking and reading the land. We define each and provide justifications for their selection. The first practice—*instructional launches*—include the defining utterances of a teacher as they begin instruction. We take up launches because of the kinds of framing effects launches have for the directionality of action and learning are key points in which settled expectations are introduced *or* transformed (see Marin & Bang, in press). The second practice—*naming*—are instances in which aspects of the natural world (e.g., places and concepts) are assigned names which become semiotic signs of nature–culture relations. As Cajete (2000) points out knowing and building a relationship with land occurs through the “creative act” (p. 181) of naming. Naming from this view is more than a word—it is fundamental to all forms of learning and entails the directing of attention to make present (Ingold, 2011) conceptual and relational realities. The third practice—*reading land*—involves identifying and highlighting kinds, entities and phenomena in the environment. Nested within each of these practices are particular pedagogical forms that shape the unfolding of and possibilities within activities. For example, we hypothesized that ascriptions of agency shape the practice of reading land. Often these practices and forms are inter-twined and recursively inform each other.

Findings

We present excerpts from transcripts¹ where these practices were evident and trace the time-space relations and forms of agency that emerge from their use. Through our analysis of practices, two important pedagogical forms emerged: (1) remediating time-space constructions through naming places, often through the use of Indigenous languages as well as English and (2) constructing non-humans as agentic place makers. We suggest that through the use of these pedagogical forms (Indigenous language, attentional directives, interrogatives, etc.) time-space constructions were (re) mediated and made Indigenous ontologies and epistemologies present. In addition, structures were transformed through repeated use of and reflection upon these pedagogical forms. We argue that the process of structuration through the use of pedagogical forms transformed the potential identities and forms of agency available to Indigenous youth. We trace these dimensions across three illustrative examples.

Excerpt 1: Instructional Launches, Naming and Renaming Land. This excerpt is drawn from a larger unit in the summer program that focused on waterways. The unit included a wide range of activities including assessing water health, visiting important places within the Chicago area waterways, and emphasizing the impacts of urban landscapes on watersheds specifically with respect to runoff and infiltration. The focal teacher, Robert, in addition to being a language revitalization advocate, had been working with his tribe’s historic preservation office and recently found a map of the great lakes region (had a focus on now Illinois) with Miami names for the river

ways. The teachers decided to use the map as a launching activity for the unit on waterways. A group of youth gathered around Robert as he presented the map and talked through the representation. Robert used gesture and drew on recent weather events, directing the youth's attention to the names of the rivers and asked them if they could find Chicago. We suggest Robert's question ("Can you show me where Chicago is?") presented an interactional opening for students to animate the representation. We aim to show how this pedagogical move and the kinds of embodied performances it invited, placed students within the map relations being presented (both figuratively and literally). Once the youth had an approximate location of Chicago on the map, Robert moved to name the river in Miami, his heritage language. Robert's teaching practice is characterized by locating and identifying place and by naming and renaming place. Further his discursive moves positioned youth to make these dynamics part of their own "memory traces." With this in mind, we share excerpts from Robert's turns of talk where he used Miami to identify and name rivers in ways that both reflected an emergent stance about time-space relations and learners' relations to land and disrupted normative nature-culture relations.

Robert: Getting closer, right in here, yeah. Can you see that, can you read that at all? It says.. it says šikaakwa (shikaakwa) siipiiwi, šikaa, that's the Chicago River, so Chicago's right here.

Robert verbally responded to children's gestures and attempts to locate Chicago on the map. His "getting closer" first served as support and encouragement to the non-verbal wayfinding the children were doing in the representation. In his reading of the map šikaakwa and Chicago, are inter-changeable. This move resists a narrative of the loss of Indigenous language as normative and time-space structuring that marks Indigenous names as past and English names as present. Robert then moves to explain why names—and thus language—are important.

Robert (continued): What we wanna learn by looking at these maps, look at the names, all these names mean something. This is the Des Plaines River and its šiihšiiikwa (she she kwe a), what does that? What animal makes a sound that goes shhh-shhh shhh-shhh, shhh, shhhhh?

Robert is helping students to understand the ontological stances reflected in Miami, here water-animal relationships imbued in language. Further he does this by exploring word-sound relationships further reflecting embodied performance (he could have asked who or what is this river named after? Rather than performing the sound). In addition, his naming, "this is the Des Plaines River and its šiihšiiikwa" makes Miami ways of knowing present and becomes a discursive stance that resists settler-colonial time-space relations that erase Indigenous present (Larsen & Johnson, 2012). Although there is important theory about how this stance may presume a settler presence in the future (Tuck & Yang, 2012) it doesn't inherently foreclose a sovereign Indigenous future. Given that settler-colonial presence is a reality in youths' lives, this stance may be a critical point in a transformative trajectory in Indigenous futures (Coulthard, 2014). This form of temporal remediation was increasingly interwoven through teacher and student discourse in our learning environments and carries a spatial simultaneity, or as we suggest time-space synchronicity, that is critical in resisting the on-going conceptual appropriation of land to settler-colonialism. Smith (2012) argues that appropriating and renaming the lands of Indigenous peoples facilitated an ideological system where "space was appropriated from Indigenous cultures" (p. 107). This appropriation of space is implicated across IWOK and cultural practices (Smith, 2012). In this sense, Robert's discourse during science instruction may be seen as an act of counter-mapping

(Taylor & Hall, 2013) where he is disrupting settler renamings of Indigenous lands. The interaction continued as Robert facilitated students into explicitly considering their own memory traces.

Robert: They connect together. Look at all the big ones connected all together here, right. These are small rivers. They all connect to::: a bigger, this is the Illinois River. So they all connect to bigger rivers. The Mississippi coming down here. So, all these little ones, we call them watersheds, so when it rains right here, on our streets before Chicago had sewers, it would go in the ground and eventually run into (..) the Chica:::go siippiwi, the Chicago River and some of it actually went into the lake or it would run into the šihsiiikwa, Mississippi River () and this river here, (in lower Indiana) can anyone say that word, mahweewa? Does anyone remember mahweewa? (...) The mahweewa (sa), is the Wolf River. . .

Robert's explanation makes visible an important epistemological and ontological stance that opens empowering possibilities in sense-making. In this thread of utterances, Robert read the waterways in the map and wove English and Miami names in syncretic time-space relations. Robert also introduced a time-space shift towards the past in relation to water's movement "where water moved before Chicago had sewers," but this shift was accompanied by an explicit remediation of the word Chicago (e.g., Chica:::go) from English to Indigenous forms. Not unlike his opening move to ask young people to locate themselves in the place, Robert then asked another remarkable question "Does anyone remember mahweewa?" This question positioned the students to have a "memory trace" structured by the Miami name—not the English name. Giddens (1984) wrote, An ontology of time-space as constitutive of social practices is basic to the conception of structuration, which *begins* from temporality and thus, in one sense, "history" (p. 3). This interaction reflected the history Giddens suggests, and resisted students being positioned to only experience erased Indigeneity. In many learning environments, as Smith (2012) argues, the space-time relation is squarely settled in settler-colonial framings. We see a profound sense of purposefulness in Robert's navigation of time-space relations. This coordination makes land present elsewhere to settler-colonial enclosures for learners, thus opening and transforming boundaries and practice typically reflected in science learning.

Excerpt 2: Naming and Reading the Land. Engaging in observing walks became a routine practice in our learning environments. These emergent pedagogical practices prompted us to understand how families engaged in these forms of practice in their everyday lives. The discourse reported here is from the Meadow's family case study of walks in a local forest preserve. The Meadows family went on five walks over a period of six months. The first excerpt that we present is from the family's third walk and includes the mother, Jackie, and her sons Jeremy (6.5 years old) and Samuel (4 years old). We selected this excerpt because it demonstrates a parallel form of time-space relations seen in excerpt 1 and introduces expanded agency of non-humans as an ontological assumption in sense-making. It also demonstrates that Jeremy is actively mapping meanings and insights between his family experiences and the designed learning environments in which he has been participating.

Immediately before this excerpt, while walking in the forest, the family had found a dead tree and Samuel was somewhat in awe and asked "It's a dead tree?", suggesting he had never seen a dead tree before. He began to step towards the tree and Jeremy warned him against it. As the conversation unfolded, Jackie focused on the intended meanings of Samuel's question rather than the literal form of his question—it is not specifically a dead tree that Samuel has never seen (she does not say "yes you've seen a dead tree before") but rather how this particular tree died.

Jeremy: Yeah don't go too close. I see like, the- there like glowing eyes in there sometimes. Or it might just be the sun.

Jackie: Do you know wha, Jeremy, do you know what erosion mean?

Jeremy: What is erosion mean?

Jackie: Erosion? It's like when ah, things wash away,

Samuel: Batter up.

Jackie: you know like when you're at the beach

Jeremy: Yeah

Jackie: and stand by the edge and the sand kinda washes away

Jeremy: Yeah

Jackie: Well this tree probably fell over because the soil, er ah, the [soil erosion. And maybe like the roots came up and it was too heavy and a big wind came and blew it over.]

Samuel: [(hitting a can with a stick)]

Jackie: Leave it alone↑

Samuel: ((inaudible))

Jackie: and then it just toppled over!

Samuel: I don't see anything (inaudible)

We pause to note that indeed Samuel seemed to have his wonderings met and moved from being in awe of the dead tree to returning his attention to his brother's warning about proximity and seeing "glowing eyes." Samuel said, "I don't see anything." The presence of something in the tree became the focus of their joint sense making (e.g., Rogoff, 2014).

Jeremy: We should first check with the stick. Something came out, maybe. Don't get to, that close

Samuel: Hello? Hello?

Jackie: When you say that, do you think something's going to answer you? ((laughter))

Jeremy: Nothing's in there, guess I was wrong. Maybe, it just a illusion, that I was seeing.

Samuel, now focused on his brother's lead, tried to talk to the glowing eyes, presuming he can be in communicative relations with whatever is living in the tree. Jackie's initial reaction (laughter) seemed to reject this ontological premise and structures a normative nature–culture

relation that has the effect of discouraging the boys' inquiry. The boys seem to think she meant that there was nothing in the tree and that human communication is separate and distinct from non-humans. Further, this structuration seemed to close Jeremy's intellectual agency—he narrated a negative judgment (i.e., wrong) on his own thinking and recast his observation to illusion. In short, the meaning making space was narrowed. However, Jackie noticed, and quickly shifted to support their initial ontological stance and links it to their Anishinabe worldview.

Jackie: Some people say that like animals, they a, they'll understand, like um, if you speak in Anishinabe, so maybe you should be saying "boozhoo"

Jeremy: Boozhoo?

Jackie: Mm hm

Jeremy: And I'll be like [[[twirling walking stick]]]

Samuel: [Shoo, shoo, shoo, shoo ((whacking plants))]

Jeremy: And I'll see like an animal way, that kinda sounds like yes (inaudible)

Jackie's shift resourced and expanded the identity frames at work in this moment by explicitly naming and mobilizing Anishinabe language (Nasir, 2011). Further, the temporality marked by the introduction of Indigenous language, similar to Robert's, functioned to expand the sense-making space. Mom didn't historicize IWOK; for example, she does not say "some people used to say. . ." and she used the word speak instead of spoke. Moreover, she oriented to future (e.g., "you should be saying"). This shift repaired the unintended consequences of her initial reaction—her redirection suggested that Jeremy was not wrong about something being in the tree; rather there may be a different mode, or in this case, language of inquiry. This redirect reopens for Jeremy both the human-non-human communicative space and a way of seeing—he says, "I'll see like an animal way." This is a remarkable ontological transformation of the presumed possible relations between humans and non-humans as distinct and separate that was present when the interactional medium was English. We suggest the use of Anishinabe language (Ojibwemowin) supported relational perspectives between humans and non-humans. After this interaction Jeremy and Samuel continued to explore and investigate the dead tree and its possible dwellers, constructing important ecological knowledge (e.g., erosions impacts, dead trees play an important role in ecosystems and more). The recognition of agentic non-humans is an important dimension of transformed nature-culture relations that was consistently present or it emerged throughout this family's walks. Jeremy's perspective taking (i.e., "I'll see like an animal") poignantly articulates the way in which he consistently engaged in expansive sense-making especially, as shown next, through evidential reasoning.

Excerpt 3: Reading Land. The next excerpt is from the family's second walk. Jeremy has taken on the role of leader and was directing them through the forest. Jackie was concerned that the trail they were on would end. In response to Jackie's concern, Jeremy pointed out a deer trail. A deer trail is a path, often through tall grasses, that deer make and travel on. Jackie questioned if what they were seeing was actually a deer trail and asked how Jeremy knew. Relying on previous experiences from his participation in our science programs (he referred to Sam, a teacher in our program), Jeremy demonstrated how deer trace their steps. In doing so, he assigned agency to deer

as trail makers—“they make trails by “wa, walking.” Then Jeremy observed other features of the environment and suggested that the deer must have crossed the river. Assembling his observations, he began to narrate a story of the deer’s experience. He said:

Jeremy: Hey ma, the deer ma (2.0) The deer musta crossed here

Jackie: m:h::?(3.0)

Jeremy: but then they got stuck (0.03) this a, this musta been, like a long time ago when it’s flooded, because lookit, there’s a deer trail in the river.

Jackie: (laughs) (1.0), ya think there’s are deer trails in there?

Jeremy worked to construct the deer’s path as well as the relationship to the water that was previously there (flooding). He focused on cycles and dynamics in order to understand what he was seeing and noticed something that evidenced to him the deer crossing didn’t occur smoothly (they got stuck). Jackie offered an alternative explanation for what they were seeing in the riverbed. She suggested that what they were observing was not a deer trail but instead holes in the riverbed. Jeremy was undeterred by her explanation and walked along making observations.

Jeremy: yahh [Yeah, it could be]. But, I j- a deer woulda gone this way. Here there’s more (.) well this is a trail. (8.0) The deer musta walked through here (2.0)

As Jeremy continued to work out his “deer path explanation,” he coordinated his observations by taking on the perspective—or the “*memory traces*”—of the deer to help himself *orient* to and interpret the unfolding activity—or conduct—of the deer. As Jeremy and Jackie contemplated possible paths through the forest and constructed narratives about what they were encountering, they pursued meaning-making by, in part, taking on the perspective of non-human actors (river, deer and other living kinds) and tracing their paths. We see this process as weaves of movement or evidential readings of non-humans’ structural modifications of land. Imagining and exploring phenomena from within lived perspectives has been found and explored with other non-dominant communities (e.g., Warren, Ogonowski, & Pothier, 2005). Jeremy has done this with an expanded form of nature–culture relations, in which structured divisions between humans and non-humans are not present, thus enabling distinct and expanded forms of agency, perception, explanation, and ultimately meaning-making.

Discussion and Conclusions

Giddens (1984); in working to understand agency, linked perception to the process of selective attention and suggested, “it expresses the active engagement of agents with their environments” (p.48). What people perceive then is not by chance but by the process of attending to affordances in the environment. This is a positive rather than negative selection (Giddens, 1984) and is guided by particular memory traces and orientations in practice. As Giddens (1984) notes: “Ordinary day-to-day life. . . involves an *ontological security* expressing an *autonomy of bodily control* within *predictable routines*” (p. 50). This time-space ontology structures activity and is grounded in perception, a multi-sensory activity that involves the whole “body in active engagements with the material and social worlds” (p. 47). For many Indigenous communities (both from North America and Africa), settler-colonialism has dramatically altered our engagement with the material and social worlds and disrupted many predictable routines,

thus preventing ontological security. However, communities have developed various resiliencies in navigating the epistemological and ontological complexity that is predicated by “normative” structures, particularly nature–culture relations often reflected in science learning environments.

In this paper, we presented rich cases that reflected emergent pedagogical forms and practices that expanded time-space relations and opened a simultaneous agentic heterogeneity (Massey, 2005). Indeed, we see Jackie, Jeremy, and Samuel, simultaneously navigating the routine presence of disrupted ontological security and reorienting their “memory traces” and practice (i.e., from impossible to possible human-non-human communication). This family’s navigation between disrupted ontological security and the reorganization of observations from Anishinabe world-views resituates their perceptions and ontologically (re) places and (re) stores their “body sense” (Cajete, 2000). A key aspect of this reorientation was to instantiate a time-space framing counter to settler-colonial time-space structuration—the erasure and absence of an Indigenous presence and Indigenous places (Smith, 2012). The map reading activities like the one shared in this paper could easily have relegate place names and land to settler-colonial constructs of indigeneity as pre-modern and/or erase the presence of Indigenous peoples (Smith, 2012). Robert’s use of attentional directives during map reading critically supported students in navigating through time-space relations by creating temporal and spatial synchronicity that refused settler colonial erasure: his facilitation interwove Indigenous present and possible futures in generative and agentic forms as they continued to learn about watersheds.

Building science learning environments that expand the boundaries of reality and possible futures for students is both vital and possible. Doing so requires relentless attention to the ways in which normative forms, or structural principles, create moments of interaction that reproduce or reinscribe inequity. In addition, it requires the reorganization of talk-in-interaction so that memory traces, which support Indigenous futurities, may take shape. While we did this by engaging IWOK, we are not suggesting that all learning environments must do this (though for Indigenous communities we think yes as well as language revitalization). Indeed, what may be more critical is engaging structural principles derived from settler-colonial dynamics with respect to nature–culture relations and settler lifeways. This requires analysis of the pervasive time-space orientations and structuring born of settler colonialism. The time-space synchronicity reflected in our work shifted possible meanings and identities for Indigenous youth by unbinding and expanding, or desettling, temporal and spatial constructions and agentic ontologies from settler-colonial constructs of peoples and lands. Importantly this has not meant the principled absence of western scientific ways of knowing. Rather we are working toward a politically and restoratively conscious form of heterogeneity of learning and engagement that has a multiplicity of possibilities in practice for Indigenous students as well as other students. Critical to this, and we think most transformative work, is deep engagement with communities and families and the ways in which they are (and have been) negotiating their everyday lives and practice. In our view science education needs to relentlessly empower and build from ontological heterogeneity reflective of peoples’ lived lives, particularly those historically dispossessed and dominated, in order to expansively educate for all of our collective socio-ecological futures.

Notes

¹Discourse was transcribed using modified conventions from conversation analysis (Goodwin, 2000; Jefferson, 2004). Colons indicate prolongation of sound and talk, which was emphasized, is underlined. Brackets indicate overlapping talk. Double parentheses indicate non-verbal actions. Numbers within parentheses represent the length of a pause in seconds. Parentheses following Miami words are the phonetic pronunciation.

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