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Desettling Expectations in Science Education

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Abstract
Calls for the improvement of science education in the USA continue unabated, with particular concern for the quality of learning opportunities for students from historically nondominant communities. Despite many and varied efforts, the field continues to struggle to create robust, meaningful forms of science education. We argue that 'settled expectations' in schooling function to (a) restrict the content and form of science valued and communicated through science education and (b) locate students, particularly those from nondominant communities, in untenable epistemological positions that work against engagement in meaningful science learning. In this article we examine two episodes with the intention of reimagining the relationship between science learning, classroom teaching, and emerging understandings of grounding concepts in scientific fields – a process we call *desettling*. Building from the examples, we draw out some key ways in which desettling and reimagining core relations between nature and culture can shift possibilities in learning and development, particularly for nondominant students.

> Because of [the sea's] fluid capacity to link the smallest microorganism to the largest ecosystem, the ocean is a medium through which to explore shifting limits of the category life in the biological sciences. [Helmreich, 2009, p. 5]
> Many tribes speak either of periodic renewal … or of periodic cleansing of the planet with some disruption of landscape and destruction of life followed by the appearance of new life-forms and new networks of responsibility. [Deloria, Deloria, Foehner, & Scinta, 1999, p. 25]

Despite continuing calls for improvement [National Research Council, 2007, 2011], the field of science education has struggled to create robust, meaningful forms of education that engage nondominant students in complex learning as empowered

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makers of meaning and actors in the world. In this article we explore some key contours of this challenge through a reimagining of relationships between science learning, teaching, and shifting understandings of grounding concepts in biological science. Specifically, we explore what it might mean for learning and development if we were to dislodge the 'settled expectations' that current practice in science education simultaneously imposes on subject matter, learners, and teachers.

We mobilize the construct of settled expectations from Cheryl Harris's [1995] foundational analysis of racial hierarchies in her essay 'Whiteness as Property.' Harris defined settled expectations as 'the set of assumptions, privileges, and benefits that accompany the status of being white … that whites have come to expect and rely on' across the many contexts of daily life [Harris, 1995, p. 277]. The Americas were founded in doctrines of manifest destiny in which culture (equating to whiteness) and property ownership (equating to white forms of use of the natural world) gave 'legitimacy' to settler colonialism. These same constructs set in motion the gradation of human beings [Smith, 1999]. Those identified as 'not fully human' were relegated to the natural world, a realm where white ownership and human entitlement ruled and was manifested through mass removals, elimination, and enslavement of indigenous peoples of North America and Africa [Lee, 2009]. While the contemporary face and consequences of the hierarchical ordering of human life have shifted, settled expectations based in whiteness remain deeply embedded in the multidimensional structure of our society. Moreover, they are embedded in ways that make them seem natural and objective rather than socially or ideologically constructed, at least to whites for whom they function as assets to be protected [Harris, 1995]. Often, settled expectations are implicit and associated with blindness to institutionalized privilege and associated ontological and epistemological constructs.

When applied to schooling, the construct of settled expectations can usefully articulate and problematize entrenched, usually hidden, boundaries that tend to control the borders of acceptable meanings and meaning-making practices. These have also shaped deficit-oriented discourses concerning students from nondominant communities [Bang & Medin, 2010; Gee, 1990; Heath, 1983, 1989; Hymes, 1996; Ladson-Billings, 2003; Lee, 2008; Martin, 2009; Nasir, 2000, 2002; Nasir, Rosebery, Warren, & Lee, 2006; Rosebery & Warren, 2008; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001; Warren & Rosebery, 2011]. Deficit discourses operate to control the scope of what constitutes an acceptable explanation, argument, or analysis; what 'smart' looks and sounds like; whose narratives and experiences are valued and for what purposes – to name a few well-documented aspects of classroom discourse [Bang & Medin, 2010; Ladson-Billings, 2003; Lee, 2008; Martin, 2009; Nasir, 2000, 2002; Nasir et al., 2006; Warren & Rosebery, 2011; Warren et al., 2001]. Further, normative descriptions of discipline-specific subject matter in schools shaped by settled expectations tend to restrict the intellectual and expressive opportunities youth have in school and thereby reproduce the privileging of whiteness [Barton & Tan, 2009; Gutiérrez, Moralez, & Martinez, 2009; Lee, 2009; Nasir & Hand, 2006; Warren & Rosebery, 2011].

In science, technology, engineering and mathematics (STEM) education, and biology specifically, these normative descriptions of subject matter operate at what is referred to as the nature-culture divide [Helmreich, 2009; Ingold, 2011; McLean, 2009; Pierotti, 2010] where they border and define, usually in hierarchical terms, acceptable STEM understandings and practices, including relationships between hu-

mans, other organisms, and the environment. These boundaries function ideologically to (a) restrict the content and form of science knowledge valued and communicated through education and (b) devalue and dismiss boundary-expanding forms of knowledge, experience, and meaning-making with which students approach scientific phenomena. One consequence of STEM-related settled expectations as manifested through the nature-culture divide is to locate students, particularly those from nondominant communities, in untenable epistemological positions that work against engagement in meaningful learning of scientific ideas, practices, and phenomena.

From this point of view, what we call 'desettling' settled expectations in science education requires an explicit reworking of the nature-culture divide by consideration of knowledge-power relations, historically structured inequalities, and assumed assimilation into particular knowledge paradigms.[1] In this paper, we examine the nature-culture divide by juxtaposing recent research in biological science, specifically in marine microbiology, with examples from two lines of our design research in science education. The examples from marine microbiology and classroom science pivot on reconfigured constructions of possible relations between nature and culture [Helmreich, 2009]. To preview our argument, we will suggest that constructions of the nature-culture relationship prevalent in school science – for example, in the form of context-independent classifications of intrinsic attributes of things [Ingold, 2011] – make unspeakable for students and teachers questions of how nature and culture are intertwined. In this way, these dominant constructions marginalize or silence the heterogeneous 'hives of activity' [Ingold, 2011, p. 29] involved in living and making sense of the world, including those of contemporary biological science, in which complexity, relationality, and environmental variation increasingly figure in explanatory accounts [Helmreich, 2009; Pierotti, 2010].

Why is it important to reconsider settled construals of the nature-culture divide in the sciences and in STEM education? We argue that unless such desettling takes place, students from nondominant communities will continue to become alienated from STEM education. To draw out some key ways in which desettling core relations between nature and culture can shift possibilities for learning and development, we explore two core phenomena: life and water. We offer examples from our research as invitations to our readers to imagine the kinds of meaning-making that can arise within a desettling paradigm – that is, one focused on developing transformed and transforming relationships to core phenomena by explicitly engaging students with them at the nature-culture boundary.

A Story of Two Worlds

We begin with stories from two worlds that pose the question, *What is life*?, but answer it from different places. One world, the deep sea of microbial oceanography, highlights shifting understandings of life within a developing scientific field studied by cultural anthropologist Stefan Helmreich [2009]. The other world, standards-based science education, hews to a rather more fixed understanding of life.

[1] The desettling construct is informed by conceptions of decolonization [Smith, 1999] as well as by Harris's [1995] analysis of 'settled expectations' in critical race theory.

First, consider the world of standards-based science education. In a widely used middle school curriculum called *Diversity of Life Course* [Lawrence Hall of Science, 2003], students are tasked with developing an 'operational definition of life' based on characteristics common to all living organisms. As part of this activity, students sort pictures of objects and organisms into categories of living and nonliving. The pictured objects include, among others, rain, a rocking horse, the sun, a robot, and fire. The pictured organisms include, among others, jellyfish, a horse, a spider and web, and trees. The sorting and defining are meant to feed each other, with the goal being to develop a set of criteria to use in determining what is living and what is not.

In a classroom discussion focused on this activity, seventh grade students in an ethnically and socioeconomically diverse classroom were eager to discuss the question of whether to classify the sun as living or nonliving [Warren & Rosebery, 2011]. We focus on Jonathan, an African American male, whose teacher worried about how to structure his participation in science in ways she felt would be productive for him and his classmates. Following a discussion of the idea that stars are described as having a 'life cycle,' Jonathan posed this question: 'If the sun is nonliving, then how does it like produce the flowers … cuz like if you think about it, if something's dead, how does it help another thing out?' The conundrum he posed – how is it that a nonliving sun, an object without the vitality of organismic life [Helmreich, 2011], can help living things such as plants – propelled a vigorous discussion. At one point, a European American female student offered an analogy that she and the teacher felt explained to Jonathan why the sun should be classified as nonliving: 'Well, I don't know if this makes sense but like for Jonathan's we have to have water even though water is not living … we still need it like plants need the sun.'

In his response, Jonathan resisted being positioned as not understanding or as simply wrong with respect to the student's explanation and the teacher's acceptance of it. He argued that the water-human relationship was not in fact an explanation but the very same question with the very same logic he was exploring. In effect, he was asking about the presumed coherence of the living/nonliving binary classification of physical objects like the sun on which earthly life depends, a logic that locates the sun and a toy rocking horse in the same category. More than simply questioning, Jonathan was suggesting a different, more dynamic way of seeing the sun and its connection to life on Earth by framing the argument in terms of an essential relationship between the sun and plants. He was moving toward a view of the system as living. Working at making ecological rather than categorical sense [Bang, Medin, & Atran, 2007], he was thinking from a different, arguably deeper perspective than the curriculum, one closer to contemporary scientific thinking [Earle, 1995; Pierotti, 2010]. Further, he was problematizing the settled, implicit epistemological relation between nature (e.g., the sun and its relationship to organisms) and culture (e.g., the binary categorization of living and nonliving) represented in the curriculum. Despite the intellectual force of his argument, he ultimately yielded to the normative authority of the curriculum that the sun belonged in the nonliving category.

Like the school experience of many students from nondominant groups, in this situation Jonathan encountered the rippling effects of settled expectations through which the thinking of a European American student was treated as a valuable asset, in alignment with the curriculum, while his thinking was essentially dismissed. In this context, the construction of the nature-culture relationship not only dominated classroom discourse, making the classificatory paradigm uncontestable, but it al-

so led Jonathan to detach from serious engagement with a meaningful scientific question.

Moving now to our second story, we look to the world of microbial oceanography investigated in the anthropological work of Stefan Helmreich [2009, 2011]. Helmreich studied biologists as they investigated microbial life forms living in deep-sea hydrothermal vents at extremes of chemistry, temperature, and pressure. These *extremophiles*, as they are called, thrive in ecologies of a kind that 'pressed against the boundaries of what biologists believed living things capable of' [Helmreich, 2011, p. 683].

In one chapter of his book, Helmreich [2009] focuses on an emerging development within microbiology, not to be confused with creationism or intelligent design, that is challenging, at least for microbial life, the Darwinian view of the unity of life. The Darwinian view is rooted in genealogical descent – also the basis for Darwin's idea of natural classification – and is represented as a branching tree. As Helmreich [2009, pp. 76–77] reminds us, Darwin borrowed this representation from Victorian practices of tracing family lines and an earlier tradition of tracing property inheritance. The modern-day rethinking of the tree of life some scientists are engaged in, admittedly not uncontested, has been stimulated by the discovery that microbes engage in 'lateral gene transfer' within generations across species boundaries in addition to vertical inheritance from generation to generation. This has led some microbiologists to reimagine the tree of life as a net or net-and-tree synthesis [Doolittle, 1995, as cited in Helmreich, 2009, p. 82] or to 'think of life as something with properties similar at all scales, a system of self-stabilizing networks …' [Chisholm, 2005, quoted in Helmreich, 2011, p. 687]. In short, desettling the tree of life has generated new forms of thinking among microbiologists, agitating previously stabilized nature-culture relations.

We have only touched on Helmreich's remarkable account of deep-sea science. Our intent is not to argue for a particular view of the boundaries of life but, rather, to make visible a deep theme in Helmreich's ethnography: the *fluidity* of the relation between 'life forms' (e.g., organisms situated in ecologies) and 'forms of life' (e.g., 'those cultural, social, symbolic, and pragmatic ways of thinking and acting that organize human communities') [Helmreich, 2009, p. 6]. Life forms, also known as nature, and forms of life, also known as culture, are not separable:

> What does all this mean for the form that life takes? It is multiple; even when reduced to genes, it flows all over the place. Marine microbiologists are clear that classifications are matters of framing. The form in 'life forms' changes with scale and context … The question, how to think about the forms life might take, depends on which properties are relevant to the unit of description in question and on how sociopolitical frames – biotechnological, environmentalist – condition these choices, even as they are themselves summoned forth by biological knowledge in a complicated cycle in which life forms and forms of life recursively inform one another. [Helmreich, 2011, p. 687]

This fluidity among life forms and forms of life is not unique to marine microbiology. It is also visible in the water management and climate change work of indigenous scientist Michael Blackstock [2001, 2002, 2008] and in cutting-edge research on human-bacterial relationships described by the Human Microbiome Project [Human Microbiome Project Consortium, 2012]. Building from an indigenous perspective, Blackstock's research locates water as the *center of life*, connecting all things [see

also Pierotti, 2010]. In a register of meaning unacceptable in school science, Blackstock [2001] writes that 'the Elders believe water is alive or biotic' (p. 12). This view is fundamentally different from that privileged in Western science and based in analysis of the physical and chemical properties of water [Blackstock, 2001]. Aligned with emerging work in anthropology [Ingold, 2011; McLean, 2011], Blackstock suggests that the taxonomic lens of Western science 'has created a chasm between the living and non-living components of our world' [Blackstock, 2002, p. 3], a chasm that reflects a human-centered ontology [McLean, 2009].

The conceptualization of water (or the sun) as living or nonliving matters scientifically as well as educationally. Blackstock [2002] argues that by locating water as a substance that is part of a nonliving physical environment which interacts with a living world, science fails to take account of the way in which it functions as *the* fluid component that fundamentally connects organisms in an ecosystem. He suggests that broader understanding of changes in the world's water, especially in the rhythms of the global hydrological cycle (a focus overshadowed by the prevailing focus on carbon) would better help us adapt to and understand climate change as a matter of 'sustainable survival' [Blackstock, 2008, p. 15]. In these ways, Blackstock's water-centered ecology rescripts the dominant human-centered framing of the nature-culture relationship and parallels Helmreich's [2009] analysis of developments in marine microbiology and the startling discoveries of bacterial microbiologists who are re-envisioning the human body 'life form' as a form of life akin to an ecosystem [Human Microbiome Project Consortium, 2012]. In short, emergent understandings of life forms and forms of life are entwined in complicated cycles of knowledge-making in the world of research science.

These examples from professional science show the ways in which desettling taken-for-granted assumptions is an unexceptional, if conflictual, part of scientific work that is leading to critical shifts in ways of thinking about core and emergent phenomena related to life. In the cases examined above, life is conceptualized as increasingly relational rather than essentialized or comprised of sets of defining properties [Ingold, 2011; Perotti, 2010]. As Helmreich [2009, p. 8] suggests, '… life is being redistributed into a fluid set of relations.' As he further suggests, with profound conceptual shifts taking shape in contemporary science, it becomes important to rethink the relations between human cultural worlds (forms of life) and worlds of scientific concern (life forms) as being more entangled than previously thought [for studies in other biocultural domains, see Harding, 2010; Kohn, 2007; Raffles, 2002; Tsing, 1995]. Helmreich argues this rethinking for anthropology; we argue its importance for education.

These stories from different worlds are meant to illustrate the idea that 'life forms and forms of life recursively inform one another' [Helmreich, 2011, p. 687]. In the world of middle school science, Jonathan's interest in exploring the ontological status of the sun created a possible opening toward making the settled framing of life in school science visible. Traversing context and scale, he argued against typological forms of life in biology and in the classroom that he viewed as restricting the ways he and his classmates were allowed to think about webs of meaning connecting life forms. In the world of marine microbiology, Helmreich described how biologists' conceptualizations of their core subject matter are being transformed as they increasingly try to account for the fluidity of relations between life forms and forms of life in their research. Without suggesting an isomorphic relation between these two

worlds, we nonetheless want to highlight the way in which life forms and forms of life are being put into motion in both, admittedly with different effects. We see in these examples the contour of an orientation toward desettling settled biological and cultural frames as *linked explanatory practices to be examined and contested* rather than merely assumed and applied [Helmreich, 2009; Nasir et al., 2006; Pierotti, 2010; Warren & Rosebery, 2011].

On Desettling Science Education

Our classroom research has focused on designs for science learning based in an expansive view of human meaning-making as fundamentally heterogeneous and multivoiced, both within and between socially and historically constituted communities [Bakhtin, 1981; Bang, Curley, Kessel, Marin, & Suzokovich, in press; Cole, 1998; Engeström, 1987, 2001; Gutiérrez & Rogoff, 2003; Lee, Spencer, & Harpalani, 2003; Nasir et al., 2006; Rosebery, Ogonowski, Di Schino, & Warren, 2010; Warren et al., 2001]. This work sits in some tension with an educational environment focused increasingly on defined normative progressions within knowledge paradigms associated with and established through dominant Western forms of knowing [Bang, 2009; Cajete, 1999]. Typically, in school science students and teachers are left on their own to navigate the conflicts and contradictions that arise in relation to the core ontological and epistemological commitments that structure normative progressions and related judgments of students' meaning-making. As demonstrated by Jonathan, questions of how to connect particular conceptualizations of life forms and forms of life in the science classroom are often muted, or worse. These unsupported border-crossings can be treacherous for students, both for those who problematize or resist what is taken for granted in school science and for those who learn to acquiesce or accommodate to it [Aikenhead, 1996; Bourdieu, 1992; Marker, 2006; Nasir & Saxe, 2003; Warrior, 1995].

How can we change the conditions of learning and development for these students so that the demand for such perilous border-crossing is eliminated? More specifically, how might a teacher take up Jonathan's dissatisfaction with the boundaries of settled meaning related to both life forms and forms of life that were operating in his classroom? We suggest that expansive possibilities in learning and development attuned to 21st-century problems of life will develop by simultaneously desettling (a) historically constructed deficit discourses of nondominant students, in Jonathan's case of black boys in particular [Nasir, Snyder, Shah, & Ross, 2012; Noguera, 2008] and (b) the normative ontological and epistemological divide between nature and culture in science education.

In our view, desettling entails imagining multivoiced meanings of core phenomena as open territory for sense-making in the science classroom, similar to the kinds of meaning-making opportunities that are available to scientists in the field. Furthermore, we believe that engaging with diverse meanings amplifies rather than attenuates learners' relationships and experiences with the larger world and the places in which they live [Ingold, 2011]. In the next section, we present two learning episodes that illustrate students and teachers engaging in desettling activity around nature-culture relations embedded in curricular representations of water.

Forms of Life and Life Forms in Science Learning and Teaching

The learning episodes that follow share pivotal intersections in the ways in which participants showed attunement to shifting currents in water as both natural substance (life form) and cultural form (form of life) [Blackstock, 2002; Goodman, 2000; Helmreich, 2011; Sultana, 2011]. In this way, the learning and teaching work shares key characteristics with that of Helmreich's microbiologists and Blackstock's water-centered ecology. Our analysis of these episodes highlights attendant possibilities for transformative teaching, learning, and development.

Episode One: Meanings of Water Depend on Forms of Life

We begin in a grade 6–8 classroom that participated in a design research project with the Chèche Konnen Center. The classroom was part of a literacy program for recent immigrants from Haiti in an urban public school in the Northeast USA. The teacher, Ms. R., was responsible for teaching all academic subjects, including science, to her middle school students in both Haitian Creole and English. Ms. R. approached teaching and learning as an emergent process actively negotiated in moments of expansive exploration with her students. Her approach reflected a profound respect for her students' sense-making and intellectual life. In the following episode, Ms. R.'s students troubled settled relationships between nature and culture as they considered the meanings represented in two curricula on water.

In line with the district's middle school science framework, the students studied the water cycle, learning how water circulates through the earth's surface, oceans, and atmosphere, renewing the earth's constant supply of water. They also studied water conservation using a curriculum developed by a state-level water resources management unit. One day they were discussing the many ways in which water is wasted in a typical American home. They cited how people, including themselves, leave the water running while washing dishes or brushing teeth. During this discussion (translated from Haitian Creole), Markenson shared a question that had arisen for him: 'Ms. R., I need to know the difference, when I read in our book about water (an earth science text), it says it's always the same amount of water as there was long ago. Then what makes this one (the water conservation curriculum) say water is wasted?'

Markenson's question expressed an urgent desire to understand an apparent contradiction in the ways water was being represented in the two authoritative water curricula. In the earth science text, he learned that water cycles through a natural system in which the amount of water on Earth does not change. In the water conservation curriculum, he learned about the many ways in which water is wasted through practices of human consumption and use. With his question, Markenson was wondering how this difference in representations of water – in Blackstock's [2002] view 'a chasm' between an invariant global nature and a human-centric culture – was to be understood or reconciled? His classmates took up his concern from varied places, with different consequences for conceptualizing the nature-culture divide.

Jean Marc asserted the claim that 'water is never wasted.' He supported his claim by invoking the hydrological cycle, noting that a water source is always replenished: 'Even if it is empty, it comes back again … Then it goes to a place where it was, to its place.' But he did more than invoke the authority of the hydrological cycle as an in-

variant global process. He narrated water as having 'its place' – a home, which it actively seeks out and to which it belongs. Jean Marc oriented to water with a tone of reverence for its eternal rhythm of loss and return, a rhythm vividly experienced in Haiti with rainy seasons punctuated by droughts and floods. He meshed, in other words, a hydrological perspective with a sense of water's actively flowing nature. In this respect, Jean Marc's way of seeing water echoed perspectives highlighted by Blackstock [2001]. In his orientation to water, Jean Marc emphasized the rhythm and flow of water's movement; the place of human activity, including consumption, was dislodged from the center of water's meaning.

Another student, Mirey, assumed a different stance. She contrasted people in the USA who waste water with 'other people elsewhere who can't find any,' including many in Haiti. She noted that nature imposes limits on humans' use of water: 'The amount of water on earth is not the amount of water for us to use. People can't use salty water. There is water for us to use, but it's only a little bit.' She mobilized established facts about water to argue for more responsible ways of living on both a global and local scale: 'If we would take precautions with water, it would be better …' In linking water facts to locally and globally consequential contrasts in human beings' ways of living in water-rich and water-scarce regions, Mirey conceptualized water through a dynamic relationship in which nature and culture were entwined.

Next, Keenon took up the nature-culture tension expressed in Markenson's question. Building on Mirey's orientation, he introduced a new, profound layer of complexity to the conceptualization of water. He focused on the intersection between natural and cultural *distributions* of water in the world: 'People here and people in Haiti, there are places where they can't find water. Is it the places where they are wasting water that they always find more?' Where water is scarce, as in Haiti, people are hard pressed to find more. Where water is abundant and wasted, people '*always* find more.' Keenon complicated the space of emerging water conceptualizations by reframing the nature-culture relation as a problem rooted in both historical and geographical patterns of water use and access (note his use of 'always' in this regard). He problematized the object, water, as an index of inequality, a perspective that also redefines the nature-culture chasm as something more than an individually or locally focused interaction between natural variation in the water cycle (a fact not represented in water cycle models used in schools but acutely experienced in Haiti) and human cultural activity.

Mirey responded to Keenon by locating his provocative question within a specific, localized history of land use in Haiti: 'It's the way they use the land that makes Haiti lack water.' In Haiti, water scarcity results in part because of human activity, specifically deforestation, which, as is well known, has had devastating environmental, social, and economic consequences. Taking a long view of human history, Mirey imagined a past in which people likely did not use water 'in the same way we use it,' implying that they had a different relationship to water and did not experience the same problem of scarcity. She then recontextualized her argument in a more intimately relational frame: 'But it's especially *we* who have changed things, because we cut the trees down.'[2] Here Mirey located herself as part of a national narrative lived

[2] We note that deforestation in Haiti reflects a complex history of environmental factors, colonization, enslavement and revolution, long-standing political and economic turmoil, and more, all contributing to the enduring poverty of the vast majority of its people.

at the nexus of nature and culture. In this narrative, it is people who, echoing the words of the Elders cited by Blackstock [2001], 'disrespected water' through land use practices that did not take account of the ways in which ecosystems are complexly interconnected through water.

In this episode, we see the students wrestling with varied views of the object (water) problematized by Markenson. In their discussion, they worked to make sense of water *across* the two forms of curricular representation, recognizing deep tensions between them. They blurred settled relations imposed by the curricula between nature and culture, putting into motion both water (as life form) and ways of thinking about water (as forms of life). In these ways, they reached beyond what the canonical curricular representations of nature and culture supported them to do. Further, in their responses, they mapped a considerably more complex, multivoiced network of locally and globally consequential relationships involving movements in and across history and place of water, land, people, and practices of many kinds at varied scales.

While Markenson addressed his question to Ms. R., she did not immediately respond. As was typical in her practice, she let the students engage expansively with the question. She knew that they would mobilize their considerable skill in *bay odyans*, a discourse practice widely shared among Haitians [Hudicourt-Barnes, 2003; Warren & Rosebery, 1996], and draw on their life experience and historical knowledge to complicate, from varied angles, the ways in which water was being represented in the two curricula. She did not intentionally plan for a lesson aimed at desettling normative disciplinary constructs of water as both life form and form of life. However, by approaching the curriculum as emergent, open territory for intellectual inquiry, she routinely fostered engagement with questions at the nature-culture boundary that were closed down for Jonathan in our earlier example. In Ms. R.'s classroom, the students did not have to concede to the epistemic control and cultural dominance of the science curriculum [for more on Ms. R.'s teaching practice, see Jean-François, 2008].

In our second episode, we consider a learning environment explicitly designed to address the nature-culture chasm. In *Alien Ocean*, Helmreich [2009, p. 6] writes that 'marine microbiologists' meditation on the meanings of microbes as long-lost relatives …' reflects their effort 'to connect life forms to forms of life,' that is, to mend the nature-culture divide. In a design experiment in an urban indigenous community, indigenous teachers and community members set this as the explicit goal for science teaching and learning [Bang et al., in press]. With this next example, we focus on the discourse of teachers, whose aim was to desettle normative science learning and disrupt the settled, invisible constructs of the nature-culture divide by designing from decolonizing methodologies [Smith, 1999].

Episode Two: Water's Life Depends on Forms of Life

In an effort to improve opportunities for indigenous youth in an urban midwestern US community, the first and last author and local community members engaged in a community-based design experiment to create learning environments that actively supported border crossing in science learning for middle-school-level indigenous youth [Bang & Medin, 2010; Bang, Medin, Washinawatok, & Chapman, 2010]. As part of the design process, the design team (comprised of parents, teachers,

elders, youth, and other experts as well as project staff) engaged in critically reflective activities to explore relations between Western science and indigenous knowledge systems (e.g., conflicts, similarities, overlaps) [Bang et al., 2010; Barnhardt & Kawagley, 1999].

For present purposes, we describe two specific dimensions that emerged from these critical reflections and were used to frame the learning environments [for a more detailed description, see Bang et al., in press]. First, the design team focused on epistemological differences in relational construals between indigenous and Western knowledge systems [Barnhardt & Kawagley, 2005; Brayboy & Castagno, 2008; Cajete, 1999; Kawagley, 1995]. Science classrooms typically segregate relationships between life forms that are foundational in indigenous epistemologies and reject indigenous conceptions of life forms. For example, designers conceptualized water, rocks, and other phenomena (identified as 'nonliving natural kinds' in Western science) as alive and as having an active presence and entangled relations with others in the natural world [Ingold, 2011]. The design team was deeply committed to teaching youth this orientation that all things are related – that is connected in dynamic, interactive, and mutually reciprocal relationships [Cajete, 2000; Wilson, 2009].

Secondly, the design team specifically pondered explanatory frames of the place of human beings in, and their relations with, the rest of the natural world in both knowledge systems. They focused on differences in nature-culture ontologies between knowledge systems that view human beings as either 'a part of' or 'apart from' the natural world [Bang et al., 2007]. Designers came to view anthropocentricism in Western knowledge systems as a settled expectation in learning and development and intentionally worked to make its cognitive and ideological consequences visible. One insight they kept in view was that anthropocentricism often manifests as human entitlement to and domination over the natural world. These two analytic dimensions of the design speak to the ways in which settled expectations of nature-culture relations are implicitly embedded in school science and often experienced as epistemic control by students and teachers.

The design team developed learning environments premised on relational construals present in holistic systems linking life forms and their habitats. For example, to desettle the implicit nature-culture chasm, the design team, like Helmreich's microbiologists who think of microbes as 'long-lost relatives' [Helmreich, 2009, p. 6], engaged students in 'remaking relatives' through a series of inquiries and interactions with plants in their local ecosystems. The view that plants and other animals are relatives emerges directly from indigenous knowledge systems [Cajete, 1999] and reflects the designers' epistemic and moral stances toward the world [Hall & Horn, 2012]. Further, the designers came to view classrooms, particularly in urban contexts where the natural world is often conceptualized as elsewhere, as a structural metaphor for the epistemological separation between humans and nature.

To counter this epistemological divide, community teachers who were also members of the design team engaged students at an oxbow, a place in which a river used to flow but over geological time has changed course. Sometimes this results in a lake but in this case a wetland was formed, creating an ecosystem in which many culturally salient plant species thrived (e.g., arrow root are tubular plants harvested for food by Great Lakes people). To assess the health of the river, students were asked to engage in the relatively canonical task of collecting water samples and examining the content of these samples for the presence or absence of macroinvertebrates. Typ-

ically in this activity, students and teachers stand at the edge of a river and collect samples using a dipping method. These teachers, however, identified a need for their students to *feel* the river and develop a respect for and relationship to it that went beyond what shoreline collection would allow. To meet this need, they had students put on waist-high waders and immerse themselves in the river as they walked in it, erasing the chasm between themselves and the river [for a discussion of related issues in studies of embodied cognition, see Hall & Nemirovsky, 2012].

To begin this activity, Allan, one of the community teachers, explained the general parameters of the relationships between macroinvertebrates and pollution in rivers. He and Ashley, a second community teacher, reframed the prescribed orientation [see Hand, Penuel, & Gutiérrez, 2012] to help students view these relationships within the 'hives of activity' and 'circulatory flows' of life [Ingold, 2011, p. 29; see also Wilson, 2009] at the oxbow. Ashley explicitly connected students' knowledge of and experiences with local forms of life (e.g., harvesting edible and medicinal plants) and the life forms in the oxbow (plants and animals in the ecosystem) to the activity: 'So one of the reasons that this is important is that we've harvested medicine from this place, right? And this river feeds the plants and animal life that's here. So we want to make sure that we're harvesting medicine when it's ready to be harvested. So in addition to finding out just basic health indicators, we also want to know the health of the system here.' Similar to Blackstock's [2008] suggestion regarding productive forms of water-centered inquiry, Ashley structured relations between life forms ('this river feeds the plants and animal life that's here') as a vital connection among the organisms in this system.

Allan, co-constructing with Ashley, commented: 'The plants that we use to heal ourselves are going to heal the earth before they're ready for us. So if we find out that this place is unhealthy, we're not going to want to use the plants here because they're not ready to be used for us, they still have to work on the earth first.' Allan made visible the plants' active relationships with the local habitat. Significantly, he also structured human life forms in deference to both plants and habitat. Relationships of respectful deference between human and nonhuman life forms are seldom, if ever, present in school science. In this way, Allan explicitly desettled normative anthropomorphic constructs of human entitlement and domination of the natural world.

Following the walk in the river, the teachers engaged students in understanding how the river had moved over geological time to create the oxbow and explored related implications for their plant relatives. The goal was for students to learn about the unique soil composition present in the oxbow, an unusual amount of clay that allows for a particularly watery substrate that is amenable to unique forms of plant life. The day's activity was designed to build students' relationship to the history of the river by walking the river's old path while collecting and analyzing samples of soil along the way. In opening this activity, Jacks, a practicing hydrogeologist and teacher, opened by defining an oxbow for the students: 'An oxbow is an old spot where the river used to be.' But almost instantly, as if anticipating an ahistoric or settled view of rivers, he worked to redefine a core understanding of rivers and their purpose: 'Now rivers – rivers don't stay in one spot. They never were meant to stay in one spot. Rivers always moved around. They widen, they retract just like a heartbeat.' Continuing, he narrated rivers in a register of life form: 'the river itself, which is alive …' He went on to emphasize its relational fluidity: 'It may be like – the river may be thinking that 'I'll go back to where I was before but this is where I'm needed right now.' Like Jean

Marc in episode 1, Jacks narrated the river's generative capacity and flux in the world [Ingold, 2011; McLean, 2009]: 'where I'm needed right now.' Like Ashley and Allan, he engaged in explanatory practices that framed the river in relational and reciprocal terms, thus also desettling ontologies of human entitlement and use.

The teachers' discourse reflects the design team's intention to engage students' relational epistemologies as they were learning about natural phenomena. Further, wading in the river and walking the river's old path created learning environments in which the students, in Ingold's words, 'perceive(d) the world through their feet' [Ingold, 2011, p. 33] and placed them *in* the moving world in 'paths of observation' [Gibson, 1979, p. 195]. In this way, rather than approaching the science of rivers from a distanced, stationary perspective (i.e., from inside classrooms in school buildings), their relationship to the river and its life course was amplified and imbued with multivoiced, intersecting meanings.

Inhabiting the world in these ways constructed different possibilities for understanding the conditions and potentials of life forms within a relational form of life [Deloria et al., 1999; Ingold, 2011]. Like the students in Ms. R.'s class, the community teachers reconfigured the settled relations imposed by school science curricula on nature and culture, putting into motion transformative life forms (e.g., water as alive) and transformative forms of life (e.g., dislodging anthropocentricism, human entitlement and domination over nature). Thus, the designed learning environments desettled the historically configured, normative knowledge-power paradigm and epistemological tensions characteristic of science learning for students from indigenous and allied communities.

Implications for Teaching and Learning

> Life is outrunning the pedagogies in which we have been trained. [Fischer, 2003, p. 23]

> In a practical sense, it is not reality we transform but those aspects of our lives that define the boundaries of reality. [Deloria, 1979, p. 8]

In this article, we have explored the importance of desettling and reimagining core relations between nature and culture – understandings of 'life' in Fischer's sense entwined with 'the boundaries of reality' in Deloria's sense – in order to shape different networks of possibilities and responsibilities [Deloria et al., 1999] with respect to science learning and development, particularly for students from nondominant communities. While the examples discussed in the preceding section began from different design spaces, they shared some key commitments. Both included explicit rejection of deficit-driven discourses of students and communities, deep respect for students' heterogeneous sense-making and its power to cultivate understanding of the world, and expansive intellectual engagement with nature-culture relations beyond what standard curricula and pedagogy expect. In this section, we offer some concluding thoughts on what we consider to be grounding orientations for design within a desettling paradigm.

A first implication of our analysis is that science education selectively appropriates from scientific fields an unnecessarily narrow framing of nature (life forms) and culture (forms of life) and their interrelationships. As argued by Kidman, Abrams, and McRae [2011; see also Richardson, 2011], these selective appropriations of disci-

plinary knowledge routinely leave as settled the very knowledge-power relations defined by whiteness that have historically structured and continue to structure inequalities in society, science, and science education. To design within a desettling frame means, then, to understand and take up these knowledge-power relations – and assumed assimilation into particular knowledge paradigms – as an explicit object of inquiry in the science classroom.

Lest we be misunderstood, we are not arguing for cultural relativism but for serious intentional engagement with understandings of nature-culture relations emerging within modern scientific fields. These understandings, we would add, also circulate in varied forms in everyday contexts of social life where cutting-edge issues in biomedicine, biotechnology, ecology, climate change, and astrobiology, to name a few, are publicly discussed. Nor are we blind to the challenges of such an approach in an already overstressed public education system. However, as we have tried to show, the settled knowledge paradigms of science education can fail, for good reasons, to persuade students of their epistemic and moral authority. Indeed, by virtue of their engagement in the diverse, generative fluxes of living [Ingold, 2011, p. 29], the students with whom we have worked seem already attuned to expansive, relational perspectives on life forms and forms of life. In this light, expanding the settled conceptual territory of school science seems to us to be justified scientifically, developmentally, and educationally.

Further, we would suggest that a desettling frame in science learning and teaching would take the entanglement of relations between humans, organisms of all kinds, matter, and environments as the centering site of inquiry, not merely as the alternative. In a way similar to shifting constructions of mind and body in studies of embodied cognition [Hall & Nemirovsky, 2012], we want to suggest the importance in desettling of shifting constructions of relationships between human beings, other organisms, and the material world. These shifts entail movement away from hierarchically organized frames in which humans stand apart from and dominate nature toward relational frames in which humans are a part of thickly networked, multiple storied 'hives of activity' [Ingold, 2011; see also McLean, 2009, 2011]. Thus, like Helmreich's microbiologists, Blackstock's water-centered ecology, and the multivoiced perspectives of the students and teachers highlighted in our two episodes, a desettling frame entails grappling with life more complexly and immersively as 'a fluid set of relations' [Helmreich, 2009, p. 8] or a 'meshwork of intertwined trails' [Ingold, 2011, p. 149; Wilson, 2009].

More than 20 years ago, Shirley Brice Heath [1986] argued that in matters of learning, teaching, and development we should elevate the creative over the uniform, 'the search for possible worlds' over acquired assimilation of worlds defined and organized by others. For us, her claim resonates no less deeply today. In this paper, we have explored what it might look like to approach science learning and teaching from a desettling stance. We have argued for its importance in fostering a more transformative science education experience for nondominant youth, one that can generate new forms of knowledge, new modes of engagement, and 'new networks of responsibility' [Deloria et al., 1999, p. 25] in a heterogeneous, pluralistic, and fluid world. The pressing socioscientific challenges of our time, demanding though they are, call for this kind of generative capacity to expand beyond human-centric frames of activity and understanding [McLean, 2009]. Perhaps in this way, the challenges we face can be transformed into creative opportunities for imagining possible futures that are both sustainable and sustaining for life in all its varied forms.

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