



Learning with water: centering more-than-human interactions in science learning for more just social-ecological futures

Marijke Hecht¹ and Christopher C. Jadallah²

¹The Ohio State University, Columbus, OH, USA

²University of California, Los Angeles, CA, USA

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LEARNING WITH WATER: CENTERING MORE-THAN-HUMAN INTERACTIONS IN SCIENCE LEARNING FOR MORE JUST SOCIAL-ECOLOGICAL FUTURES

Marijke Hecht¹ and Christopher C. Jadallah²

¹The Ohio State University, Columbus, OH, USA

²University of California, Los Angeles, CA, USA

Abstract: *Science education that provides learners with opportunities for deep and direct engagement with water and water-related processes is critical to address the many threats facing waterways across the globe. Posthumanist, new materialist, and Indigenous perspectives on nature-culture relations offer expansive theoretical frames that can guide educational research and practice to more substantively consider water - and all of its more-than-human entanglements - as an essential actor building more just social-ecological futures. We push for a broadening of approaches to ethnographic data collection that includes accounting for the agency of more-than-human beings. To ground our discussion, we present vignettes from two informal science education programs, each of which conceptually and physically immersed learners in small streams to engage in scientific inquiry and data collection activities that informed ongoing ecological restoration of two watersheds. From these vignettes, we consider how methodological approaches guided and informed by posthumanist, new materialist, and Indigenous perspectives can and should inform research on learning and the design of L/land-based learning environments.*

Keywords: *water; informal science education; more-than-human; methodology*

The story is also about much more than literal water. It is about water as flow, movement, and transformation, water as culture, and about water in life and death. It is about grieving what we have lost as well as finding the water that is already there. (Somerville, 2013, p. 191)

Headwaters: Introduction

Teaching and learning in times of changing waters

Water functions as a literal and symbolic connector between nature and culture, serving as a conduit bridging learners and learning environments through material and sociocultural entanglements. It is through water that we are “mutually implicated with other humans, with more-than-human others, and with the fabric of the world” (Somerville, 2013, p. 82). Focusing specifically on rivers and streams, Wölfle Hazard (2022) conceptualizes waters as multispecies commons: imaginaries that hold space for

more-than-human relations. This begs the question, how might the design of learning environments - specifically those that are field-based - catalyze expansive and reciprocal relations with water, and how does water further reciprocal relations with other beings? In this paper, we reflect on data from two informal science education programs to consider the question: How do different methodologies shape our approach to accounting for both human-made tools and more-than-human beings as agential actors in field-based science learning settings?

As science and environmental education researchers, we take seriously the ways that relations between humans and more-than-human beings are vital for learning processes that build healthier and more just social-ecological futures. Examining and embracing these relations requires relinquishing human efforts to control the more-than-human world in ways that only serve human interests. To this end, we draw on several theoretical perspectives to consider how human-made tools (e.g. nets, stadia rods, waders, etc.) and more-than-human beings (e.g., macroinvertebrates, frog eggs, water, etc.) are agential actors and vital to learning processes. Specifically, we consider the affordances and constraints of posthumanist, new materialist, and Indigenous perspectives on more-than-human relations, paying particular attention to how power and agency figure into research that interrogates nature-culture relations (Bang and Marin, 2015). We review how these perspectives have played out in education by discussing place-based and L/land-based pedagogies. We then look at vignettes from studies of two field-based informal science education programs to consider the implications of these perspectives for educational practice and research methodologies. In our headings, we explicitly lean on the language of water and watersheds with the goal of calling attention to how water shapes the flow of our writing and to use language to help us change our patterns of thinking about research and methodology to more fully account for the more-than-human world (Wilson, 2008).

A note on language: Throughout this paper, we employ several terms and want to acknowledge the limitations posed by written English in substantively conveying the ethos behind them. With the phrase *more-than-human*, we refer to the relations between and among humans, lands, and waters, recognizing that humans are both part of the larger more-than-human whole and also a unique and specific element of that whole. With the term *more-than-human beings* or *more-than-human actors*, we refer specifically to the plants, animals, water, earth, air, and other elements of the so-called natural world. We use *human-made tools* to indicate other important material artifacts in learning that are developed and created by humans specifically. We use these terms instead of *non-human* to avoid centering humans in our way of conceptualizing these complex relations.

Why this, why us, why now

Posthumanist, new materialist, and Indigenous philosophies all offer approaches for educators and educational researchers to recalibrate interactions between humans and water environments, including with more-than-human beings that make their home in water and with human-made tools we use to engage with these environments. Before proceeding, we want to directly address our reasons for drawing on both Eurocentric and Indigenous perspectives. Leigh Patel, in her book *Decolonizing Educational Research*, asks researchers to carefully examine three questions before proceeding with their work: “Why this? Why me? Why now?” (Patel, 2015, p. 57). As settlers in the United States that come from two different diasporic communities, we grapple with how to substantively consider more-than-human relations, how to challenge the colonial norms that permeate conventional theoretical and methodological approaches in learning research, and how to address tensions between European-

derived posthumanist/new materialist and Indigenous approaches.

First, we consider, *why this?* Water protectors around the world remind us that water is life (Estes, 2019). Humans have organized ways of life around rivers and other waterways for millenia, relying on them and their seasonal floodplains for drinking water, irrigation, travel, ceremony, and more. And yet, many bodies of water are under threat given various complex and interrelated social-ecological pressures, many of which stem from drivers such as dam building and water diversion, industrial and nonpoint source pollution, and climate change - drivers fueled by racial capitalism and colonialism (Davis et al., 2019; Liboiron, 2021). The conceptualization of water as a ‘natural resource’ solely for human use is linked with centuries’ old colonialist and capitalist logics that position humans as dominant over rather than in relation with Earth (Grande, 2004). Given the dominance of this ideological framework in science education (Bang et al., 2013), we must move beyond these modes of thinking if we have any hope of real and sustained improvements to environmental health. Water, as a central sustaining life force, is an important focus for a recalibration of science education, and science education has a powerful role to play when it comes to reshaping human interactions with water in ways that support adaptive capacity and resilience of waterways in times of social-ecological precarity (Krasny and Roth, 2010; Wallace et al., 2022).

Next we examine, *why us?* Expansion of methodologies that effectively account for relations between humans and more-than-human beings requires that we, as educators and researchers, first understand our own thinking, which is grounded in our histories. We must be open to our own growth and development, or what Freire (Freire, 1993) calls *becoming*, as a result of this work. This means exploring who we are and where we come from and, through writing of this manuscript, inviting you as readers to join us in this process. Shawn Wilson, in Research is Ceremony (2008), emphasizes the need for readers to understand a storyteller’s background, or what dominant qualitative research calls our positionality, to reflect on what we share. While our full positionality is beyond the scope of this paper, we share a little of our backgrounds as related to water below.

Marijke: I first understood that the ground froze when I was 18 years old. I was walking across a grassy quad my first semester of college in rural New England and realized that the earth suddenly felt like the concrete that I grew up experiencing as a child in New York City as a member of the Jewish (Ashkenazi and Sephardic) diaspora in the United States. In that moment it first dawned on me that water moves through soil and becomes ice in winter and changes something about the earth and the way that I connect with the earth. Why tell this story from more than 30 years ago to explain something of my positionality? This story reminds me, and describes for you, my origins as a city child becoming familiar with an active awareness of the more-than-human world. This story shows the beginnings of my own embodied learning of the ways that water moves through the world, my consciousness of the feeling of my feet on ice filled earth. That early physical sensation drove my interest in thinking about and working with water in a meandering path that led to nearly 15 years of work on urban watershed restoration and ultimately my current work as an environmental educator and researcher with an interest in water as a powerful force in learning.

Chris: It wasn’t until later in life, while living in California’s Sacramento Valley, that I came to know rivers so intimately. Yolo County - where I made my home - is in the ancestral homelands of the Patwin people and has its name originating in the Patwin word *yoloy*, meaning “abounding in rushes.” Once a vast, seasonal wetland supporting abundant life, the Sacramento Valley began to experience significant

change starting in the mid-nineteenth century as a result of settler water projects that transformed the lush landscape into one dominated by industrial agriculture. Related stories of settler water management similarly transformed the landscape of my ancestors in Palestine, where colonial rhetoric of ‘making the desert bloom’ through water technologies has been used to justify the ongoing displacement and dispossession of Palestinians from our homelands. It has been through both my research on river restoration and my own embodied engagement swimming in the Sacramento Valley’s rivers that I have come to know water’s dynamism, complexity, and resistance to settler management. As someone growing up without experiencing rivers, swimming in them seemed foreign - even intimidating - to me. And yet, as Wölfle Hazard (2022) describes in the introduction to their book *Underflows*, rivers have long been places of encounter for those outside of straight settler propriety, and where queer-trans people make joyous moves of solidarity. Thanks to dear friends, rivers have served as a site for me to build deep, intimate connections with community and with place, and inform my commitments to social and ecological transformation.

Finally, we consider *why now?* We have a sense of urgency in our work to improve waterways and more-than-human relations that is proportional to the current dire condition of people and planet. As educational researchers, we aim to consider how different methodologies can guide educational research and practice that recognizes agency of more-than-human beings in ways that are necessary for healthier ways of living and being. We echo questions raised by Somerville (2013), who asks “how is it possible to move beyond the dominance of science and the hierarchical binary of nonindigenous/indigenous knowledge, in our thinking and practices of water?” (p. 82). Our goal here is to engage with Indigenous scholarship in respectful ways (Rosiek et al., 2020) and synthesize where appropriate. We are keenly aware of the dangers of cherry-picking bits and pieces of Indigenous philosophies and pedagogies without deep understanding of the cultures where these ideas have developed over generations. Tuck and Yang (2012) note the “long and bumbled history of non-Indigenous peoples making moves to alleviate the impacts of colonization... which problematically attempt to reconcile settler guilt and complicity, and rescue settler futurity” (p. 3). Thus, our intent is to synthesize posthumanist, new materialist, and Indigenous methodologies with respect to their politicized origins.

We are working not to claim Indigenous thinking, but rather to learn from it and consider how we might expand our own thinking and research methodologies in ways that emphasize relationality (Patel, 2015). Oscar Kawagley writes about the careful integration of Indigenous and Eurocentric science as a positive tool for Indigenous peoples to “...strengthen our own (Indigenous) culture while simultaneously embracing Western science as a second force” (Kawagley, 2006, p.96). We inversely apply this concept by suggesting that those of us trained in Eurocentric sciences need to embrace and learn from Indigenous sciences in order to simultaneously disrupt and improve our own dominant cultures. Exploring multiple philosophies that intentionally embrace more-than-human relations is urgently essential for our individual growth as researchers, for science educational research and practice, and for the long-term sustainability of our communities and planet.

New materialist, posthumanist, and Indigenous perspectives on more-than-human relations in science education

Science education in the United States typically upholds Eurocentric scientific traditions that enforce sharp binaries, particularly the artificial divide between culture and nature (Bang et al., 2013) and human exceptionalism (Stevenson et al., 2018). Several leading feminist philosophers (e.g., Barad; Haraway) offer expansive theoretical frames to form a foundation for posthumanism and new materialism as

schools of thinking that challenge these traditions. However, both posthumanist and new materialist philosophers have often ignored or downplayed Indigenous philosophies and pedagogies that have long held a view of humans as part of the natural world (Rosiek et al., 2020). In this section we explore application of posthumanism and new materialist philosophies for science education research. We consider posthumanism and new materialism together because they are closely aligned, and it is beyond the scope of this paper to examine in detail the distinctions between them. Then, we consider points of intersection and difference with contemporary Indigenous scholarship coming from what are now English-speaking nation-states.

Both posthumanist and new materialist philosophy valuably push against ideas in dominant Eurocentric sciences such as human exceptionalism and binaries of subject/object and nature/culture. The physicist and new materialist philosopher Karen Barad breaks the divide between humans and the rest of the world, reminding us that “humans (like other parts of nature) are *of* the world, not *in* the world, and surely not outside of it looking in.” (Barad, 2007, p. 206, italics in original). She extends this thinking by showing how, as material beings, we come to exist through what she terms “intra-actions” of multiple phenomena. Our reality is shaped by our experience of these intra-actions, from the subatomic level to more visible examples such as a leaf existing through intra-actions of light, water, and nutrients. Framing reality as intra-actions demands that the ontological unit be relational phenomena rather than independent objects with inherent boundaries. This also reorients thinking at a societal scale towards what posthumanist philosopher Donna Haraway calls the “naturalsocial” (Haraway, 2016, p. 148), entwining nature and culture as relational rather than distinct phenomena.

The adoption of posthumanist and new materialist ideas in science education provides a foundation for challenging traditional Eurocentric ideologies of human exceptionalism and separation from the rest of the natural world that undergird current environmental crises. Educational researchers outside of science education have taken up these ideas in a range of ways including through multispecies ethnography (Pacini-Ketchabaw et al., 2016); childhood connections with nature (Stevenson et al., 2018), and graduate education (Guyotte et al., 2020; Nxumalo et al., 2020). Implications of these ideas for science and environmental education have also been explored vis-à-vis sustainability education (Clarke and McPhie, 2014); place-based pedagogies (Lynch and Mannion, 2021); and in urban settings (Rautio et al., 2017). These efforts push towards relationality and relational thinking for both educational practice and research.

Applying posthumanist and new materialist ideas to science education, including and perhaps especially the subdisciplines of sustainability and environmental science education, presents an opportunity to rectify negative behaviors grounded in traditional Eurocentric scientific thought by emphasizing relationality across human and more-than-human worlds. These philosophies are important for challenging dominant Eurocentric scientific thought from within, and we see value in this approach. However, posthumanist and new materialist scholarship are often presented as new ideas and are not respectful of or engaged with Indigenous scholarship, practices and pedagogies that have long been grounded in relationality (Rosiek et al., 2020).

Shawn Wilson, who explored cross-cultural Indigenous scholarship in what is now Canada and Australia in his book Research is Ceremony, writes that “...the shared aspect of an Indigenous ontology and epistemology is relationality (relationships do not merely shape reality, they *are* reality).” (2008, p. 7, italics in original). Later in the same book, he shares nearly the same sentiment as Barad when he writes:

“Rather than viewing ourselves as being *in* relationship with other people or things, we *are* the relationships that we hold and are part of.” (p. 80, italics in original). A critical difference between the aligned statements of Barad and Wilson is that Barad is pushing against the dominant frame that she, and we authors, were educated in, while Wilson is illuminating long standing Indigenous beliefs and practices that treat science as part of the holistic exploration of the world that includes philosophy, psychology, art, etc. rather than as a separate discipline (Cajete, 2004). This practice is what Eurocentric academia would term interdisciplinary. A central tenet of this pedagogical approach positions more-than-human beings as human relations and central to sense-making (Cajete, 1994; Kawagley, 2006).

Although Indigenous and posthumanist/new materialist perspectives on more-than-human relations stem from different traditions and aims - the former a call to resurgence and renewal of Indigenous cultures (Grande, 2004), the latter a call to challenge long-standing Eurocentric scientific beliefs - they share an important focus on an ethic of care. Both traditions emphasize knowledge production that makes a difference in the world and can inform science education as a practice that supports more equitable, just, and healthier communities at local and global scales. Current environmental crises demand new forms of care which is why we must look to multiple sources of guidance for this.

Place-based and L/land-based pedagogies

Just as these ongoing theoretical developments have sought to interrogate nature-culture relations, similar conversations have emerged in relation to the design of science learning environments. Science educators are increasingly recognizing the need for pedagogy and programming that provide learners with opportunities for deep and direct engagement with social-ecological processes to promote caring and stewardship (Wallace et al., 2022). This is a type of care that moves beyond the conception of unidirectional humanistic stewardship which positions humans as caretakers of the earth, and towards the embrace of mutually constitutive care that reflects relationality between and among human and more-than-human beings (Puig de la Bellacasa, 2017; Taylor, 2017). Stemming from this recognition, multiple paradigms for science education - many at the intersection of environmental education - have emerged from critiques of dominant science education practices.

Place-based education, for instance, seeks to cultivate relationships between people and place and intentionally aims to counter anthropocentrism by foregrounding the role of the natural environment in teaching and learning (Gruenewald, 2003). In science education, integrating critical pedagogies of place that pair decolonization and reinhabitation as “twin goals” of place-based education (Greenwood, 2013) can provide a context for the development of critical consciousness in learners (Schindel Dimick, 2016). Field science as another form of place-based education can additionally foster curiosity and awe as learners engage with the more-than-human while conducting inquiry-based activities (Stroupe and Carlone, 2021). In contrast to dominant forms of science and science education that have typically sought out “placelessness” as defining features (Calabrese Barton, 2012; Gruenewald, 2003; Stroupe and Carlone, 2021), place-based education is both informed by, and seeks to inform, the social-ecological configurations of local places. Calabrese Barton (2012) further notes, “the very notion that place ought to serve as context for, subject of, and driving relationship framing the doing of science stands in stark contrast to the norm in science education that the focus is on standardization through testing and curriculum” (p. 3).

While sharing similarities with place-based education, Indigenous L/land education departs in notable ways. L/land is more than just material (Tuck et al., 2014), simultaneously having spiritual dimensions that involve accountability (Styres, 2011). Importantly, L/land education foregrounds Indigenous histories and futures in relation to place, rejecting politically-neutral forms of education and instead actively critiquing colonization as an ongoing structure that organizes land relations (Tuck et al., 2014). Tuck et al. (2014) further problematize “reinhabitation” as a goal of critical place-based education, asking, “*how can a place be reinhabited if it has already long been inhabited by Indigenous peoples without this functioning as another form of settler emplacement as colonization?*” (p. 17, italics in original). Furthermore, Marin et al. (2020) note that, “learning with lands/waters, and more-than-humans *as agents in their own right*, is a central aspect of land-based education” (p. 272, italics ours). Rather than the natural environment serving as solely a context for teaching and learning, as is often the case in place-based education, L/land education positions humans, organisms of all kinds, matter, and environments as agential, with essential spiritual links between humans and land (Bang et al., 2013; Styres, 2011). Relational epistemologies rooted in these interdependencies both challenge and exceed Eurocentric science as ways of knowing about the natural world.

Up to this point, we have reviewed two parallel onto-epistemological conversations that inform our research methodologies and methods as they relate to learning with water. New materialist and posthumanist perspectives on nature-culture relation share similarities with place-based education in that they all call attention to mutually constitutive elements of nature and culture. Indigenous perspectives guide L/land education and differ in that they intentionally foreground critiques of settler colonialism as shaping nature-culture relations, and ascribe agency to more-than-human actors. In the following sections of this paper, we discuss how these various theoretical considerations play out in research on informal science-based educational programs. After describing the context for each program, we present data in the form of vignettes. We then grapple with the opportunities and challenges of holistically accounting for the role of the more-than-human in water-based learning environments in our research methodologies.

Watershed: Project Context

Water serves as a productive site for teaching and learning in and from the natural world. To explore these opportunities, we focus our analyses on two informal, field-based summer programs that engaged young people in various activities concerning the health of local waterways (Table 1). The first took place in urban parks in Appalachia and involved watershed restoration focused on addressing sewage overflows and nonpoint source pollution. The second took place in a federally-designated wilderness area in the Mountain West and focused on monitoring watershed health following dam removal. While we use the term wilderness to reflect this area's designated status, we also call attention to the notion of wilderness as a colonial construction that falsely connotes images of a pristine nature devoid of human presence (Gómez-Pompa and Kaus, 1992). Eurocentric imaginaries of both urban and wilderness settings often position humans as apart from nature rather than a part of nature (Bang et al., 2013), even though nature and culture are inseparable (Cronon, 1995; Styres et al., 2013).

In both programs, youth collected data that were shared with scientists and land managers to inform

ongoing adaptive management efforts in the respective watersheds, in addition to other activities, which creates both challenges and opportunities for building a sense of place (Jadallah and Wise, 2023). As learning researchers, we were both active participant observers in the programs. Given our interest in the primacy of place as context for both learning and our own research (Bell et al., 2013; Tuck and McKenzie, 2015), we begin by describing both land and programmatic elements concerning each program before we further describe our methodological orientation. Note that we use pseudonyms approved by program participants to describe specific individuals and place names to preserve the privacy of our research partners.

Table 1. Summary of Appalachian and Mountain West program contexts

Program of Study	Setting	Stream characteristics	Program Activities	Participants	Duration
Appalachian	Urban park	Small surface stream (1200m) in urban watershed heavily impacted by nonpoint source pollution	Stewardship including erosion control and invasive plant management; macroinvertebrate monitoring; nature journaling; guest lectures	Eleven high-school age youth, two to three program leaders	Five-week summer internship
Mountain West	Designated wilderness	Coldwater stream (23m) undergoing dam removal to support habitat improvements	Mountain biking; in-stream habitat monitoring; nature journaling; guest lectures	Six high-school age youth, two to three program leaders	Two-week summer program

Appalachian Program

Wildcat Hollow Stream is a small and shallow creek that flows above ground for about 1200 feet through a popular 340-acre city park on ancestral lands of the Osage people. The park contains several large recreational facilities for sports and a wooded valley that is heavily used for walking. The majority of waterways in the region were culverted in underground combined storm and sewer pipes in the early 20th century, making this one of the few surface streams in the city. Therefore, this stream served as an important and rare opportunity for city residents to walk near flowing water. However, the stream also suffered from nonpoint source pollutants (e.g., road salts, trash) and high bacterial levels (primarily *E. coli*) from human and other animal feces (Hopkins and Bain, 2014). Because of both the value of this open water and its poor treatment, the Wildcat Hollow Stream and its watershed, which extended beyond the park boundary into the adjacent urban neighborhoods, were the focus of a more than decade-long restoration project led by a parks nonprofit in partnership with municipal agencies and other nonprofits. The parks non-profit also used this project as a point of engagement for youth in a

paid summer internship focused on learning and stewardship in urban green spaces. (For further information on this program of study see Hecht and Nelson, 2021).

Mountain West Program

Caddisfly Creek is a cold-water stream that flows over twenty miles from its headwaters in designated wilderness area, through an urban park, until its confluence with a larger river for which it is a major tributary. These are the ancestral lands of the Salish and Kalispel peoples. Its braided channel is lined with gravel, river rock, and large boulders, and alternates across its length between fast-moving shallow stretches, to sprawling beaver dam complexes, to cold and deep pools. Its broader riparian corridor is home to a spectacular array of biodiversity, including several endangered trout species whose access to traditional spawning grounds was blocked for over a century by a concrete dam until its removal as part of a broader watershed restoration effort. Dam removal provided an impetus for the summer youth program, which was administered by a small environmental education-focused non-profit organization in coordination with collaborating scientists from various organizations. Through the program, youth classified and mapped the distribution of large woody debris, pools, and beaver complexes in the stream's upper reaches as part of a citizen science effort, sharing the data with project organizers and scientists.

Meander: Methodology

Onto-epistemological stance

Both of our projects begin with a stance that learning research and learning design are connected practices that inform one another. Our work is part of research-practice partnerships that aim to build capacity and knowledge through the process of working collaboratively with community partners (Coburn and Penuel, 2016). This process includes stepping in as educators and participant-observers and maintaining sustained relationships with partner organizations. Relatedly, we each built caring relationships with the waters themselves through our own embodied engagement and time spent with them as integral to our research endeavors.

Our aim in this section is to reveal and deepen our methodology as more than research practice, but as what Max Liboiron describes as “a way of being in the world.” (Liboiron, 2021, p. 36). Drawing on Wilson (2008) and Tuck and McKenzie (2015), we use the language of methodology to name the epistemological, ontological, and axiological assumptions guiding research design and implementation, and use the language of methods to refer to specific tools of data collection of analysis.

Together we have talked/thought/written about our methodology to develop our way(s) of being in the world as researchers, as environmental educators, and also as learners. Our own learning about water and how water connects us with land is ongoing. What we present in academic papers like this one is not something we learned (past tense) from our research efforts but rather ideas and practices we are trying to actively learn.

Data collection and analysis

During the data collection phase in our respective studies, our position as learners included pushing ourselves to move past noting only what humans were doing by considering and recording what more-than-human elements of the learning landscape were doing. Our work began with traditional ethnographic methods of participant observation (Emerson et al., 2011; Merriam and Tisdall, 2015). However, we strove to identify robust episodes of engagement between human and more-than-human beings that figured into learning using relational processes as the unit of analysis (Hecht and Nelson, 2022). In doing so, we aimed to account for sounds, movement, presence of tools, lands, waters, and creatures that were also part of our studies (Kohn, 2013; Ulmer, 2017). This was a challenge, as evidenced by this comment in the field notes from the Appalachian program, “I find I am just recording dialogue, which is not what I want to do,” followed by rough drawings of more-than-human beings and notes on interactions between youth, more-than-human beings and tools in the field journal. Similarly, in the Mountain West program, researcher jottings in the field included aerial maps, landscape sketches, and diagrams of various spatial arrangements as strategies to overcome a bias toward solely recording discourse and human interactions.

We extended this approach during our data analysis by orienting our reading of field notes and interviews first on the water itself and secondly on the human actors in the scenes. When possible, we wrote reflective memos in the presence of the waters themselves. We also attempted to engage more physically with our notes by intentionally incorporating physical work, such as cutting and pasting of materials, into our process rather than only coding on a computer screen.

Pools & riffles: Vignettes

In our two programs of study, the youth we worked with drank water for their personal hydration, explored puddles and side-channels for frog eggs and garter snakes, got soaked by rain, and played in flowing streams to understand more about water and the environment water provides for other more-than-human creatures. San Pedro and Kinloch write that “Storying is the convergence of theory and practice, theory and methods, which allows us to be invited into relationships where we dialogically listen and give back to the stories shared and questions that arise with others”, (San Pedro and Kinloch, 2017, p. 377-378). Below, we share stories that extend beyond human relationships, stories that enfold water, tools, and other more-than-human beings inside the boundaries of our field of study. This storying pushes us to consider who and what are part of our relationships in learning spaces.

We present one short vignette from each of the programs that illustrate how youth participated in the water environment through the use of tools, engagement with creatures, and immersion in the water itself. Both vignettes are taken from jottings gathered via participant observation during each research project and then translated into typed field notes shortly after each observation. These two vignettes were selected as examples of how the youth engaged with more-than-human beings, such as water and macroinvertebrates, and utilized human-made tools to extend this engagement in ways that supported their learning.

Wildcat Hollow stream, Appalachia

Brian was the first one in the stream. On that morning, the youth were doing macroinvertebrate monitoring in Wildcat Hollow Stream. Sieve in hand, Brian called out, “We found something already!” The sieve, which he had dipped into the shallow stream, was filled with a dozen or more scuds and Brian wanted a container to hold them. Although Brian had not had prior experience with stream survey work, he quickly picked up identification skills for macroinvertebrates. His enthusiasm on this day was indicative of his overall engagement with both scientific inquiry during stream surveys and the physically challenging stewardship that was also a regular part of the program. Just before the stream survey began, Brian had been quietly walking along the edge of a nearby small lake looking for frogs, displaying his keen eye and interest in learning about creatures of all types that made their home in the park, including the macroinvertebrates that we were now tasked with inventorying to help restoration ecologists understand more about the health of the stream.

The sieve, a simple and inexpensive plastic model made for kitchen use, was a tool that allowed Brian to find tiny scuds that were far too small to be picked up by human hands (Figure 1). The scuds, sometimes called side-swimmers, look like miniscule translucent shrimp and while they are visible to our eyes, you need to look closely (these were about 5-10mm). After moving the scuds into a small plastic container that another youth had passed to him, Brian moved upstream a little farther to get above all of the sediment that our group had kicked up. He continued dipping the sieve at this new spot and the tool became an extension of Brian’s hands, one he wielded gently as he lowered it into the water.



Figure 1. Youth participant uses sieve to collect macroinvertebrates from Wildcat Hollow Stream.

However, even the sieve’s fine mesh was no match for the scuds. Another youth, Skye, had also made her way down to the stream and dipped a sieve in. “Look, it can go through”, she said as she pointed to a scud that was so small that it could work its way through the sieve’s very fine screen. She pulled the sieve up close to her face and kept turning it over, looking first in the concave catchment area and then at the convex undercarriage of the sieve. One of the scuds deftly moved from one side to the other of the fine mesh, eluding Skye’s meticulous efforts to move it from the sieve to the bucket using a small plastic-handled paint brush designed for children’s art projects. The tools - both the sieve and the paintbrush - were meant to serve as mediators between the youth and the macroinvertebrates, closing the scalar gap between the youth and these tiny residents of Wildcat Hollow stream.

However, the macroinvertebrates did not accept this treatment easily. In fact, they often resisted the youths' efforts to move them. One of the more charismatic macroinvertebrates we might find in this impaired waterway - a web spinning caddisfly - was also at Wildcat Hollow stream that day. Eve, Brian's twin sister, was nearby in the stream. She had found a caddisfly and was getting a small cup to hold it so that she could look at it more closely. Eve, quieter but just as observant as her brother, was trying to move the caddisfly from sieve to cup with one of the paintbrushes. The caddisfly, however, kept throwing out its silk onto the small brush head every time Eve tried to move it and would swing from its silk, which was attached to the brush, repeatedly. Eventually, Eve gently pulled the creature's silk off the brush and successfully deposited it into the cup for further inspection.

Caddisfly Creek, Mountain West

On the second day of the program, youth were conducting in-stream monitoring in two teams, each taking a different bank of the creek to record the presence of any large woody debris. Large woody debris provides critical habitat for fish and other riparian species. While surveying "river right" - the right side of the river when looking downstream - Josh lost his footing and slipped, catching himself on a boulder to avoid fully immersing himself in the clear pool of water. The other youths' heads swiveled, and Emma, one of the trip leaders, quickly moved to assist him, but Josh said, "I'm okay, there's just a lot of algae here." The group was wading upstream through a shaded section of the creek that varied between one and three feet deep. Most of the rocks were covered with a thin layer of slimy, green algae under the water's surface. As Josh got back on his feet, his movements stirred the sediment resting on the bottom of the creek, causing a murky cloud to form around him. "The algae is probably because the water's moving more slowly here," said Emma, "so just be careful where you step. Keep your hands out for balance."

As we continued to move upstream, I asked Josh if he "topped off" his waders - if water entered them - when he fell, to which he replied, "Just a little bit, but it actually feels kind of nice." Indeed, the water did feel nice - I had periodically been splashing the back of my neck to stay cool. It was a hot day, where you could feel the baking heat of the sun on your skin. I was even tempted to forego waders, but then the water would have been too cold for prolonged exposure. They helped maintain a comfortable temperature allowing our sustained engagement with the stream. Josh's waders went up to his hips, secured by a strap that attached to this belt. The bottom of the waders' soles were textured and intended to provide traction, which generally worked well except in particularly slippery areas.

After his fall, Josh and other members of the group began using their stadia rods as walking sticks (Figure 2). Around four feet long, the stadia rods were intended to be used as a data collection tool that each student had for measuring the diameter of large woody debris and the depth of various pools. The trip leaders had made the stadia rods in advance of the program using PVC pipe marked with permanent marker and colored tape to delineate measurements. Before stepping into an area of unknown depth, the youth would use their stadia rods to gauge the depth and ascertain whether or not they'd be able to safely move through the water without topping off their waders. Moving more slowly and carefully through this slippery section of the creek, the youth planted their stadia rods firmly between rocks, shifted their body weight toward the rod, and stepped forward, planting their first foot firmly and intentionally before lifting the other to continue walking.



Figure 2. Participants wear waders and use stadia rods while moving through Caddisfly Creek.

Meander: Entanglements

Both human-made tools and more-than-human beings play vital roles in youth learning, and for our own process as educational researchers. These two vignettes exemplify youths' engagement with water, with creatures that live in water, and with tools that help mediate this engagement. In this section, we draw from these vignettes and consider the implications of posthumanist, new materialist, and Indigenous perspectives for both the design of youth learning environments and for methodologies for learning research. We first explore the role of more-than-human beings and human-made tools in the youths' embodied learning. Then, we return to methodology and discuss implications for research on learning with water.

Learning with water

How might educators support learning with water? In both of these programs, a primary goal was to learn about water environments, which is common in environmental and science education curricula and standards (e.g., Next Generation Science Standards, Project WET). In the vignettes, we see how youth are also learning with and from water and the creatures that make their homes in water environments. Human constructed tools were significant for mediating the relationship between humans and more-than-human beings. Furthermore, the intra-actions between water, creatures in the water, tools, and youths themselves were influenced by the agentic role of more-than-human elements.

Examples of more-than-human agency for learning was abundant throughout both of the programs. Scuds and caddisflies in Wildcat Hollow Stream actively resisted efforts by Skye and Eve to control their bodies, artfully slipping through sieve holes and leaping off paint brush fibers as the two girls tried to capture them for closer inspection. Both girls were pushed into more careful observation and slower movements in response to the creatures, adjustments that allowed them to ultimately corral the creatures

into containers that allowed for additional observation. The algae in the Mountain West stream, acting like a jester, destabilized the youth and forced Josh and others to slow their gait and rely on rocks and stadia rods to help them maintain balance.

In both settings, learning from and with tools and more-than-human beings took place through the youths' bodily engagement with the environment. Recognition of the role of movement and embodied learning with/in the world has become more widely recognized as important for place-based learning and is theoretically supported by Indigenous scholarship (Marin, 2020). In both stream settings, more-than-human beings set the pace for youth learning, forcing attention not only with their minds, but with their bodies - feet, hands, eyes, core muscles - in response to their behaviors. Youth didn't merely learn *about* caddisflies or stream dynamics, they learned *from* them. Josh learned to move in response to the stream's flow and slippery conditions; Eve learned to gently move the caddisfly from the brush. This learning with and from water and creatures was often mediated through human-made tools that were essential for this embodied connection with the water environment. The sieves, brushes, stadia rods, and waders served as boundary objects that bridged the space between human and more-than-human elements. The sieve became an extension of Brian's hand; the stadia rod an extension of Josh's legs.

For Eurocentric-based science education to address current environmental issues at the community, regional, and global scale, we need to move beyond learning about water and towards learning with and from water and the creatures that make their home there. Our observations of learning with and from more-than-human beings and human-made tools offers an opportunity to consider how Indigenous pedagogical approaches that center relationality with more-than-humans can be integral for the design of learning environments for non-Indigenous youth as well. Margaret Somerville, an Australian settler, calls this kind of embodied learning "think(ing) through country" and asks, "How can I learn to think through Country if I have no country?" (Somerville, 2013, p. 47-8). Her answer, in the form of a poem, concludes with these lines:

Or is it my body
in any place?
and what is the body,
is it only the body-in-connection-with
all places,
and the practice of a body-in-place
is a practice of Country?

This passage is a reminder that even those of us who live as part of diasporic communities can still find connections between our bodies and the places we inhabit.

Field-based science education could be structured to offer more intentional emphasis on water as a teacher. For example, recognition of more-than-human agency can and should influence approaches for data collection, as is done by members of Max Liboiron's CLEAR Lab (Liboiron, 2021), and for science education programs (McDaid Barry, et al., 2023). During macroinvertebrate sampling in the Appalachian program of study, creatures were returned to the stream as close to the collection point as possible, but they were surely disturbed for the sake of education and data collection. New protocols, such as species identification closer to collection points, ought to be considered. An emphasis on care is a central place of convergence between posthumanist/new materialist and Indigenous approaches. This has extended benefits for people and planet. As Puig de la Bellacasa writes, "Care is not one way;

the cared for coforms the carer too” (Puig de la Bellacasa, 2017, p. 219).

Researching with water

How might educational researchers better account for the role of water in learning processes? Posthumanist, new materialist, and Indigenous paradigms each offer perspectives on more-than-human relations that come with their own guiding sets of assumptions. These assumptions figure into our methodological choices, which then inform how “methods are used, and with and by whom” (Tuck and McKenzie, 2015, p. 79). All of these paradigms share commonalities in that they challenge longstanding notions of human exceptionalism rooted in Eurocentric thought by recognizing the centrality of more-than-human actors in constituting human activity. Indigenous philosophies and pedagogies diverge in that they explicitly highlight analyses of coloniality and settler-coloniality, and foreground respect, relevance, reciprocity, and responsibility - often termed the ‘four Rs’ (Kirkness and Barnhardt, 1991) as integral to processes of research. Given longstanding histories of Indigenous erasure in knowledge production, we place particular emphasis on thoughtful and intentional engagement with Indigenous perspectives in research on more-than-human relations.

Tuck and McKenzie (2015) provide a review of both established and emerging written, oral, visual, arts-based, and social media methods, and how each offers affordances for collecting place-related data. Surveys, for instance, can be used to assess connections to waters and time spent in waters. Semi-structured interviews can similarly be used to assess connections to waters and time spent in waters, while also opening up additional opportunities for understanding how people make meaning of their relations with water. Ethnographic observation was a primary method in each of the above studies, and allowed us to document embodied engagement between humans, water, human-made tools, and more-than-human beings in real time.

With the affordances of these methods also come constraints. Take ethnographic observations as an example. As reflected upon earlier in our descriptions of our own methods, holistically accounting for more-than-human relations with water proved challenging. For instance, we found ourselves recording dialogue between humans at the expense of substantively recording more-than-human relations. The reasons for this are threefold. First, we encounter a barrage of information while in the field - particularly in outdoor settings - and need to make decisions as to how we filter and select phenomena to include in our fieldnotes, and it is impossible to account for all phenomena in a setting. Second, our own humanness informs what phenomena we filter from said barrage of information, necessitating that we actively strive to counter biases we hold toward privileging human activity. Third, our training in conventional social science research methods, also rooted in Eurocentric thought, reflects their traditional emphasis on human activities, interactions, and discourse. In order to overcome some of these constraints and challenges, we were led to improvise more creative fieldnote-taking practice in-the-moment, such as drawing and sketching. In our analyses, we focused on relational processes as a unit of analysis - looking at episodes of engagement - as a way to account for more-than-human entanglements rather than examining individual human learners (Hecht and Nelson, 2022).

Methodological innovation is necessary should we desire to more adequately capture the expansiveness of more-than-human relations with water in research on learning. We see great potential in methods that foreground the embodied experiences of being in relation with water, in addition to conventional

methods that often privilege spoken language and human-human interactions. Others offer suggestions and examples in this regard. Fijn and Kavesch (2021), for instance, suggest how sensory anthropology and a focus on touch, taste, and smell can afford ethnographers the opportunity to relate to other beings as subjects with the ability to communicate beyond language and to engage in a more meaningful way to interspecies knowledge-making” (p. 13). In another example, Marin (2020) develops “ambulatory sequences” as a method rooted in Indigenous epistemologies that foregrounds the relational, embodied aspects of how lands and waters shape walking and talking, and vice versa. Wilson discusses the valuing of intuition in Indigenous research, which sharply contrasts with Eurocentric insistence on rational thought for knowledge production (Wilson, 2008). Each of these approaches should be considered, perhaps in combination, for future educational research that takes seriously the role of more-than-human beings in human learning – a stance that demands an undermining of the dominant hierarchy of rationality over feeling in its many forms, including embodied, emotional, and spiritual. Observation, a fundamental scientific practice, must draw not only on the analytic brain, but also on other ways that researchers attempt to make sense of the world through our bodies and spirit.

Confluence: Concluding thoughts

Dominant scientific logics and practices position humans as exceptional and distinct from nature, undergirding contemporary environmental problems such as habitat destruction, biodiversity loss, pollution, and climate change, all problems that threaten water and waterways around the globe. There is an urgent need for science education that prepares learners to engage with the complexities of these social-ecological problems. Science learning environments that promote engagement with both human-made tools and more-than-human beings can promote ecological caring and stewardship as a pathway toward better relations with water. Embracing more-than-human agency also means shifting power from humans as dominant forces, even when that force is framed as beneficial stewardship. Instead, relationality between human and more-than-human beings recognizes the mutual care that is both given and received.

In this paper, we have reflected on the values of and tensions from attempting to bridge posthumanist/new materialists and Indigenous theory in educational research. Our aim is to push science educators and educational researchers – including ourselves – to account for agency of the more-than-human world in learning processes by integrating multiple epistemologies in respectful ways. We challenge the science educational research community to consider: How are we answerable to water and our many more-than-human relations? Posthumanist, new materialist, and Indigenous philosophies and pedagogies offer perspectives that can guide research on learning and the design of learning environments that engage water as a teacher to learn with and from. These perspectives help make visible the agential role of human-made tools and more-than-human beings in learning processes and can guide methodological approaches that more substantively account for science learning as inseparable from the L/lands and waters where learning takes place. Indigenous perspectives in particular can shape education and research practices that confront coloniality and maintain relational accountability. Science education that recognizes the value of Indigenous scholarship and pushes against Eurocentric human exceptionalism and distance from the rest of the natural world offers powerful

opportunities for building and sustaining more-than-human relations and making new worlds possible.

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