Field Ecology: A Modest, but Imaginable, Contestation of Neoliberal Science Education

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Abstract:

Science education has become a valuable market tool, serving the knowledge economy and technocratic workforce that celebrates individualism, meritocracy, entrepreneurship, rational thought, and abstract knowledge. Field ecology, however, could be a modest, but imaginable contestation of market-driven neoliberal ideology. We explored diverse high school youths' meaning making of a summer field ecology research experience. Youths' narratives, elicited with a modified card sort and qualitative interviews, highlight the cognitive, social, emotional, and physical aspects of learning demonstrating considerably broader views of knowledge, meanings of the natural world and their place within it, and access to scientific practices than implied by neoliberalism.

Keywords: science education | field ecology | youth | high school | neoliberal ideology

Article:

Unchecked in a neoliberal context, science education could become uncritically narrow (Hursh, Henderson, & Greenwood, 2015), hyperrationalistic (Lemke, 2001), overly utilitarian (Deresiewicz, 2015), and/or unduly reliant on decontextualized knowledge (Gruenewald & Manteaw, 2007). Lemke (2001) argued that science education is complicit with neoliberal aims when it privileges the mind as the primary unit of meaning making, which in turn risks a science education devoid of emotion. Further, common rhetoric pairs science education with neoliberal aims of market rationality; science education serves the knowledge economy and technocratic workforce that celebrate entrepreneurial initiative (Apple, 2001). This argument extends logically to posit that neoliberal ideals marginalize sciences that do not serve the market directly, which includes sciences that promote wonder (Gilbert, 2013), learning for learning's sake, aesthetics (Wickman, 2006), collective agency, interdependence of living things, conservation, and altruism. Field ecology, our focus, is one such science. The purpose of this article is to explore the potential of a residential summer experience that engaged high school youths in field ecology as a potential counternarrative to neoliberal science education. Fieldwork in schools is "under threat" (Dillon et al., 2006, p.110), despite its value for students' learning (Ballantyne, Anderson, & Packer, 2010). In the United States, the Next Generation Science Standards make no mention of fieldwork as a productive context for youths' scientific engagement and learning (NGSS Lead States, 2013). This is a missed opportunity.

Field ecology and unification: alternatives to neoliberal ideologies

A neoliberal context that maximizes corporate entrepreneurship through deregulation shifts responsibility for environmental sustainability from collective to individual action (Dimick, 2015). Thus, there is resistance to developing policies related to environmental issues like climate change (Hursh et al., 2015) and a simultaneous push for *individuals* to "go green" (e.g., LEDs, ENERGY STAR products) through policies aimed at increasing individuals' responsibilities (e.g., plastic bag taxes; Dimick, 2015). The environment becomes commodified in market-driven endeavors like eco-tourism, eco-business, and geo-engineering (Hursh et al., 2015). Contesting neoliberal entanglements with environmental sciences requires us to interrogate our relationship with nature (Hursh et al.,2015).

Field ecology, as enacted in Herpetological Research Experiences (HREs; the context for this study, summer residential research programs), focused on studying reptiles and amphibians, their place in the ecosystem, and their interconnectedness with other living and nonliving things. Animals, in this context, are not simply the objects of scientific investigation; they are essential facets of a complex ecosystem that must be explored as whole and from a systems-level approach as opposed to an organismal approach. We conceptualize field ecology as a modest, but imaginable contestation of neoliberalism's instrumentalism, techno-rationality, and "self-serving individualism" (Giroux, 2001, p.3).

Field ecology intertwines (*unifies*) the social, physical, cognitive, and emotional aspects of learning. Interdisciplinary by nature, field ecology embraces multiple scientific epistemologies as it combines various disciplines such as biology, geology, and environmental sciences while opposing explanations that reduce observations to individual interactions and isolated occurrences. Rather, field ecologists use multiple perspectives by considering systems-level interactions and interchanges and acknowledging the interconnectedness of living and nonliving

systems and the complexity of scientific inquiry. To understand youths' meaning making, we use the concept of *unification*, which is emphasized in sociocultural learning theories (Vygotsky, 1994), anthropology of education (Lave, 1996), cultural studies (Giroux, 2005), curriculum theory (Dewey, 1910), and feminist studies of science (Barad, 2012).

Recent work published in *Mind, Culture, and Activity* highlighted the relevance and timeliness of unification (Hedegaard, 2012; Magiolino & Smolka, 2013). Vadeboncoeur and Collie (2013) illustrated schooling's historical dichotomization of cognition and emotion and the ways that standards-based reforms perpetuate a narrow, techno-rational curriculum assessed with quantifiable methods. They argued for a "need to develop approaches to social and emotional education that reduce the emphasis on behavioral skill sets and individual assessments and, instead, develop methods for linking social and emotional ideals with social practices in schools" (p. 205). They positioned Vygotskian perspectives as a "radical response" to the test-driven measures that pervade today's schooling practices. Instead of separating out perceived influences on learning to reduce complexity, Vygotsky (1994) urged the field to consider units of analysis, rather than reductionistic and isolated "elements." These units of analysis, ideally, maintain both the unifying and internal contradictions of the whole. In particular, he sought units of analysis that fused intellect and affect (Vadeboncoeur & Collie, (2013).

Others have wrestled with the unsatisfying ways that emotions have been treated in the literature as external to, but affecting cognition and action. Roth (2007), in forwarding a third generation of cultural-historical activity theory, proposed to make emotion a more prominent and integral aspect of *activity*, highlighted the interconnected nature of *action* and emotion, as well as individuals' emotions within social groups. He theorized that people participate in activity systems based on their probability of success and higher "emotional valence" (p. 46) and that emotions are shaped by and shape the "collective emotional state" of a given setting or group (p. 46). Roth highlighted the importance of cultural norms and practices in cultivating certain ways of approaching new and/or uncertain situations. Thus, newcomers may learn about how to feel about certain situations based on the "collective emotion" expressed by a cultural group in activity. This connection between emotion and action became a way to understand youths' fairly swift shifts in emotional responses in this study—for example, from viewing a snake as something to fear and/or kill to viewing it as an organism important to the ecosystem, as something worthy of scientific investigation, wonder, and excitement.

A unified view of learning is not new for those studying learning in ecological settings. For instance, Brody (2005) introduced a succinct yet comprehensive theory of learning in nature, explaining that "meaningful learning in nature is a result of direct experience(s) over time in which personal and social knowledge and value systems are created through complex cognitive and affective processes" (p. 611). Among other things, his theory privileged physical experiences in nature with other people, which evoke emotion and offer opportunities to construct personally and socially meaningful knowledge.

Our project goals did not include explicit efforts to understand ecological systems in political, economic, and social contexts. Thus, the pushback on neoliberal ideologies, for this study, may be modest. Yet we see a striking juxtaposition when we compare the nature of youths' narratives of experience in this study, individually and collectively, to the youths' narratives of experience

in our previous ethnographic studies of prototypical school science, which emphasize narrow, final-form, "right-answer," bookwork-driven science (e.g., Carlone, Johnson, & Scott, (2015; Carlone, Scott, & Lowder, 2014). A unified perspective on learning opens the door to considering alternative, broadened educational goals, pragmatic and imaginable enough to find their way into schools, but transformative enough to speak back to market-driven, competitive, hyperrationalistic, and individualistic prototypical school science.

METHODOLOGY

Context

This study is part of a larger project called The HERP Project (herpetology education in rural places and spaces). For four summers, we engaged high school youths in free, week-long residential HREs and a month-long HRE course in a college access program in three sites across the Southeast. More than 200 youths participated in the program over 4 years; we recruited participants from diverse ethnic, racial, geographic, and socioeconomic groups. Youths had wide-ranging experiences with and interests in outdoor science, wildlife, and reptiles and amphibians. The HRE's primary instructors were university biologists and science educators with more than 20 years' experience running youth-centered herpetology programs (Huffling, Matthews, and Tomasek, authors on this article, were HRE instructors).

The HRE group, in its 4th year at the time of this study, enacted cultural norms and practices that allowed it to function as a community of practice (Ash, Carlone, & Matthews, 2015), promoted broader views of competence and smartness than is the case for prototypical school science (Carlone et al., 2016), and enabled youths to work outside of their comfort zones—what we explain as "identity boundary work" (Carlone, Huffling et al., 2015). These norms and practices included (a) the use of boundary objects, (b) responsive time and space to enable youths to adapt to new experiences, (c) social support and collective agency, and (d) access to and practice with scientific and anecdotal knowledge coupled with practical animal-handling skills to minimize fear. Consistent with sociocultural theory, our work makes the assumption that individuals' narratives are contingent upon meanings promoted by the HREs' cultural norms and practices.

Youths in weeklong HREs participated in field excursions focused on snakes, box turtles, stream amphibians, aquatic turtles, lizards, and ephemeral pools, shifting to a different focus activity daily. They set and emptied traps, marked and captured animals for aquatic and box turtle population studies, collected data with field science tools, and learned how to safely handle and identify animals. Evening activities included guest lectures, nature photography, frog call hikes, and other electives (e.g., radio telemetry to locate marked box turtles, snake and turtle road kill dissection). As the HRE curriculum progressed, we included in daily activities the consideration of local Herps' ecosystems. This systems-level approach enabled participants to consider multiple levels of inquiry to formulate questions such as, How do forest fires affect the ecosystem? and How has the development of pastureland affected the stream's ecosystem? We suspected that our shifted approach afforded a more holistic, unified view of science, and we designed this study to examine this claim more systematically.

Youths valued the HRE experience because of newly acquired knowledge and skills, but they also highlighted how *they* had changed, the value of experiencing something new, their bravery, and "helping others" were essential aspects of the HRE (Carlone, Huffling et al., 2015). We wondered whether, and in what ways, participants would discuss the HRE practices as unified. Our research question was, In what ways did youths experience the HRE's scientific practices, norms, values, and typical emotional experiences as unifying cognitive, physical, social, and emotional components of learning?

Participants

Data collection focused on a subgroup of the Year 4 cohort (summer 2014), 22 of whom participated at the Piedmont region's HRE (HRE 1, $n = 22$; 19 first-time participants and three returning youths) and five of whom participated in the Sandhill region's HRE (HRE 2, all of whom were returning participants, serving as student research assistants and assisting instructors at one field science project). We included the student research assistants to elicit a wider range of perspectives. Youths at both HREs experienced similar curricula and had many of the same instructors. Approximately half of the participants were White, and the rest were African American, Asian, biracial or multiracial, Latino, or Native American. Most participants were from medium income ($50,000–$74,999) to low income ($49,999 and below) households.

Data collection and analysis

Our primary data collection method involved audio-recorded interviews with 27 youths at the end of the HRE week. We initially interviewed most youths in pairs. Our goal was to create a data collection method that would make tacit knowledge explicit and involved "some level of critical reflection to be socially based, active, visual, and dialogic" (Keeffe & Andrews, 2015, p. 361). We created a modest, but effective elicitation method similar to a card sort that we called a chip sort, which included a circular, laminated board with equi-distanced labels "head," "heart," and "hand." The 20 "chips" were colorful discs that included a statement representing a practice, norm, value, or common emotional experience prevalent in previous years' data.

We asked youths to choose chip statements that were "typical" at the HRE and place each chip they selected on the head–heart–hand board based on their experience. A purely cognitive experience (thinking, logic, analytical) was placed on "head," a purely emotional experience (good and bad feelings) on "heart," and a purely physical experience (using senses; physical activity) on "hand." Youths could also place chips in between two categories (e.g., head–heart, hand–head) or at the board's center if they interpreted the chip statement as integrating head, heart, and hand. They reached consensus about the chip placement by talking through their meanings of the chip statement with one another, which yielded rich discourse. We took a photo of their completed board, with all chips placed.

We also conducted audio-recorded interviews with participants individually, designed to elicit more open-ended narratives. We asked them to tell us about a memorable moment, one challenging experience, one "great" experience, a new encounter with an animal, and what they learned about themselves through the experience. All interviews were transcribed (30 hr of audiorecording). We use pseudonyms to protect participants' identities.

We used photographs to build a reproduction of the chip board that compiled all groups' chip placement (Figure 1). This gave us an overall picture of the extent to which youths viewed the HRE experiences as unified. We examined the placement of each chip statement (across all groups) one at a time to determine which statements elicited the most placements in the center of the board. We identified six chip statements (described in the Results section) that indicated the most unified perceptions. Next, we used the Dedoose web application (www.dedoose.com) to code all transcripts (from the chip sort and individual interviews) for instances when they discussed the top six chip statements and subcoded based on *unified* perspectives. These readings of the data enabled us to identify primary themes to organize the results.

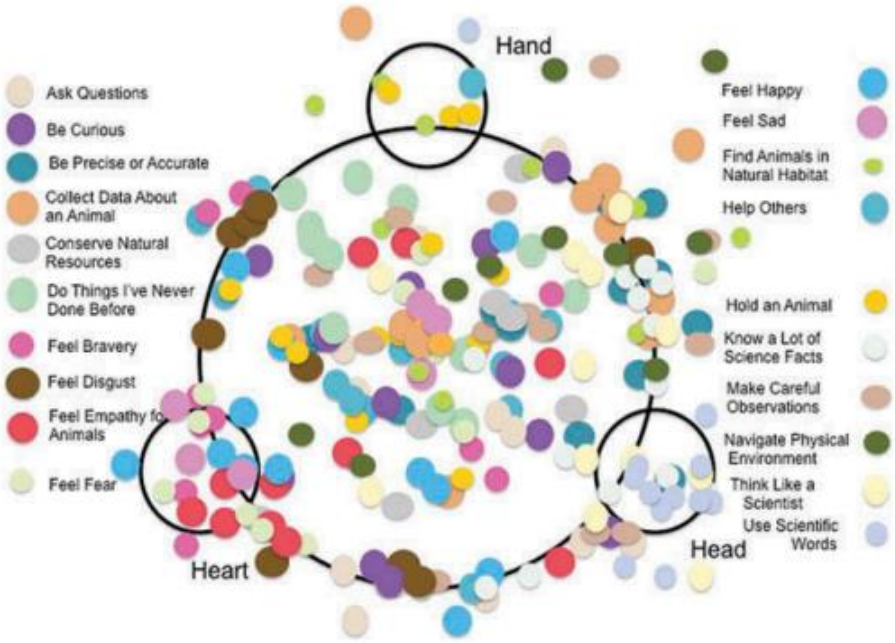

Figure 1. Compilation of all groups' chip placement on the head-heart-hand board, demonstrating youths' meaning-making as highly unified.

RESULTS

Youths' chip placement and narratives about the scientific practices, norms, values, and emotional experiences illustrate that they viewed their HRE experiences as highly unified. We compiled groups' placement of the chip statements to produce a visual display of the data. Their chip placement mostly fell in the middle of the head–heart–hand board (Figure 1).

Youths placed even the most physical (e.g., navigate physical environment), emotional (e.g., feel happy), and/or cognitive (e.g., think like a scientist) statements at the center of the board. For example, when describing the chip "feel empathy for animals," Taneesha said,

> [Feeling empathy is] first about the "hand" because in order for me to completely understand why it isn't good for you to have deforestation, I would have to do something hands-on. People say in school deforestation isn't good, but you don't really know until you get in the woods and see everything that's going on. … I went into the woods here, and I saw how cute the little frogs were, and when I held a frog, I was like, "This frog is so

> innocent." I was like, "How could you destroy something like this?" … I [even] think that venomous snakes are innocent, but the people that destroy our woods—they don't know that. … You also have to think about your feelings for the animal. … You should consider their habits and where they live in order to feel that empathy. … When I saw the animals, when I held them, there was just a feeling that I got in my heart that I couldn't do this to them. They're just so cute and innocent, and it was very heartfelt. It was emotional.

Taneesha described the *emotional* experience of feeling empathy as emerging from the *physical* experience of being in "the woods" and holding the frog. The physical and emotional experiences helped her understand better (*cognitively*) the process of deforestation, which she had previously experienced only as an abstract concept, taught within school walls. Figure 1 demonstrates that youths experienced many of the HRE practices in this unified way, as evidenced by how few chips were sorted in solely one category (head, heart, or hand).

To get a better idea of data patterns, we pulled out chip statements that produced the most unified perspectives across the entire group. This analysis yielded six chip statements that youths most consistently interpreted as integrating the cognitive, emotional, and physical dimensions of learning (be curious, do things I've never done before, help others, hold an animal, make careful observations, and navigate physical environment). It is telling that nearly all of the six most unified practices and norms are not part of typical school science. We further collapsed the six statements into four broad themes, discussed next: (a) novelty (doing something you have never done before), (b) navigating the physical environment, (c) helping others and collaborative fieldwork, (d) curiosity and wonder. These four themes define aspects of the HRE that prompted youths' meaning making as strongly unified.

Doing something you have never done before

Youths experienced many firsts—searching out and finding wildlife in their natural habitats; removing salamanders, aquatic turtles, and newts from traps; or pulling leaf packs from ephemeral pools or streams. Youths who vowed never to touch a snake wound up fearlessly, joyfully, and rather confidently handling nonvenomous snakes with pride and asking questions about their anatomy, behaviors, habitats, and predators. They experienced tick bites, large spiders crawling on their backs, and scratches from twigs as they navigated off-trail to track box turtles.

> [At the beginning of the week], some of the girls in our cabin were like, "Ew, I got sand …," and, "Ew, that frog! I could get warts." … Yesterday, when I was in the bathroom at the pool, a female Southern Toad apparently hopped into the bathroom with us. No one screamed or freaked out. We all just wanted to go and get it. (Amanda)

Amanda's quote illustrates a pattern we saw throughout the data; youths handled novel experiences with grace and open-mindedness, working through fear and uncertainty in the process.

The new experiences were emotional (thrilling, scary), physical (exhausting, uncomfortable, pleasurable), and prompted a desire to know more. Youths often mentioned firsts that centered on "gross stuff," illustrating their experiences as visceral and emotional.

> Harry: When I was in the snake hut and saw it musk. That was pretty disgusting. I had never seen that before, surprisingly.
> Amanda: I want to see that. What is that?
> Harry: Basically, you pick it up from the cage and it just . . . You know how it has its vent down there by the tail and it just spews the stuff.
> Amanda: Is it the cloaca?
> Harry: No, it's called the vent.
> Hayley: It's the same thing. Cloaca, vent. It's just different names. Yeah, I've seen that. It's really nasty.
> Harry: It just comes out this yellow white liquid all over . . . your arms and hands.
> Hayley: It looks like raw eggs. It looks like scrambled eggs.

The youths' discourse here evokes Weinstein and Broda's (2009) discussion of the "biological grotesque" as "a powerful moment, a memorable moment" (p. 761) that evokes both disgust and allure. The grotesque has potential to serve "as a kind of magic to bind student interest: to fascinate. At the same time, the grotesque is used to challenge and problematize hierarchies, rules, and authority" (p. 762). The HRE experience invoked the biological grotesque in similar ways. Youths engaged the grotesque as a performance of fear and fascination. The raw physicality of the work also minimized power hierarchies between experts and novices. Everyone, including university professors and guest herpetologists, could get musked, peed or pooped on, stung by a bee, bitten by a tick, or end up with a muddy bottom from a tumble on the banks of the stream.

Social leveling was also accomplished through fear and vulnerability. The physical aspects of the experience prompted worries about the animals' and one's own safety. Many youths coupled the chip "doing something for the first time" with "feel bravery." Bravery, evoked by trying something scary for the first time, was a resource for complete engagement, learning, and wonder.

> One thing I'll never ever forget is that when we were getting that Amphiuma. … It was a really feisty one that got out [of] the cage. When we were trying to put it into the water, it jumped out. Then it … I guess I mentally thought it hissed at me, but it had its mouth wide open trying to bite people, so it can get away. … I was excited. I wasn't scared. (Amanda)

Two-toed Amphiumas, the most unusual salamanders found at the HRE, are native to blackwater habitats and, to the best of our knowledge, visible only if trapped. They have dark, long, slimy eel-like bodies and possess a long, pointed jaw with rows of sharp teeth.

> My first real excitement that I got was when we found the two-toed Amphiuma. I've never heard of them before until I came to the HERP camp, and it was just an eye opener to what else is out there that's really, really cool, or what else is out there from, on the Earth, that we can learn about that's just not human or that I already know about? So after we caught

> the two-toed Amphiuma, we looked it up in our field guides, and I really like doing that, to classify stuff in the field guide, because you really have to think and you have to prove it wrong and prove it different before you actually get the right answer. (Amadahy)

This find sparked excitement from experts and novices during the post-fieldwork debrief. Amadahy's discovery thrilled her and sparked her curiosity and wonder about what else might be "out there," all aspects of doing good science.

Navigating the physical environment, encounters with animals, collaborative fieldwork

The physicality of fieldwork required a good-natured attitude; helping others; and, again, working through fear.

> I've always been out in the woods before. I had no objection to crashing through brush, but we had to get down on hands and knees and crawl through a marshy swamp area to get out to the other side, and no one else wanted to go through. And Timmy and Mr. Tom were like, 'Ethan, lead the way.' I had to, and I was proud of myself for doing it. I had to physically get down and go through the muck. … If I refused to go through it, then no one would go through it. (Ethan)

Going "through the muck" and navigating the physical environment yielded more robust scientific engagement, including up-close encounters with animals in natural habitats. They described navigating the physical environment as unified, requiring knowledge about habitats, ways to protect themselves from possible dangers, and empathy for the ways one's treks through habitats may harm animals. Many students' narratives included rich descriptions of encounters with live animals, another first for many, and illustrative of the unified nature of the experience:

> I had never really picked up a snake before this week or picked up a turtle or really picked up a salamander or picked up a newt or picked up anything just about, but now I'm not really scared of any of them——or anything. You feel fear maybe in the heart or feel excited or confident. And in your head you're thinking about it—what you're picking up, what you're going to do with it, how you'd react if it did something. (Logan)

Their narratives often centered on not harming themselves or the animals, which arose out of empathy for the animals and/or fear for their own safety. However, they also mentioned that holding animals enabled engagement in scientific practices and increased knowledge:

> Another experience for me would be the box turtles and aquatic turtles because I was measuring them with a special science tool called a caliper and I was measuring them, weighing them, caring for them. (Kaitlin)

> At the aquatic turtles, you have to think like—if you find one and you're about to, like, have you already registered it? Have you already marked it before? Or if you're gonna mark it, you have to collect all the data about it. Does it have any injuries? (Vanessa)

Youths' physical encounters with animals facilitated new knowledge that may have been inaccessible, or at least not as memorable, had they not done so. Identifying animals meant making careful observations while holding them and knowing enough about their anatomy to use field guides properly.

> I think you have to make careful observations because some of the lizards look really similar to each other and you have to read your field guide and read the details about that specific animal in order to identify what animal it is. … You physically have to make the observation and look it up, but then you also have to use your head to think about the observation you just made and process it. (Destini)

Kaitin, Vannessa, and Destini highlighted scientific observation as unifying the physical (holding, measuring, and weighing the animal), cognitive (using field guide, connecting observations to textual descriptions), and emotional (caring for the animals as you collect data about them) aspects of learning.

They also realized that they could not do fieldwork independently. Almost all mentioned "helping others" as a unified experience that arose from the physicality or the emotional aspects of the work. For example, the chest waders were challenging to don; youths often relied on one another to get them on. They could not easily set and retrieve traps without at least two people and often needed a hand when venturing out into the lake or ephemeral pool with chest waders because of the muddy terrain.

> One of us would get stuck. The other one would be like, "Okay, hold my shoulder here, and then give me your other hand." And we were just literally pulling each other out of the mud because we kept getting stuck. And we, kind of, helped each other mentally sometimes through some of the activities because it was hot and tiring. … We definitely did that a lot this week because we had to work in our group together to find the answers for things. So we definitely had to help each other when we were trying to catch animals, or we were trying to answer questions or learn more about them, and get data for different animals. (Catherine)

Fieldwork, which is almost never an independent endeavor, is done in fundamentally different ways than prototypical school science, which is often an individual, competitive endeavor.

Curiosity and wonder

Curiosity, a cornerstone of doing good science, was an aspect of the HRE that all agreed was an integral disposition, and most agreed unified head, heart, and hand.

> I would say being curious does have a lot to do with how you think because in this HRE program, it helped me to ask more questions pertaining to … the types of traps we would set and what those traps would catch whether we caught more traps with bait, without bait. It was a lot to learn and then I also said it would also be hand because there was also a bit of a physical aspect to it because being curious made you want to do hands-on stuff and actually take that lizard and actually catch that frog and hold that snake so that it was being

> curious … because you thought a lot, and it had the hand because we had to put in some action. (Taneesha)

Youths' narratives illustrated the ways curiosity arose from sensory experiences, shaped by their emotional experiences and cognition, manifesting itself in the need to know more about an organism or its habitat. Yet there was another dimension to the ways they discussed curiosity. Some discussed the HRE as a world-opening experience, filled with awe and wonder.

> Nature has always just taken my breath away just because it's so beautiful and relaxing. … I always did nature, but [at the HRE], I kind of opened my eyes. It was like there's so much more. Looking out here, you don't notice how many turtles there are in here and how many two-toed Amphiumas there are. … There's just so much more than what you actually see, the populations that are endangered or populations that are overpopulated. I kind of just opened my eyes to that. (Hayley)

The emotional experience seemed to change Hayley's relationship with the natural world, at least in a situated way (i.e., in that moment and place). This is also similar scholars' discussions of wonder, which has emotive and aesthetic qualities (Gilbert, 2013; Hadzigeorgiou, 2012).

Youths discussed how the HRE changed or would change their behaviors once they returned home:

> It'll probably get me outside more. Like, just go outside and see what there is to see because I know where I live, there's a lot of really cool stuff that's probably just being wait—or probably just waiting out there. So I think it would get me outside more in the forest and stuff around my house just seeing what's outside. (Garrett)

> Doing the HRE program … I think it made me walk in the woods a lot more and just go around, even if I get spider webs all over. I am terrified of spiders. I break out in a rash when they're near me, but ever since the first year, I've been walking through woods, even with my mom saying no. I will just go. If I get poison ivy, I don't really care. I'm just like "I don't even care if I get hurt anymore." I just want to go out there and just see what's out there. (Amanda)

Their narratives are reminiscent of researchers' work about aesthetics in science learning (Wickman, 2006). Jakobson and Wickman (2008) explained, "Every experience and learning is not merely cognitive, but always includes values, emotions, and doing" (p. 48). Aesthetic judgments are essential aspects of meaning making that go beyond the purely cognitive; they operate normatively, to draw participants' attention to what counts, what is worthy of one's attention, what is beautiful, and what is grotesque (Jakobson & Wickman, 2008). Many youths' aesthetic judgments changed over the course of the week—from viewing a frog as disgusting to something worth examining closely; from viewing one's backyard with little regard to framing it as a place teeming with hidden life and worthy of exploration. These changes shifted in line with the HREs' community norms. Gilbert (2013) argued that as youth connect with the beauty of the natural world, they became more engaged with science content. The same seemed true for the

HRE participants; their narratives point to wonder as potentially powerful "shift[s] in perspective" (Hadzigeorgiou, 2012, p. 987).

DISCUSSION

"I feel like changing how we approach science. Instead of coming from a black and white textbook to more of a green and sandy, muddy, blue sky book." (Amanda)

Science education is implicated with neoliberalism. Better science education means a stronger workforce for a stronger economy.[1] But what kind of science education are we talking about here? Would the field sciences, and certainly the fieldwork associated with it, be included in the kind of science education that a neoliberal imaginary says would strengthen the economy? It is unlikely.

We focused on the ways field ecology and the study of biodiversity (a bulwark against climate change), as enacted in the HRE, offer an alternative vision of science education that works against neoliberal ideology. Here, we pull out three assumptions of neoliberal education and discuss the possibility of field science as a *modest, but imaginable and practical push back*. Our proposal here is not particularly revolutionary. The HRE practices are not inherently radical, and yet their rarity in schools makes them startlingly so.[2]

Assumption 1: education should be primarily about acquiring knowledge

Olssen and Peters (2005) argued that "the most significant material change that underpins neoliberalism in the twenty-first century is the rise in the importance of knowledge as capital" (p. 330). This type of knowledge economy relies more on intellectual capacity than natural resources or physical labor and uses that intellectual capital to improve society through technological and scientific advancements (Powell & Snellman, 2004). This narrow definition of knowledge fails to capture aesthetic, emotional, and physical aspects of learning, learning for learning's sake, learning for the sake of the nonhuman common good, and the survival of resources humans need to survive. Certainly, the HRE participants learned plenty of canonical knowledge. For instance, they had an 18.95% average score gain between a pretest at the beginning of the week and a posttest at the end of the week that measured their knowledge of herpetology, fieldwork, and field ecology. However, they learned a lot not easily measured on a test.

For instance, HRE participants were challenged to help researchers determine accurate population estimates of species of organisms by sampling their habitats (woods, streams, ephemeral pools, fields). They helped figure out how to capture these organisms and then measured and marked them before their release. Marking a large snapping turtle is quite different than marking a green anole lizard. All of the captures required data to be carefully recorded, compiled, and shared to establish baseline population data in specific environments. What effect, if any, do changing temperatures have on how long pool water is available and ultimately on salamander populations? They learned that data are important; they tell us stories about what lives "here" and what might be changing. Participants wondered, How can an aquatic turtle stay

[1] See Teitlebaum (2014) for an alternative perspective.
[2] Thank you to Angela Johnson for the insight.

submerged for months at a time? How do terrestrial animals find their way back to pools? Where do frogs go in winter—not frogs in general, but *this* frog, in my hand? Many questions had no definitive answers.

This kind of knowledge and learning is not easily captured on traditional assessments. Constructing this kind of knowledge demands physicality and elicits emotional reactions, curiosity, and wonder. Further, youths relied on peers' "tales from the field," knowledge borne of experience in the field—what to do if a snake bit you, if you caught a big snapping turtle, if you lost your footing in the pond while wearing chest waders. This knowledge was essential in building community and confidence and for doing scientific work. We conceptualize this broadened view of knowledge as a challenge to neoliberalism's privileging of techno-rational, reductionistic, authoritative knowledge.

Assumption 2: education should serve the market

Education "is increasingly understood in terms of jobs and careers, which means business, especially entrepreneurship" (Deresiewicz, 2015, p. 30).

> [Neoliberal education] does not seek fundamental change; [it seeks] technological or technocratic change within a static social framework, with a market framework. Which is really too bad, because the biggest challenges we face—climate change, resource depletion … —will require nothing less than fundamental change. (Deresiewicz, 2015, p. 31)

Field ecology has the potential to make real and urgent these big challenges defined by Deresiewicz. Youths explained that they did not really "understand" the urgency of some environmental problems until the HRE.

> When you're at school, and they may say things about deforestation, and you're taking away … amphibians' and reptiles' homes, it's like, okay, deforestation. But when … you're actually here, and you actually hold the frogs, and you hold the snakes, it's a whole different story. Like, you're actually here, and you put yourself in their position. I don't want to take away their home. (Taneesha)

Field ecology gets students outside so that they can physically and emotionally experience the beauty of nature, the hidden world of reptiles and amphibians, wonder about it, connect to it, and cognitively begin to understand how living things are intertwined and interdependent.

Assumption 3: individualism is more important than the collective

Competition and meritocracy, often under the guise of personal responsibility (Giroux, 2005; Harvey, 2007), are essential to the proper functioning of society. For proponents of neoliberalism, any attempt to defer to the collective reduces competition and, thus, weakens the individual's resolve. Neoliberalism creates a de facto caste system in which "winners and losers" are clearly defined, and the "best and brightest" compete for various aspects of the good life (Deresiewicz, 2015, p. 30).

Prototypical science education was built on this competitive, hierarchical legacy long before neoliberalism pervaded educational policies. Yet the HRE presents a compelling juxtaposition to this competitive milieu. Field ecology cannot be done individually, no matter how smart or accomplished one is. One needs help setting and fetching traps, handling animals to get accurate measurements, and finding animals in the field for population studies. Further, field ecology is saturated with social leveling; the natural environment treats every participant, novice or expert, the same. A newcomer to the field can make a great find nearly as well as an experienced herpetologist. Once one has made a find, it may take a few herpetologists gathered together to determine the organism's species. Field ecology is a collective endeavor that nurtures participants' regard for one another, as well as their regard for the flora and fauna of the natural world. One cannot be selfish and competitive in this environment and thrive.

CONCLUSION

Neoliberalism is based on an ideological assumption that our social world "is not going to change, so we don't need young people to imagine how it might" (Deresiewicz, 2015, p. 28). Those who push back are dissatisfied with the status quo, believe transformation is possible, and focus their efforts on learning in/with/from the groups at the margins. Field ecology is a science at the margins of the discipline. Knowledge production in field ecology *contests* prototypical scientific epistemologies that are reductionist, techno-rational, and perpetuate subject/object dualisms. It is holistic and systemic, brings in emotion, demands physicality, and focuses on understanding interdependent relationships. It is a science where women are more equally represented (National Science Foundation, 2014), it is virtually ignored in the Next Generation Science Standards, and it will not bring us immediate economic gains. We work with youths whom society and science may give up on simply because of their race or ethnicity or their lack of access to socioeconomic resources. These youths "see" from the margins. They are not generally the group to benefit from neoliberal education. Their insights, goals, and engagement with this science at the margins are worth our attention. Are we willing to restructure science education based on what we see, learn, and understand when positioned at the margins?

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