Ecocritcally (Re)Considering STEM
Integrated Ecological Inquiry in Teacher Education

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The acronym STEM is a ubiquitous term for seemingly anything in—or related to—the fields of science, technology, engineering, and mathematics, and the current dominant educational STEM discourse in teacher education is often organized around questions of how to integrate math and science into the other content areas or vice versa. The purpose of this essay is to pose a different question: *How can an ecological model for subject inquiry become the organizing focus for an integrated ecological inquiry?* In this article, we provide a glimpse of where we are currently in our thinking and writing as we put theory to work in teacher education. For the past few years, we have been working on a number of exciting endeavors in teacher education, ranging from theoretical explorations to more practitioner-based projects that attempt to outline how PK-12 educators might utilize ecocritical frameworks in their Common Core State Standards (CCSS) aligned lesson plans. However, in our efforts to develop and apply an ecocritical framework for examining deeply rooted cultural assumptions with/in teacher education,

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we keep ending up involved with—and too often boxed in by—STEM. In response to this dilemma, this paper takes up what we feel is a key next step in our rather non-linear conceptual work to challenge modernist, Western, industrial dualisms and their associated discursive influences that shape and maintain superior/inferior value-hierarchized dichotomies in teacher education. More specifically, we are interested in how it is that these dualistic habits of mind all too often map an Either/Or onto how we—as educators and educational researchers—interpret the differences between dominant STEM content and moving toward an ecocritical framework for teaching for social justice and sustainability. Such work finds us in conversation with Bateson (1972) and Code (2006), as we study new materialism (Barad, 2007; Bennet, 2010; Coole & Frost, 2010) and critical posthumanism (Pedersen, 2010) and focus on the potential that such perspectives have to help us reconceptualize curriculum and pedagogy in teacher education supportive of social justice and sustainability—or, as we term it, as an integrated ecological inquiry.

In this essay, we draw on Bateson (1972) through an EcoJustice theoretical framework (Martusewicz, 2001, 2016; Martusewicz et al., 2015) in connection with Code's (2006) "ecological thinking," as well as use insights from our ecocritical research examining the promise of pedagogical projects that recognize, respect, and represent difference as a valued, productive, and interpretive condition (Lupinacci & Happel-Parkins, 2015a, 2015b, 2016). Building from our ongoing work, we seek to advance scholarly understandings and conceptualizations of the project of constructing an integrated ecological inquiry—an inter/transdisciplinary approach to learning framed by Code's (2006) notion of an "ecological intelligence," or knowledge that resides in natural systems, and in accordance with ecocritical efforts from scholar-activist educators to recognize and resist deeply-rooted assumptions of Western industrial culture. Currently, literature in related fields offers very few models that illustrate what this (re)conceptualization looks like in practice, and even fewer that examine the operationalizing of such efforts in teacher education. In this exploratory essay, we briefly introduce an ecocritical theoretical approach and apply that lens to (re)constituting STEM as inseparable from, rather than superior to, a multi-disciplinary/multi-sensory ecologically-centered education. Concluding this brief theoretical de(re)construction and re(con)figuration, we share a concrete example that illustrates one such ecocritical exploration in practice.

What we present in this essay is therefore a very tentative and exploratory line of our current thinking, and as such, we do not assert ourselves from the position of new materialist philosophers in teacher education, but rather as scholars learning about and thinking with said

perspectives and working toward their application with(in) an ecocritical framework in teacher education. In other words, we are scholar-activist educators reading and co-learning with one another and sharing what emerges when we dive into theory and put it to work. Since this paper represents a snapshot of our current thinking about ecocritical work in teacher education, it is a perfect time to pose questions that can hopefully push thinking in teacher education in productive and generative directions. Drawing from what James Paul Gee (2014) calls "big 'D' discourse" (p. 24)—the constructing, defining, and relationally-productive process of making meaning that includes language and everything else like gestures, bodies, environments, technologies, and deeply held social values—we briefly outline how dominant STEM discourses take up the notion of "inquiry" so that we can begin to open up, expand, and even reconstitute these understandings. We chose to focus on "inquiry" since it has such a pervasive presence within educational, and specifically STEM, discourses. Simultaneously, we assert that inhabiting and critiquing dominant discourses of inquiry is imperative for broadening the concept and creating space for those of us who advocate for ecocritical understandings and practices.

Inquiry in Teacher Education, Public Schools, and Communities

The increasingly narrow scope of research in teacher education has generated constant talk about, and related funding allocations for, the need for programs and projects that provide ongoing evidence to "prove" that teacher education can, in fact, produce "effective" teachers. What was often in the past called best practices, and Ladson-Billings (1995) called "just good teaching" (p. 159), is now saturated by rhetoric such as inquiry-based instruction, inquiry learning, inquiry-informed lesson planning, and any of the variety of the like. We often joke that if we had a hundred dollars for every time the words "inquiry" and "measurement" were uttered in our colleges of education that we would not be stressed about our student loan debt. While we often discuss whether or not working with STEM projects is in some way reinforcing its power, in this project we have committed to critically examining what occurs when we say "no" to dominant conceptions of STEM by simultaneously saying "yes" to alternative understandings. We draw from Holloway (2010), who suggests that when working toward a different world—for us, a world not disciplined by dominant conceptions of STEM—we should seek to break from what is by opposing such dominant conceptions and proposing alternatives. Holloway explains:

> If all we do is oppose… then we simply follow in their footsteps. Breaking means that we do more than that, that we seize the initiative, that we set the agenda. We negate, but out of our negation grows a creation, an other-doing, an activity that is not determined by money, an activity that is not shaped by the rules of power. (2010, p. 3)

These alternatives subversively emerge from unexpected (dis)entanglements with(in) STEM discourses which, in some ways, embrace the concept of inquiry as a potential space to create from our negation what Barad (2007) refers to as (im)possibilities, which we assert have the potential to radically break and (re)constitute STEM discourses.

As ecocritical scholar-activist educators, we are interested in what might constitute "inquiry" if the root metaphors of the concept were not grounded in what Val Plumwood (2002, p.120) calls an "Illusion of Disembeddedness," which is the false understanding that one's self exists as an individual separate from and often superior to all others. This Illusion of Disembeddedness is rationalized by what Karen Warren (1990, p. 128) refers to as a "Logic of Domination." This ecofeminist philosophical argument suggests that there is a logic of superiority which is used to justify domination and oppression. Specifically, this logic justifies systems of oppression built on anthropocentrism, sexism, racism, etc., and these systems are often created by likening and understanding animals, and some humans (specifically women and/or people of color) as closer to nature, enabling and rationalizing the exploitation and domination of women and nature in Western industrial culture. Building from this we are interested in how inquiry might shift if it embodied "ecological thinking" (Code, 2006, p. 21), illuminated in educational spaces by focusing on, in Bateson's words, the "differences which make a difference" (Bateson, 1972, p. 318). Recognizing the importance of these differences, we understand diversity as a condition of difference upon which all things exist. It has been our experience that too often in mainstream teacher education, the idea of diversity has been in many ways co-opted and watered down to dis-include radical notions of difference by insisting on an overarching sameness for the sake of tolerance. To avoid this, we seek to focus on efforts that critically and ethically engage teachers and future teachers—and by extension, their students—in recognizing the crucial importance of "difference." So, in many ways, this work is about committing to a conceptual understanding of the diversity that remains not only inclusive of, but also expands on, traditional liberal framings that dominate discursive practices that limit "diversity" to representations of only race, class, and gender.

In particular, we want to work toward identifying how "normativity"—a discursive formation of dominant discourses of anthropocentrism (human-supremacy), patriarchy, individualism, consumerism, and sci-

entism—works to frame how people interpret recognized differences in connection with the problematic, and often value-hierarchized, sorting that results from a culturally constituted normalcy. *Normal* in this case is often male, white, human, able-bodied, heterosexual, property owning, and so on. In Modernist cultures normativity is commonly referred to as "just the way it is." But, we argue, nothing is "just the way it is;" rather, the "norm" is socially constituted/constructed and is therefore open to reconstitution and resignification.

Ecological Intelligence: Toward an Integrated Ecological Inquiry

Critically examining "inquiry," and the connected possibilities for such a reconceptualization for an ecocritical approach in teacher education, is about posing questions and thinking ethically and critically about how we understand difference, and how we make decisions when faced with the need to engage with one another. It is also about insisting upon critically examining the foundational assumptions that inform commonsensical understandings of concepts such as inquiry and diversity. Before returning to inquiry, let us first clarify how we define "ecological." We use the term ecological to broadly refer to all the interconnected relationships, both physical and social, that constitute existence for humans and more-than-humans. In this line of thinking we primarily draw from Code (2006), who introduces what she calls "ecological thinking," which she explains is a way of:

> …developing a conceptual framework for a theory of knowledge—an epistemology—sensitive to human and historical-geographical diversity and well equipped to interrogate and unsettle the instrumental rationality, abstract individualism, reductionism, and exploitation of people and places that the epistemologies of mastery have helped to legitimate. (p.21)

Believing that ecological thinking is possible, and even necessary, to learn, our questions include:

1. How do our understandings of inquiry shift when we conceptualize inquiry from the perspective of ecological thinking?

2. What questions and scenarios ought we be learning to recognize and address?

3. What will help both current and future generations learn to situate those questions and scenarios in response to local needs of sustainability and social justice?

Code (2006), explaining ecological thinking, calls for a self-reflective process mediated by an interruptive, reconstituting process that:

> …relocates inquiry "down on the ground" where knowledge is made, negotiated, circulated; and where nature and conditions of the particular "ground," the situations and circumstances of specific knowers, their interdependence and their negotiations have claims to critical epistemic scrutiny equivalent to those of allegedly isolated, discret propositional knowledge claims. (pp. 5-6)

In other words, such an inquiry would include a multitude of relationships that are valued and leveraged in an ecological inquiry. Following this, we ask: How might we rethink the foundational assumptions which undergird current, dominant STEM-based understandings of inquiry?

Let us suppose, despite the seeming impossibility of such, that the actual sign here—"inquiry"—can shift from what is currently signified and slip toward signifying something less rooted in scientism (the modernist discourse that only one valid way of knowing exists, which is rooted in the Scientific Method and post-positivist understandings of and belief in objectivity, reliability, and replicability). Consider how inquiry might be able to signify something that considers the multitude of possibilities for understandings within an ecological system, as opposed to a mechanistic approach which likens living systems to a machine. For example, when inquiry is taught in a mechanistic way, the process of thinking is understood as occurring in the brain, which is often understood as an organ likened to a computer or command center with replaceable parts and programmable functions. However, thinking and meaning-making are relational. They occur in relationship among the interconnectedness of the many organs in the body which are in relationship with a multitude of other living and non-living beings in an ecological system. When we teach about inquiry, or scientific inquiry as a mechanistic feature of Western industrial culture, we locate knowledge in the brain and as something to discover, or be taught, and then store for our use at a later date. This is problematic and turns attention away from the location of knowledges (or understandings) as existing in the relationships and mediated by the diverse language systems between and among the vast interactions and exchanges occurring in any specific locale. Rather, a mechanistic metaphor for inquiry presents the false supposition that learning and knowledge can simply be uploaded, upgraded, or improved with the right parts replaced or put to use properly. We argue against the latter for all forms of education and invite educators to consider a shift from a mechanistic understanding of inquiry to one that understands that inquiry is constituted by all the interactions in one's body and the

environment. This shift is exactly our aim when we reconceptualize inquiry through ecocritical frameworks. We are reconstituting STEM content learning to be a part of multidisciplinary learning, much like place-based and project-based learning, but to include intentional efforts to situate the learning experience in broader living systems in efforts to support an ecological intelligence. Simply put, we are envisioning working with(in) what exists toward the abolishment of some of the limiting assumptions traditionally embedded in STEM learning, and in public schools in general. We suggest that this re-envisioning can be enacted through diverse reconfigurations of classrooms that, while looking very different, will share that they engage students in the ethical process of asking questions such as, "Who/what benefits?" and "Who/what suffers unjustly?" and with the crucial subsequent question, "So now, what do we do about it?"

An Example from Teacher Education: NGSS Standards, Ecological Intelligence, and Inquiry

The process in which we engage through teacher education when considering the questions in the previous section is the application of what we have been calling an ecocritical framework to the concept of "inquiry." To illustrate, below we offer an example which facilitates a practical conversation about the Next Generation Science Standards (NGSS), a framework written by the National Research Council (NRC). The NRC explains that proficiency in science "rests on a view of science as both a body of knowledge and an evidence-based, model and theory building enterprise that continually extends, refines, and revises knowledge" (http://www.nextgenscience.org/three-dimensions, para. 1). Furthermore, the NRC's framework—one, we might add, that is being rapidly adopted in many regions of the United States as the state's science standards—presents three dimensions (practices, cross-cutting concepts, and disciplinary core ideas) that combine to create each standard of the framework. According to their website, the third dimension, disciplinary core ideas, consists of the content of the physical sciences; the life sciences; the earth and space sciences; and engineering, technology and applications of science. While all three dimensions are important to consider in the curriculum planning process, we will focus on the third dimension—disciplinary core ideas—in our example to emphasize that curriculum, instruction, and assessment be centered on practices and cut across concepts (NCR, 2012).

In an era of standardization, we are both highly critical of national standards. Yet, we simultaneously look for unexpected openings through which teachers can bring an ecocritical framework to an interdisciplinary classroom in ways that meet, and often exceed, imposed or adopted standards. However,

our assertion is that an integrated ecological inquiry is not just a rethinking of science education. It requires a full (re)conceptualizing of curriculum and pedagogy—for example, viewing these four aforementioned aspects with the other two dimensions in NGSS and with other subject area standards together with students, teachers, the implicit and explicit curriculum, the school, and all the members of the community inclusive of the more-than-human world—as a complex entanglement. So, when we work with teachers, we bring all the sets of standards and relationships to the table and have found that, in addition to CCSS Mathematics and English Language Arts standards, we also have been bringing the National Council for the Social Studies' (NCSS) College, Career, and Civic Life (C3) Framework for social studies standards, as well as local state standards for Art, Music, Physical Education, and Health, into this planning process. In other words, when we begin to think about what constitutes an integrated ecological inquiry, these (re)conceptualizations of curriculum and pedagogy lead us toward working to consider more broadly connections between content areas— and the content standards and frameworks—as interdependent and interdisciplinary. We argue that ecological inquiry is required to be more organically organized and thus is not able to be mechanically separated and atomized into learning objectives fitting neatly within fifty-minute time intervals. This work "relocates inquiry" (Code, 2006, p. 5) on the ground and in the multi-sensory learning relationships of diverse beings existing in complex ecosystems (which is one reason we passionately support school/community gardens, but that is not the topic of this essay).

As an example of this type of classroom inquiry, consider a classroom learning about water in which an essential question is posed—*How is it we are all a body of water?*—with the following sub-essential questions: *Where does that water that makes up over 80% of our bodies come from? What is in that water? What is in us? How do different beings interact with, depend on, and use water? What role does water play in our lives and in the lives of all the different members in our communities?*

Imagine in the classroom that students are engaging in an activity that models a local water cycle. When teaching about water there are many ways to model a water cycle—or the ways water moves between its varied states through precipitation, condensation, and evaporation and back again. One way we consider teaching the water cycle is to focus lessons on modeling how a drop of water travels from bodies of water—like ground water, lakes, oceans, snow, ice, and glaciers—and then with energy from the sun works to evaporate into water vapor that rises and condenses in clouds. Following a drop of water now condensed in the clouds (and noting that volcanoes also emit steam that form clouds), air currents move the clouds and the condensed water

drops from the clouds as precipitation (rain and snow), which builds up again as bodies of water, snow, ice, and glaciers. However, it is important that teachers include teaching about interferences, or interruptions, to this system. For example, built environments often pave over the ground leading to excessive run off which picks up toxins as the water makes its way back into the ground. Similarly, climate change affects precipitation patterns, resulting in increased droughts and floods. Too often, we omit humans—and even other living beings like animals and plants—from how we teach lessons like the water cycle. An integrated ecological inquiry approach explicitly examines the ecosystem's diverse relationships with humans, and encourages teachers and students to explicitly identify their own cultural assumptions and how these assumptions influence how it is that they think about water and their relationships—specifically their dependencies—with water. For example, teachers might encourage students to critically examine practices related to Western industrial development, such as paving over large parts of exposed ground as mentioned earlier in this example. This practice, coupled with concentrated large populations in locations that exceed the ecosystem's capacity to provide water at the rate in which it is needed in order to sustain human life, contribute to interferences with the water cycle that are in desperate need of our time, attention, and critique. These considerations create opportunities for students and teachers to learn to question Western notions of progress and offer the chance to explore alternative solutions without overlooking the cultural roots of a water crisis—all while learning about the water cycle.

When the water cycle is taught in this way, there is no separation between social studies and science. Students are learning to address real life civic challenges related to social justice and sustainability while learning about the science behind water cycles. In an integrated ecological inquiry model of learning the water cycle, students are learning about themselves as civic bodies of water within an ecosystem and who or what benefits and/or suffers with each individual and institutional decision. Additionally, this can be a wonderful tie in for learning about the many ways water is represented and utilized in diverse cultures. For example, students might learn about the ways in which water plays a ceremonial role in rituals like baptism in Christianity, burial in Buddhism, and for cleansings and purity in Islam, Judaism, and Hinduism. Another example could even be to recognize the many ways that water is part of the landscape and how water affects our daily interactions like playing outside, being thirsty, using the bathroom, growing food, watering the lawn, and so on. If we teach about the water cycle without including the complex beings and relationships that are dependent on

water then we are vulnerable to not recognizing that unhealthy relationships with water threaten the sustainability of our species and impact other species and their right to exist.

All too often, even the most effective STEM teachers use scenarios that might emphasize the complexity of systems, but do so in ways that position students as objective observers. This serves to reinforce the understanding of self, and humans more generally, as separate from—and superior to—the living systems that students are encouraged to "objectively" observe. Instead, in an integrated ecological inquiry, both the teacher and students are also critically and ethically engaged (at developmentally appropriate levels) with recognizing the differences between what, in our work to introduce an ecocritical framework, we call an *anthropocentric* (human-centered) understanding versus an *ecological* understanding. Indeed, exploring the differences between these two approaches to understanding something like a water cycle can become a lesson in and of itself. Teachers can use these two approaches to co-learn with their students about the importance of recognizing anthropocentric understandings, and the implications these assumptions have on their actions and, in turn, the kind of communities they live in. Thus, not only are students learning about the water cycle, they also are learning about foundational assumptions which inform how humans often learn about, and therefore interact with, the more-than-human world. It also incorporates critical conversations about expanding and deepening our understandings of, and respect for, difference and dependency. Referring back to the example explained above, learning about water cycles with attention to humans—and all other living beings—as within and dependent upon the water cycle opens up the spaces and possibilities for prompting students to consider not only the different ways water relates to our diverse daily lives, but also to questions about who—and what—has access and the rights to clean water. Furthermore, teachers can encourage students to consider current events (like the Flint Water Crisis in Michigan and the Dakota Access Pipeline Protest at Standing Rock in North Dakota) and ask for whom—and what—are such rights being afforded.

Whether it be water, or any other aspect of the curriculum, an integrated ecological inquiry illuminates the relationships among—and between—humans and the more-than-human world; and embraces the diverse ways in which we learn to recognize and understand our existence and relationships. This way of approaching inquiry relocates it "down on the ground" (p. 5) as Code (2007) suggests, and it works against an "Illusion of Disembeddness" (Plumwood, 2002, p. 97) and the dominant ways in which STEM is understood and taught. Through an integrated ecological inquiry, students are encouraged to ask questions, but they

are also held accountable to the ethical considerations of recognizing what might be influencing the questions and the processes of seeking answers—which includes an understanding that there are always many, many potential perspectives and subsequent answers that emerge when difference and dependency are recognized and valued.

Conclusion: Im/possibilities and Uncertainties of Dis/entangling

If we are to take a general approach to defining inquiry learning, we can say that it starts with posing questions or scenarios that engage students in a process of uncovering or seeking answers to locally-informed questions, situating themselves as active participants in community with other species and life forms. In the process, they learn content skills that are facilitated by a teacher. Such learning provides a stark contrast to the common practices of schooling often referred to as the "banking concept of education" (Freire, 1993 p. 58), in which learning begins with generalized and static facts that students memorize and are then asked to apply in various scenarios. In this sense, we might consider inquiry learning to be very much aligned with constructivist notions of how people learn. However, we would like to back up and suggest that if teachers and students are not learning to recognize and resist dominant ideologies of harmful foundational assumptions, such as anthropocentrism, then reconstituting how we understand or make sense of the world seems unlikely via formalized education.

In this work, then, we are suggesting working directly to (re)claim inquiry from a practice of scientism and (re)constitute it as framed by an ecological model that calls for a transdisciplinary or interdisciplinary approach to teaching across several content areas, all the while paying close attention to the harmful assumptions which undergird many of the basic and foundational lessons through which students learn about and explore their worlds. Importantly, this is not a flat-out rejection of the sciences, mathematics, technology, and engineering. Rather, our suggestion is to work with(in) and among those fields to re(con)figure the maps currently dominating the contours of what constitutes an "education." In working through such a need, we propose the notion of an "integrated ecological inquiry." While we recognize that we are not inventing this work, we are focusing our attention on how harmful assumptions and cultural practices can be examined critically through putting theory to work, so to speak, through our local educational spaces to unsettle inquiry and (re)configure the classroom in ways that foster ecological learning that emphasizes interconnectedness and interspecies equity.

We end this article by thinking through some new possibilities fostered by Barad's (2007) work and by educational researchers considering Barad and other new materialist and critical posthumanist scholarship (Bennet, 2009; Coole & Frost, 2010; Pedersen, 2010; Snaza, Sonu, Truman, & Zaliwska, 2016). These theoretical influences brought to an ecocritical framework help us to consider critical questions such as:

1. How do concepts such as entanglement and intra-action help us to recognize and value—or reconsider—difference and dependency in connection to our existence, understandings, and sense of belonging? How do these concepts point us towards new possibilities of dis/re/entanglements?

2. What new possibilities emerge when we try and dis/entangle the complex entanglements of STEM discourses shaping, and shaped by, us as subjects?

3. How can concepts like intra-action be used to further critiques of anthropocentrism within current dominant STEM discourses?

4. How are we still (re)asserting the humanist subject when we engage in challenging anthropocentric assumptions?

5. How does Barad's specific notion of agency help us to reconsider how we teach lessons such as the water cycle? How do we reconceptualize agency for the more-than-human world without engaging in anthropomorphization?

While engaged in such attempts to dis/entangle and re(con)figure some of the complex entanglements in teacher education in relation to STEM, what we can say is that this is not a project that will produce any one predictable solution with generalizable next steps. However, our next step is to dis/entangle and to continue to work towards fostering an integrated ecological inquiry with students and our peers in teacher education, with the understanding that there is no way to know what will emerge from such a process. What we can assert is that, if we ground that work in an ecological intelligence, we will learn about ourselves, each other, along with the diverse set of living beings with whom we share existence, mattering, and being.

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