

EcoJustice Mathematics Education: An Ecocritical (Re)consideration for 21st Century Curricular Challenges

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THIS CENTURY'S GLOBAL CHALLENGE, the highly complex and interwoven fabric of minute and grand social and environmental catastrophes, necessitates curriculum theorizing in a multiplicity of ways and across a variety of knowledges and other contexts. Curriculum studies as a field has begun this formidable work, examining various types of atrocities (e.g., environmental catastrophe, oppression of women, white supremacy). Often, it has approached each type in isolation; in some cases, it has approached each type together as interrelated features of Western industrial culture. Nevertheless, we consider the scholarship in recent decades as the emergence of a new program in curriculum studies that attends to both the social and environmental issues we face today. We will review this work briefly, but not only as a means to discuss mathematics education; we do so more importantly to suggest that such projects in curriculum studies have reached a depth at which we can, and arguably must, focus on specific domains, such as particular knowledges and school contexts. Therefore, this article presents an ecocritical (re)consideration of the curricular challenges of mathematics education. We approach this in two parts: first, we discuss the ecocritical scholarship relevant to mathematics as knowledge and mathematics education as practice; second, we review the domains in mathematics education relevant to ecocritical conceptions of education. The latter refers to a handful of strands, including critical mathematics education, poststructuralist feminist understandings of mathematics education, and the expansive field of ethnomathematics. From these efforts, we articulate a conception of EcoJustice Mathematics Education (EJME) and conclude with an example lesson that specifically reimagines in detail the Kolam, a mathematical, artistic practice from India of great interest to ethnomathematicians.

Our Vision, Purpose, and Approach

As educators and scholars working in the field of education, we believe that social, political, and ecological issues are integrally intertwined with educational theory, research, and practice. As mathematics educators who have worked in a variety of settings,¹ we are deeply committed to critical approaches to mathematics teaching and learning, and envision that mathematics education can play a more central role in supporting diverse efforts toward the betterment of humankind and planetary health.

Many projects in mathematics education already prioritize social justice issues. For example, scholars have questioned the role of mathematical knowledge in perpetuating a meritocratic norm used to justify economic disparities between ethnic and racial groups (e.g., Apple, 1992; Brantlinger, 2011; Gabbard, 2000; Martin, 2008; Wolfmeyer, 2014). More recently, gender as a factor in attainment of higher levels of math coursework is becoming an important research agenda, particularly in current reform initiatives like STEM (e.g., Hopewell, McNeely, Kuiler, & Hahm, 2009; Lee, Fox, & Brown, 2011; Lou, Shih, Ray Diez, & Tseng, 2011; Taylor, 2009).

However, when educational efforts do address ecological issues, such as in EcoJustice Education, very little is said about the way in which the Western discipline of mathematics may perpetuate certain worldviews that negatively affect planetary health and biodiversity. For example, scholarship in literacy education and teacher education have integrated such work with particular educational disciplines, but to our knowledge these connections have yet to be made with mathematics education.

From Critical to Ecocritical Curriculum Studies

As curriculum theorists, math teachers, and teacher educators, we recognize that the field of curriculum studies is vast and acknowledge that critical scholars and practitioners are already paying more attention to considerations of the inner workings and complexities of unjust suffering on the planet. Given our shared interest, we recommend that critical scholars and practitioners pay more attention to *ecocritical* work in curriculum studies.

The reason for our recommendation is curriculum studies' focus on the relational aspect of curriculum. The foundation of curriculum studies, *currere*, the very notion of curriculum that has guided the field for the last 40 years, is a key to critical perspectives in projects of ecocritical curriculum studies. The shift in thinking about curriculum as *currere*, as verb and not noun (e.g., Pinar & Grumet, 1976), suggests that what is taught and learned is what is *experienced*. Such emphasis on experience suggests the *relational* aspect of curriculum, as evidenced in the following:

Stated simply, *currere* seeks to understand the contribution academic studies makes to one's understanding of his or her life (and vice versa), and how both are imbricated in society, politics, and culture. Influenced by literary and feminist theory, *currere* becomes a version of cultural criticism." (Pinar, 2004, p. 36)

Using the perspective of curriculum as teaching the relationship of the learner to the world, curriculum studies addresses the context of social and environmental catastrophe. For example, in applying this perspective we can say that the emphasis on competition for grades in typical schooling promotes individualism as a dominant framework for relating to others. In another example, one mathematics educator suggests that mathematics teaches “prescription readiness,” or, the method of following sets of steps as an act of obedience (Skovsmose, 2011, pp. 9–10) and that this is preparation for the type of worker required by Western industrial culture. Thus, mathematics students learn what is required for success in a world that is increasingly driven by the pervasive spread of a neoliberal restructuring of political and economic relationships. Additionally, in the current climate of education, the success or failure of students as individuals is often understood through a measurement system that is heavily weighted by cultural values assigned to success in school mathematics. Thus, students of mathematics are learning the self-worth ascribed to them by these societal assumptions. Ecocritical curricular scholars in education consider the ways that such socio-cultural educational programs influence and develop relationships, primarily the order of subordinations and supremacies within and among life on the planet.

Ecocritical work emphasizes culturally constituted and constructed value-hierarchies within the curricular experience, to simultaneously oppose it and propose alternatives (Lupinacci & Happel, 2015). A scan of the broad expanse of work in curriculum theorizing indicates that many of its subfields indeed address the dominant value-hierarchies constructed by humans to categorize life on the planet—value-hierarchies relevant to ecocritical work. Pinar’s (2007) categories of post-1995 scholarship reveal the following:

1) curriculum history, 2) curriculum politics, 3) cultural studies, 4) race theory, 5) women’s and gender studies, including queer theory, 6) post-colonial studies, 7) Jewish curriculum studies, 8) disability studies, 9) narrative (including autobiographical, autoethnographic, and biographic) inquiry, 10) complexity theory, 11) environmental studies, 12) psychoanalytic studies, 13) technology (especially computers), 14) arts-based research, and 15) internationalization. (p. xxv)

At least half of the items on the list are direct referents to “value-hierarchized dualisms” (Martusewicz, Edmundson, & Lupinacci, 2015)—culture/nature, male/female, mind/body, civilized/savage, etc.

Now consider the notion of human supremacy. There is growing concern in curriculum studies about inattention toward the hierarchized dualism that is human supremacy. In “Towards a Posthumanist Education,” Snaza, et al. (2014) pay reference to the notion of *currere* as they motivate our attention to human supremacy:

Consciously or not, we educators and educational researchers are used to looking at schools as places where humans dwell together to learn what it means to be human and to accumulate the kinds of skills and habits required to participate in human societies as adults. (p. 39)

They also remind us that schools are situated within and among the life on the planet aside from humans:

Schools are also sites that contain: networks of wire and pipe linking the buildings' architecture to the subterranean infrastructures of cities and beyond that to the swirls of the oceans and global deposits of prehistoric dead organisms waiting to be mined and refined; dead nonhuman animals on plates in cafeterias, as well as on feet, human bodies, athletic equipment, and biology dissection trays; innumerable microorganisms, weeds, and insects colonizing every nook and cranny; pheromones and other less "natural" chemicals passing among hormone-addled adolescent humans and slightly less-hormonal adults; and stockpiles of books, computer equipment, office supplies, light bulbs, cleaning chemicals, historical records, sporting equipment, and cooking utensils. This partial list should be enough to demonstrate that anthropocentrism puts us at the center of the universe and the center of the conversation when, in fact, we are not the center of the universe. Indeed, we should not be the center of conversation. (p. 40)

Snaza, et al. then seek to explain how certain aspects of Western industrial culture, those indicative of the humanist era, have caused problems. They point out that some curriculum scholars have made "notable attempts" to address anthropocentrism, but suggest that they are meager beginnings.

Based on an ecocritical framework (Lupinacci & Happel-Parkins, 2016) we can add anthropocentrism to Pinar's list above, since curriculum studies has in fact been addressing the breadth of value-hierarchized dualisms so central to Western industrial culture. Nonetheless, it sometimes discusses each dualism in isolation. In other words, curriculum studies includes within its diverse projects ecocritical deconstructions of curriculum, but may be missing a broadly-stated connection between them and other dualisms. In particular, such frameworks have not stated how the examination of the complexities between language, culture, and knowledge, in relationship to power, is central to the constituting of a Modern subject—or a subjectivity and self-identity shaped by, and shaping, Modernist thinking. We turn to these relationships as we draw upon emerging traditions with(in) curriculum studies.

EcoJustice Education: How Language Shapes Culture

Among the ecocritical work in curriculum studies, we found that EcoJustice Education's work has critiqued the centrality of a logic of domination to Western industrial thought and language, as well the ways curriculum encourages such logic. This will serve as a springboard for more devoted discussions to particular knowledges and contexts—that is, mathematics education. To provide background, we will review EcoJustice Education's influences and its emphasis on language.

EcoJustice Education refers to fostering and developing among people an "eco-consciousness;" as defined by EcoJustice scholars, this means "a way of thinking and acting necessary to creating and protecting just and sustainable communities" (Martusewicz, Edmundson, & Lupinacci, 2011, p. 9). Founded on the premise that the ecological crisis is really a cultural crisis, they explain:

People have learned to think and thus behave in relation to larger life systems and toward each other. It can be shifted if we learn to think differently about our

relationship to each other and to the natural world, and if we help students to identify and revalue those critical practices of mutual support and interdependence that still exist in communities all over the world. (p. 8)

It is important to clarify that while the work we are referencing as EcoJustice spans nearly four decades, it draws on centuries-old knowledge and a lineage of key non-Western voices critical of Western industrial culture. A group of educator-scholars (i.e., Martusewicz, Edmundson & Lupinacci, 2011) recognizes Bowers (1993, 2001, 2006, 2011), Bateson (1972), and the ecofeminist philosophers Plumwood (1993, 2002) and Warren (1990) as key contributors to the framework known as ecojustice, eco-justice, and now as EcoJustice Education. And they built upon this work as part of an eco-democratic reform movement in education. According to Martusewicz, Edmundson, and Lupinacci (2011), EcoJustice Education's epistemology can be traced through the scholarship of Bowers and shares many of the same major influences. Here, we want to acknowledge the important contributions from Bowers and those noted as part of the eco-democratic reform movement. However, we emphasize EcoJustice Education because of its specific epistemology and focus on language and ethics. As we will claim, these points especially resonate with mathematics education. More generally, we find EcoJustice Education as the departure point for theorizing ecocritical curricular projects specific to knowledges and contexts, such as mathematics education.

EcoJustice scholars and educators work on two interrelated fronts. First, they critically and ethically examine the dominant Western culture and its impacts on social and environmental systems. Simultaneously, they identify and examine how to rethink, and consequently reconstruct, the assumptions that shape how we organize ourselves in society and share skills and strategies that directly support just and sustainable communities for all living beings. As a part of that process, EcoJustice scholars and educators directly confront systems of domination that share human-supremacist assumptions which rationalize what it means to be a human living in such a culture. Choosing this framework requires (and enables) us to call attention to language, culture, and education as we discuss mathematics education.

Understanding the language/culture relationship allows for the examination of how Western culture has emerged from a specific set of cultural practices and historical events, as well as the need for educators to take action to address these deeply-rooted cultural assumptions. Bateson (1972) made key contributions that frame what has developed into "discourses of modernity," and EcoJustice Educators have built upon Bateson's work. For example, Martusewicz, Edmundson, and Lupinacci (2015) draw from postmodernism and ecofeminism to define "discourses of modernity" as "the specific set of discourses that together create our modern, taken-for-granted value-hierarchized worldview" (p. 93).

The critical examination of these discourses, or shared cultural meanings, is complex and allows for the multidimensional analysis of language and culture, in connection with taken-for-granted assumptions regarding what is valuable, what is worthless, and how these concepts are applied. EcoJustice Educators recognize both how language shapes culture and that culture is understood by how we interpret the "differences that make a difference" (Bateson, 1972, p. 315; Bowers, 2011). In other words, everything we understand is constituted by the metaphors of our language. This distinguishes EcoJustice Education from pedagogical approaches that engage in a deep analysis of culture without considering language and the historical roots of the patterns that shape how we think and act.

Language is a process that carries forward ways of thinking from the past. This is significant in that all languaging processes—which include past ways of thinking—are framed by and reproduce the assumptions of the culture. For example, Bateson (1972) writes about the way Cartesian thinking and Occidental—or Western—assumptions create the illusion that the mind and environment are separate. In other examples, Bowers (1993) writes about root metaphors and the master metaphorical templates in reference to how metaphors in an industrial culture differ from metaphors for a sustainable culture; and Martusewicz, Edmundson, and Lupinacci (2015) explain how the ways that we identify and behave are created through discursive patterns rooted in language that “are complex exchanges of meaning that use metaphor” (p. 66). Culture is thus defined by the languaging processes passed on within it, and includes deeply-embedded assumptions. Some of these assumptions are life-threatening centric discourses from mythopoetic narratives. For example, deeply-embedded assumptions in Western culture include anthropocentrism, ethnocentrism, and androcentrism. Other deeply-embedded assumptions come from prominent “attitude” changing experiences—to draw from Bateson’s (1972) criteria for naming major historical cultural events. These mythopoetic narratives and prominent experiences are embedded into metaphors—and more specifically, root metaphors. Root metaphors work together to shape discourses that provide the framework of a culture. They are passed on, from generation to generation, greatly influencing values, problem-solving methods, habits, and traditions.

It is important to address the ways in which language shapes us because the dominant root metaphors discursively determine who or what is marginalized or silenced. Educators using an EcoJustice Education framework emphasize how industrialized Western thinking, and the habits it shapes, contributes to a culture of social violence and ecological destruction. By examining the ways in which language works, EcoJustice Educators suggest that we ought to work toward alternative root metaphors that replace modern discourses with life-sustaining discourses that are rooted in ecology rather than the Cartesian individual. To make the connections between language and mathematics education, we next review another major influence on EcoJustice Education, ecofeminism.

Ecofeminism: Critiquing A Logic of Domination

Ecofeminism is invested in critiquing and eliminating all forms of domination, not just those forms that directly impact humans. Ecofeminist scholars suggest that the unjust suffering inflicted upon women and the subjugation and destruction of nature in patriarchal cultures is inherently connected, and they insist that liberating work cannot be done in isolation. Ecofeminists, including Warren (1990, 2000), Plumwood (1993, 2002), and Gaard (2011), illustrate how all forms of domination and hierarchy are connected and mutually supportive, and how they all are normative discursive practices. Below we highlight Warren.

“Logic of domination” is what Warren (1990) calls the underlying understanding of and justification for oppression via hierarchized binaries (p. 128). Within a Western logic of domination, value-hierarchized thinking—in conjunction with value-dualism as hierarchical binaries—informs how we conceptualize relationships and therefore justify our actions. Warren (1990) defines a conceptual framework as “a set of *basic* beliefs, values, attitudes, and assumptions which shape and reflect how one views oneself and one’s world” (p. 127). Building from this definition, Warren asserts that conceptual frameworks are socially-constructed lenses through which we see the world and that some conceptual frameworks are oppressive. Drawing from

feminism, Warren explains how an oppressive, patriarchal conceptual framework works to justify, rationalize, and maintain the subordination of women. Extending such oppressive frameworks to the subjugation of nature—and really every observed difference—Warren highlights the intersectionality of different forms of oppression, which are founded upon a conceptual framework driven by a “logic of domination.”

But this is not only a logic structure, as Warren (1990) explains:

It also involves a substantive value system, since an ethical premise is needed to permit or sanction the “just” subordination of that which is subordinate. This justification typically is given on grounds of some alleged characteristic (e.g., rationality), which the dominant (e.g., men) have and the subordinate (e.g., women) lack. (p. 128)

Warren, however, does not argue that we as humans should avoid hierarchal thinking or even value-hierarchies in thinking. Rather she urges us to consider that we as humans have the potential to critically rethink how we value and organize thought. In other words, the problem is not that we as humans interpret difference and organize those interpretations into meaning and behaviors, but that we do that through an oppressive conceptual framework—a logic of domination.

Mathematics Education: Recognizing and Reconstituting a Logic of Domination

We see that mathematics plays a key role in the “logic of domination” in the following ways. Often viewed as a universal language, mathematics plays a central role in the dominant Western industrial worldview. The primary reason for our claim is that we adamantly agree that mathematics is a language and thus plays a significant role in the eco-social construction of knowledge. Thus, viewing mathematics as universal is to flatten and background the plethora of diverse cultural interpretations and applications of mathematical languages in relationship and recognition of the diverse eco-social systems within which we are all existing.

We critique this use of mathematics, one that rationalizes a logic of domination. But we also recognize that such a language can in fact also play an integral role in what Lupinacci & Happel (2015) refer to as “recognizing, resisting, and reconstituting” (p. 276) a logic of domination in support of a logic of ecological thinking. In such endeavors, education plays a critical role in perpetuating or disrupting cultural practices and western societal norms. Indeed, mathematics plays a role in constructing our understanding of our world and how we come to perceive it as relational to all living and non-living things.

Therefore, we align with and work through an EcoJustice lens to build an EcoJustice Mathematics Education (EJME) framework, advocating for two things that educators need to do: 1) recognize both how mathematical language contributed and contributes to acculturating an unsustainable economic worldview—that is, exploitive industrial markets of global scale that recognize only profits or gains and losses; and 2) recognize and value patterns and relations among unquantifiable variables, such as empathy, beauty, and kindness.

Building an EcoJustice Mathematics Education (EJME) Framework

Introductory examples of critical mathematics in EcoJustice Education. Here, we begin building our EcoJustice Mathematics Education (EJME) framework. We believe that challenging discourses of modernity should be a central feature of EJME. Existing mathematics education projects suggest how to mount that challenge. For example, de Freitas (2004, 2008) uses critical reflexive narrative to disentangle the binary of mathematics and the feminine and to disrupt the gendered identities of mathematics discourse. Indeed, mathematics is still commonly attributed to masculine characteristics, such as cold, remote, hard, uncaring, rejecting, impersonal, empty, dead, fixed, and hierarchal. De Freitas disrupts the narrative, hoping to “troubl[e] the power dynamic that structures the binary between the feminine and mathematics, while recognising the ways in which those same power relations produce the conditions of subjectivity” (2008, p. 289).

A second example of an application of a critical mathematics towards EcoJustice education can be found in Skovsmose’s (2011) reflection on applications of mathematics lessons. Skovsmose discusses a particular mathematics project called “A Terrible Small Number,” in which students examine the ecological and social implications of salmonella poisoning in Denmark (pp. 72–75). He asks educators to “consider to what extent an illusion of objectivity brings about a dissolution of responsibility (p. 75). Eco-feminist scholars would certainly agree with this question, and further ask how mathematics is used in Western culture—whom it serves and whom it oppresses.

Our position on the relationship between mathematics education and addressing social injustice. The above examples, as well as more mainstream critical approaches to mathematics education for social justice (e.g., Wagner & Stinson, 2012), contain an underlying theme: social injustices occur in many contexts worldwide, and the act of teaching and learning mathematics ought to work towards becoming fully aware of human and ecological crises, in order to establish ways for developing students as agents for change. While we cannot claim that mathematics education alone is sufficient to address social justice issues in relation to ecological problems, we do assert that mathematics education—and in particular the mathematics classroom—is a space in which these types of issues can and should be addressed and such action can have a positive effect on humanity.

Our concern is that, in many critical classrooms, ecological problems are seen as important but often as less important and separate from social justice. Such approaches reinforce a problematic value-hierarchized binary statement of culture/nature; they ignore the interplay and interdependence between the two, a major thread recognized in EcoJustice Education. In fact, the goal of EJME is to not only disrupt such binaries as culture/nature, male/female, reason/emotion, mind/body, civilized/savage, etc. but also show how mathematics can in fact help us to learn and communicate social justice and sustainability through embracing the complex relationship of interconnectedness. In other words, we embrace a mathematics education that works to transform the mind, body, and practice—from the mechanistic habits of mind in Western culture, to an ecological understanding of ourselves as interrelated to and interdependent on not only one another but on the living systems to which we belong. The path that EJME points towards is a mathematics education that can support Bateson’s (1972) idea of “ecology of mind,” an ecological intelligence that perhaps might be thought of as *less-than-rational*; however, we not only find it to be an interesting educational project but also one that is necessary but lacking in mathematics education. In the following section, we outline the strands of critical mathematics education and show how an ecological frame of mind contributes to this overall theme.

Building EJME through critical mathematics education (CME), ethnomathematics, and other thought. To build EJME, this section reviews in greater depth the variety of mathematics education scholarship, thereby situating EJME within the extant scholarship on the mathematics side. We find that the ever-expanding field of mathematics education seems to have already taken up many of the themes in the curriculum studies, ecofeminist, and ecocritical education literature we reviewed above. It is also important to note throughout this review, however, the ways in which we distinguish EJME from such contributions within mathematics education. We will start with the category of work titled critical mathematics education (CME) and move to ethnomathematics. From there, we will discuss poststructural feminist perspectives on mathematics education, and then contributions from the aesthetic experience of mathematics. To end, we bring in some work in mathematics education and the environment.

Here, we count the field of Critical Math Education (CME) as a building block for EJME. CME has been alive and well since the early 1980s. CME was influenced by many things, but it was initially influenced by critical pedagogy and critical theory. Examples are Frankenstein's (1983) application of Freirian praxis and Skovsmose's (1985) work connecting the New Frankfurt school and the math education project. CME ranges from a mathematics education that engenders equitable distribution of resources (Skovsmose, 1994) to a critical race theory math education (e.g., Martin, 2008). These two foci intersect nicely with our primary goal for EJME: to break down logics of domination. In the former, capitalist production of human needs largely leads to inequitable distribution; in the latter, mainstream mathematics education typifies a historically-embedded white supremacist project. In what follows, we will outline a few examples from CME to show the ways they help explain our objectives for EJME.

Skovsmose (2011) presents some of the major considerations CME has offered thus far. For example, CME critiques the "school mathematics tradition" for its relationship with the global economic and political elite. Calling the project "prescription readiness," school math assimilates children into the behavior of taking long sequences of commands. Accordingly, adults subjected to this education are more ready, than they would otherwise be, to uncritically accept their roles of obedience to corporate profit.

Could it be that such a prescription-readiness is serviceable for very many job functions in our society and that the school mathematics tradition serves society perfectly well in exercising this readiness? Could it be that a prescription-readiness, including submission to a regime of truths, cultivates a socio-political naivety and blindness that is appreciated at today's labour market? Could it be that a prescription-readiness fits perfectly well the priorities of a neo-liberal market, where hectic and unquestioned production serves the economic demands? (pp. 9–10)

Thus, CME takes significant issue with any project that supports and reproduces free market concepts across all domains. We agree with this perspective and accept it into EJME.

EJME also herewith incorporates Skovsmose's counter-proposal to "prescription readiness," which he calls "landscapes of investigation." In this case, "a landscape can be explored in different manners and through different routes. Sometimes one must proceed slowly and carefully and sometimes one can jump around and make bold guesses" (Skovsmose, 2011, p. 31). Skovsmose's examples span mathematical behaviors, from classic math procedures (what he calls "references to pure mathematics") to applied mathematics (what he calls "references to reality"),

such as his example of seven-year-olds designing a playground (Skovsmose, 2011, pp. 46–47). As such, EJME includes all mathematical behaviors.

While we are largely basing EJME on CME, we diverge from CME on certain points. Essentially, despite Skovsmose’s attempts to distinguish mathematical behaviors as above, we feel that CME privileges certain mathematical behaviors over others, and some of the under-represented ones are relevant to EJME. We hope that EJME engages with mathematics more broadly. CME tends to offer both criticism of math educational policy/practice, as above, and proposed alternative programs. In these, a consistent theme is teaching mathematics to “read the world” (Gutstein, 2006) with numeracy, the mathematical equivalent of literacy. The Mathematical Association of America, comprised of mathematicians, published a volume describing the relationship between quantitative literacy and democracy (Steen, 2001):

Quantitatively literate citizens need to know more than formulas and equations. They need a predisposition to look at the world through mathematical eyes, to see the benefits (and risks) of thinking quantitatively about commonplace issues, and to approach complex problems with confidence in the value of careful reasoning. Quantitative literacy empowers people by giving them tools to think for themselves, to ask intelligent questions of experts, and to confront authority confidently. These are skills required to thrive in the modern world. (p. 2)

As well, Skovsmose’s (2011) “mathematics in action” suggests a mathematics to model and solve problems. Taking up this action concept, we suggest that EJME ask a more pointed question: What role can non-utilitarian mathematics play in balancing human ecology and in locating decision-making back to the individuals and species affected by those decisions?

We move next to ethnomathematics, a large field in mathematics education with a variety of interpretations and motives. We accept some of the interpretations and motives as goals of EJME, but not others. D’Ambrosio (2002) lays out the field of ethnomathematics, positioning it within the history and philosophy of mathematics, but at the same time showing an “evident political dimension” (p. 1). In this sense, ethnomathematics relates to critical mathematics education because it firmly rejects an absolutist philosophy of mathematics in favor of the study of mathematical practice that is situated in human practice, including culture, politics, and history. It opens for study all cultural practices deemed mathematical, from manual work with embedded mathematical practice to the work of academic mathematicians. Ethnomathematics motivates necessary changes to mathematics education and, as D’Ambrosio (2002) puts it:

The pedagogical proposal of ethnomathematics is to bring mathematics to life, dealing with real situations in time (now) and space (here); and through criticism, to question the here and now. Upon doing so, we plunge into the cultural roots and practice cultural dynamics.” (p. 34)

To the latter point, Pais (2011) cautions the field to think more deeply as we thus apply ethnomathematics, as some applications perpetuate the subjugation of the Other. For example, he questions the appropriation of mathematics from other cultures into mathematics classrooms. In the lesson described as follows:

The construction of the *zampoña* [Andean flute or Pan Pipes] served as a background to the learning of curricular mathematical content like proportionality, functions, and the concept of ratio, and, at the end, “results in the test that followed were quite good.” What is the problem with this almost idyllic example of a multicultural approach? Apparently, researchers and teachers are valorizing other cultures, the manual work, the discussion among students, and the curricular mathematical content. No major problems were raised either by students or by teachers, at least, from the transcription of their opinions present in the article. But, are they really “valorizing” other cultures? What was the role of the Andean *zampoña* in these mathematical classes? Do teachers explore with students the Andean understanding of music and its meaning in the Andean culture? Do students (or teachers and researchers) acknowledge the social context involved in the local construction and use of a *zampoña*? For instance, the fact is that, in such a rugged environment as the Andes, the sense of community is absolutely integral to the concept of survival, and the way Andean people play the *zampoña* reflects the community spirit. Is this spirit compatible with the realization of standard tests designed to evaluate individual achievements of mathematical knowledge raised by the *zampoña* exploration in the classroom? (pp. 223–224)

We take this example of an ethnomathematics application to pedagogy into EJME. EJME hereby embraces ethnomathematics for its understanding of mathematics as cultural practice, and, as Pais suggests, requires more thoughtful pedagogic applications that aim to interrupt logics of domination that result in cultural appropriation.

More on this point comes from Khan’s (2011) relevant discussion of ethnomathematics, in which he first agrees to the points made by Pais (2011). Khan finds:

Mathematics and mathematics education are deeply implicated in colonialism, slavery, capitalism, modernity and ecocide. Ethnomathematics, as part of the anthropological and cultural turn in educational research, has reminded us of that. At the same time, however, mathematics education is yet to meaningfully engage with the pressing issues of grief, trauma and reconciliation in a coherent and consistent manner. It is yet to fully embrace its potential for and role in decolonization, liberation, justice and sustainability. . . . [Ethnomathematics] must find allies and ally itself with disciplines and perspectives in which the imagination is central if is to address or redress some of the inequities and injustices of the present.” (p. 17)

We take Khan’s considerations of ethnomathematics as the motives and purposes of EJME, as follows. Khan’s own reframing of ethnomathematics considers the role of language, particularly through a methodology of mythopoetics that stresses the deconstruction of the mythologies of mathematics and a reconstructive language resting on the power of poetry, narrative, and stories. Khan thus explicates the Orientalism within mathematics education and participating in the production of newer, more just mythologies (p. 16). We stress the relationship of Khan’s focus on language with the ecofeminist perspectives outlined earlier. Recall Bateson’s discussion of the role of mythopoetics in developing the languages of domination; the interruption of which, as Khan

emphasizes, results in acknowledging and reconstituting these. We therefore place Khan's and Pais's reconsiderations of ethnomathematics at the forefront of a conceptualizing EJME.

As a study of the culture of mathematical practices, ethnomathematics in some cases turns its eye on the culture and mythologies of academic mathematics. Although not positioned within ethnomathematics itself, poststructural feminist work in mathematics education has contributed significantly to this thinking. As introduced in the earlier section, de Freitas (2004, 2008) positions mathematics with regard to its masculine qualities. In addition, we now incorporate two works into EJME, giving them special attention. First, in a poststructural argument, Walkerdine (1998):

puts into historical perspective the construction of scientific ideas (or truths) about girls and boys, men and women, minds and Mathematics. It allows us to take apart these truths, their forming and informing of practices in which girls and women are taken to be poor at mathematics. (p. 18)

In deconstructing school mathematics, she locates its birth amongst the site of Cartesian rationalism, something deeply committed to gender binaries. Second, Mendick (2006) provides particular methods for interrupting these gendered commitments, such as unpacking and replacing the mythology of ability in mathematics. School mathematics, as a site of masculine rationalism, operates under the assumption that mathematical talent is innate. Such an assumption reinforces gender binaries, as well as ableism, social class hierarchies, and white supremacy. However, teachers and learners have the power to unpack this perspective (as Khan demonstrated above). First, they can acknowledge the problem and, second, they can provide opportunities to learners that openly reject such assumptions about innate talent. Both Mendick and Walkerdine require direct confrontation of the mythologies within mathematics and necessitate powerful experiences to re-mythologize, as Khan might suggest, a new rationality and school mathematics.

The efforts of CME, ethnomathematics, and poststructural feminist work in mathematics education, discussed above, clearly address the "logics of domination" perpetuated by mathematics. As part of EJME, we therefore ask more questions about the assumptions in mathematics education, such as what types of mathematical processes are valued, how does mathematics help us read the world, and what forms of knowing are put aside by mathematics' insistence on logical thinking. Here, we are considering not only epistemological questions, but also ontological assumptions about the nature of doing mathematics.

To conclude this section, we cover two more subareas within mathematics education: first, we will consider how an aesthetic dimension of mathematical practice can change the rationalistic paradigm embedded in the dominant Western industrial culture, and second, we draw on the work that relates mathematics education to planetary health.

Aesthetic appreciations for mathematics many times resonate with a masculine rationalism; language referring to a "beauty of mathematics" communicates only with those that have achieved status in an academic sense. For example, aesthetics in mathematics are framed as philosophies of mathematics, such as in Resnik's (1981) notion of mathematics as a study of patterns and Shapiro's (1997) mathematics as a study of structures. Many scholars believe in reinserting the aesthetic dimension into mathematics education beside the elite levels of education (Chenulu, 2007; Sinclair, 2001, 2009; Thirumurthy & Simic-Muller, 2012; Tymoczko, 1993). Some specifically argue that mathematics is an art, trying to reimagine mathematics and rationalism. Efforts include Betts and McNaughton's (2003) application of methods in art education aiming to increase equity in mathematics education and Sinclair's (2006) seminal text in which the beauty of mathematics

is re-described as the beauty of doing mathematics, a concept antithetical to “high art” and, instead, something that anyone can enjoy.

As Khan (2010) puts it, both Sinclair and Betts and McNaughton make aesthetics a personal, meaningful experience that transcends aesthetics itself to an ethical motive towards justice (n.p.). This is not unlike the celebrated work of Greene (1995) who argues for the role that the aesthetic experience has in “releasing the imagination” towards visions of emancipation. As goals for EJME, we take Khan’s (2010) suggestion that “Art, and mathematics education when performed as an Art, can provide us with a means to come face-to-face with and learn to welcome Others, which reveals our responsibilities to be *for* Others” (n.p.). Khan provides examples of reorienting mathematics teaching towards an artistic experience, giving an extended discussion of learner experiences with a cultural, mathematical, and aesthetic practice:

Their performances also raised questions about performing “unnatural” rituals, such as line drawings, or even formal mathematics, in public spaces with their rigid social expectations and norms. In performing this unnatural ritual, mathematics, in a public space like a beach, students engaged not only in a mathematical and aesthetic activity but a political and deeply personal one as well. (n.p.)

Khan’s conceives of the aesthetic mathematical experience as primarily ethical. We hereby give aesthetics an ethical role in EJME, as well.

Finally, it is important to review the mathematics education scholarship that relates mathematics teaching and learning to issues of the environment and sustainability. This work in education accords with an “environmental mathematics education,” in which the role of mathematics teaching and learning is related directly to planetary health. In their textbook, Coles, Barwell, Cotton, Winter, and Brown (2013) suggest teaching mathematics “as if the planet mattered” and provide an abundance of thoughtful lessons and motivations to do so. Renert (2011) puts forth a “sustainable mathematics education” in which we reorient math teaching and learning towards “environmentally conscious thinking and sustainable practices” (p. 22); Renert also provides interesting relations between mathematical concepts (e.g., chaos theory and large numbers) and ecological education.

The scholarship reviewed above moves us forward in thinking more theoretically, as well as practically, about environmental mathematics education projects. That said, we suggest that these projects can benefit from ecofeminist frameworks (as reviewed above), which highlight the consistency of logics of domination throughout Western industrial culture. To be sure, Coles, et al. (2013) tie human rights into the conversation, but this seems more of an afterthought than a direct discussion of the interrelationship between objectifying nature and “Other” people. In a sense, Khan (2010, 2011), as reviewed above, has begun addressing the limitations we perceive in sustainable mathematics education scholarship. Based on our above review of work from Khan and others, it appears to us that a deep and sustained conversation between ecocritical curriculum studies and such mathematics education scholarship is timely and holds great potential. This article represents a most humble beginning in starting this work, and it suggests several open areas of inquiry. Next, we will discuss the practicality of the EJME project, and in the concluding section we will sketch a sample lesson model, drawing primarily from the theoretical contributions discussed thus far.

EJME and the Kolam: Mathematics as an ecological language and practice. Here, we set two more goals for EJME: 1) to denaturalize normative views about the world and 2) question

human beings' hierarchical position within it. Let us here explore the philosophical ramifications of mathematical practice as they relate to an ecological frame of reference. Mathematics—a centralized, seemingly innocuous domain of knowledge in our modern world—is indeed the epicenter in which work towards the two goals mentioned above. Indeed, we intuit and learn about the nature of our reality at young ages, and such intuitions and basic knowledge are mathematical, in the sense that they govern how we relate to time, space, pattern, and relations. Drawing from ecocritical curriculum studies scholarship and related work within mathematics education, we now put forth the following sketch of an ethnomathematics lesson that we have modified towards the spirit of EJME.

To begin our efforts to provide examples of EJME in practice, here we start building upon an example from ethnomathematics in Khan (2010). This is the Kolam, which Chenulu (2007) describes as follows (p. 425). The Kolam is a geometric figure drawn on the ground outside of homes in South India. Women draw Kolams at the front entrance of their dwellings usually before or at dawn using colored rice powder. The powder welcomes birds, ants, and other small animals, who eat it. We are using the Kolam as an example because its aesthetic mathematical experience conflicts with Western industrial thinking, and because of its significant complexity with respect to mathematics. Rich in cultural significance, the Kolam also provides deep mathematical learning about pattern recognition, algebraic reasoning, spatial sense, and geometric understanding. The geometric patterns for making Kolams are made by first creating a dot array or matrix. The array can be a rectangular or triangular shape or many variations of them. In the array or matrix, the number of dots per line can be equal or made in a horizontal sequence of consecutive odd or even numbers so that the first line has one dot, the second 3, the third 5, and so on.

In this discussion of how EJME would use Kolam, we now synthesize and apply a number of points made by both ecocritical curriculum studies literature and mathematics education. Thus, an EJME unit centered on the Kolam would have five objectives: 1) more fully teach the context of the Kolam practice in south India, 2) put front-and-center the question of “who does mathematics,” 3) situate the teaching of the Kolam as an aesthetic-mathematical experience while teaching students to create Kolams, 4) fully discuss the relationship of the practice with ecology, and 5) unpack the unit through reflection on its position within mathematical and other communities. We will explain these implications in the next paragraphs.

The authors of *Kolam: A Mathematical Treasure of South India* claim that the Kolam activity can be used to meet the standards in algebraic reasoning advocated by National Council of Teachers of Mathematics, 2000 (Thirumurthy & Simic-Muller, 2012). Applying what we learned from Pais (2011), we can critique such use as cultural appropriation, which perpetuates the dangerous objectification of the Other. In light of this critique, an EJME unit centered on the Kolam must, first, dedicate space for learning objectives that address the people of South India, including their economic, spiritual and political context. Second, the lesson would focus on the women who make Kolam. Depending on the learners' readiness and prior knowledge, teachers may need to introduce to learners to the gendered nature of Kolam and its intersections with race, caste and social class, and help the learners dig deep for the capacity to start understanding these intersections. For the development of these lessons, Smit (2013) provides ethnographic narratives of Kolam artists in Tamil Nadu.

Within the Kolam unit, then, there will be lessons on *who* conducts this mathematical practice. These lessons should be situated within learner discussions about their own perceptions of mathematical identity and how we typically think of mathematicians. Depending on learner readiness and prior knowledge, the Kolam unit would ask students to reflect on their experiences

with mathematics and mathematics education. Then, through exploring the context of the Kolam as above and introductions to the practice of the Kolam itself, learners would have new mathematical experiences upon which to reflect. An EJME Kolam unit would require follow-up discussions about how learning the Kolam has impacted their understanding of what mathematics is and who does it; we can consider these to be some of the essential questions throughout this unit.

Taking a cue from the thoughtful development of Kolam teaching in Khan (2010), an EJME Kolam unit would, third, focus on the aesthetic of the mathematical practice. After introductions to the mathematics and art of the practice, and upon viewing several photo examples, learners would be tasked to create their own and with the vulnerability that Khan highlights: To reiterate, by making their Kolam in the sand on public beaches,

They were given an opportunity to become aware of their own vulnerabilities before others. . . . In performing this unnatural ritual, mathematics, in a public space like a beach, students engaged not only in a mathematical and aesthetic activity but a political and deeply personal one as well. (n.p.)

The vulnerability provides an opening by which learners can reflect deeply on the themes that ecocritical curriculum studies brings to light, in particular the logics of domination pervading Western industrial culture. Aesthetic practices, such as the one described above, have the potential to reorient our worldview. Perhaps experiencing mathematics—a discipline typically thought of as rigid, concrete, and rational—as something beautiful, flexible, and emotional may affect how we imagine other cultural, social, and political practices.

Logics of domination connect, as in the ecofeminist perspective, supremacies of “Othering” with human supremacy and the crisis of planetary health. To meet the fourth objective of the EJME Kolam unit, the discussion of the context of the Kolam will stress the ecological nature of the practice. We understand that the materials used in the Kolam remind artists of the deeply entangled connections with the ecological world, connections that humans usually attempt to ignore and reject. For example, the rice flour in Kolam can attract ants to the front of homes in India. Learners can be prompted to think: Would such a practice be welcome in my own home, with my own culture? To what extent do my artistic (and mathematical) activities reject nature? What are some ecological consequences of using particular materials to make art or do mathematics? What is the ecological significance of the fact that Kolam art is washed away on a daily basis? Then comes the fifth objective: towards the end of the unit, a creative element might require learners to develop a comparable mathematical art practice that integrates *local, contextualized* ecological considerations with the personal fulfillment and vulnerability of the Kolam. And, if coverage of mathematics standards remains a concern, it might be appropriate to require that the creation of a similar artistic practice cover a different mathematical topic.

Conclusion: *Currere*, Curriculum Studies, and Ecocritical (Re)considerations

Pinar (1975) presented a method for curricular inquiry that is regressive, progressive, analytic, and synthetic. Envisioning EJME in practice will require further theoretical development along the lines of how we attempted it above, coupled with empirical research in multiple, different educational settings. For example, how does the status quo mathematics education that we have

experienced perpetuate hierarchy among people and disconnectedness between mind and body? And in the spirit of synthesis, how can mathematics education be placed within a totalizing of “the fragments of educational experience . . . and [place] this integrated understanding of individual experience into the larger political and cultural web?” (p. 424).

This is a research agenda ripe for further development. EJME can be understood as potentially a culturally-responsive mathematics education that fosters the development of an ecological intelligence. Research into EJME, however, will yield rich descriptions of how teachers and learners use mathematics to make sense of ecological knowledge and they learn mathematics in an ecological frame of mind. This will help us better conceptualize the future of EJME and help theorize about the pedagogical considerations and open-ended questions that are implicit in this work. In turn, this will complicate the picture of ecocritical curriculum studies more broadly defined.

Finally, we revisit Bateson (1972) for his relevance to EJME. He writes: “We are not outside the ecology for which we plan—we are always and inevitably a part of it” (p. 512). Mathematics education holds many philosophical assumptions and also opens up thinking about the purposes of mathematics education and what it can or ought to accomplish within such purposes. When we think about what it means to do math in “the world around us,” we can imagine such a world as encompassing both the human cultural world and eco-biological world. Bateson makes an ethical distinction between humans and other living things in the ecosystem. Animals cannot worry about the ecological crisis the same ways humans can, although animals surely are affected by the crisis. Bateson warns us to not succumb to postmodern relativism or simple pragmatic solutions because the “ecological ideas implicit in our plans are more important than the plans themselves . . .” (p. 513). If we assume that being human involves a technological and meta-cognitive ability to manipulate our environment, then we must posit an ethical dimension in human actions, since human activities certainly surpass the human material world and have far-reaching consequences for the biosphere, of which all living and non-living things on planet Earth are a part. For instance, our global interest in developing natural renewable energy is at the very least an ethical decision to sustain the biosphere for future generations, regardless of potential capitalistic benefits. More individualistically, our decision to recycle our waste products and become more involved in our food production is partly for health concerns. But for many it is also an ethical choice for living in communal, less harmful ways with the larger ecosystem. Referring back to Bateson, it is not our actions themselves that are important but the ethical intentions behind them.

We conclude with the attention paid to the ethical dimension within mathematics education scholarship. Philosopher of mathematics education, Paul Ernest, determines that it is ethics, not epistemology, axiology, or even ontology that ought to be the first philosophy of mathematics education:

As social creatures our very nature presupposes the ethics of interpersonal encounters, even before they occur, and before we form or reflect on our practices, let alone our philosophies. This is why Levinas asserts that ethics is the first philosophy, presupposed by any area of activity, experience or knowledge, including mathematics education. If we accept his reasoning, then our quest is at an end. Ethics is the first philosophy of mathematics education. (2004, p. 14)

We agree, and therefore state that the key endeavor of EJME is primarily ethical and we are encouraged that such prominent voices in mathematics education point in similar directions. For us, we aim for mathematics education and curriculum studies to consider deeply the extents to and contexts in which we ask the hard, ethical questions of domination and subordination.

Notes

¹These include urban public middle and high schools in Los Angeles, Detroit, and New York and mathematics teacher preparation at universities serving rural, suburban and urban public school teachers in the states of New Jersey, New York, Pennsylvania, Michigan, and Washington.

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