LIVING MATHEMATX: TOWARDS A VISION FOR THE FUTURE[i]

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This paper offers specific implications for teaching and learning and brings into conversation ideas from ethnomathematics (including Western mathematics), postcolonial theory, aesthetics, biology, and Indigenous knowledge in order to propose a new vision for practicing mathematics, what I call mathematx. I build upon the work of sustainability in mathematics education and suggest we need to think not only about more ethical ways of applying mathematics in teaching and learning but question the very nature of mathematics, who does it, and how we are affected by that practice.

Keywords: Equity and Diversity, Instructional Activities and Practices

> We need to be constantly considering the forms of mathematics and what they seek to deal with. As society presents new demands, new technologies, new possibilities, we must ask ourselves whether our current version of mathematics is adequate for dealing with the ignorance that we have (Gutiérrez and Dixon-Roman, 2011, p. 32).
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> The ecology of knowledges enables us to have a much broader vision of what we do not know, as well as what we do know, and also to be aware that what we do not know is our own ignorance, not a general ignorance (Santos, 2007, p. 43).
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> We are all the product of our worldview—even scientists who claim pure objectivity…Science and traditional knowledge may ask different questions and speak different languages, but they may converge when both truly listen to the plants (Kimmerer, 2013, p.163, 165).

Everyday, we accumulate more evidence that humans are destroying the planet. We need only look at the increasing levels of air pollution, climate change, destruction of the ozone layer, and the elimination of various plant and animal species throughout the world to know that we cannot continue with the forms of living we have come to consider "normal." However, not until recently has the public become aware that the effects will deeply impact us in our lifetime (Kolbert, 2015). One might ask: what role(s) should mathematics play in stopping or slowing the rate of such destruction of the environment? The field of mathematics might serve mainly to: describe the nature of the global problem; offer excellent models for prediction; or provide efficient data analysis and statistics for calculating risk. Mathematics might also offer something else altogether. In what way(s) are current forms of mathematics teaching and learning consistent with the kinds of environmental crises we face? Do we need to think differently about our relationship between mathematics, humans, and the planet? And, if so, how?

In this article, I seek to bring into conversation ideas from ethnomathematics (including Western mathematics), postcolonial theory, aesthetics, biology, and Indigenous knowledge in order to propose a new vision for practicing mathematics, something I refer to as *mathematx*. I do so in order to promote interaction between different knowledges, different ways of knowing, and different knowers. I build upon the work of sustainability in mathematics education and suggest we need to think not only about more ethical ways of applying mathematics in teaching and learning but question the very nature of mathematics, who does it, and how we are affected by that practice. I introduce the concepts of In Lak'ech, reciprocity, and Nepantla to suggest we learn from other-than-human persons, which, in turn, may change our relationships with them. Along the way, I underscore with examples from biology the potential limitations of current forms of mathematics for understanding/interacting with our world and the potential benefits of considering other-than-human

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persons as having different knowledges to contribute. Finally, I suggest implications for teaching and learning.

Identifying the Problem

The relationship between mathematics, humans, and the planet has been one steeped too long in domination and destruction (O'Neil 2016; Martinez 2016). Due in large part to the way research is funded, the field of mathematics is often in the service of warfare and economics (BooB-Bavnbek and Hoyrup 2003; Gutiérrez 2013; Martinez 2016; O'Neil 2016; Porter 1995). With an emphasis on quantifying, categorizing, and reducing complex and multi-layered relationships between persons to mere abstractions, mathematics often supports a fallacy that modeling, big data, and software can solve anything. Some might suggest there is nothing inherent in the practice of mathematics that leads to domination; we simply need to follow more ethical practices in applying mathematics in the world around us.

Highlighting this role of domination and arguing for a new form of teaching mathematics, Coles and colleagues (2013) note,

> The history of humanity's relationship with the natural environment, at least in the West, can be summarized in one word: domination. The natural environment has been seen as a source of food and raw materials all to be placed in the service of human projects. Where the natural environment gets in the way of such projects, we simply blast our way through… (p. 4)

In an attempt to change this relationship, Coles and colleagues suggest we begin by altering the forms of teaching and the curriculum to which students are exposed. By situating mathematical problems in contexts that relate to such issues as climate change, students will have the opportunity to develop a new relationship to mathematics and new uses of mathematics in making life decisions. That is, students can be encouraged to analyze real-world statistics of temperatures in different regions to make conclusions about both the rates by which the climate is changing and the probabilities that the climate will continue to change. In this way, students would also be allowed to ponder such questions as what kind of mathematical information is necessary to address climate change? What mathematics should the average citizen know in order to make informed decisions about the consequences of their actions and the actions of others? Learning mathematics in real world social and political contexts can help students see relationships between the decisions humans make and the destruction of the planet, thereby urging them to take action to save the planet. In this way, mathematics education can more clearly highlight the roles of ethics (e.g., Atweh 2013; Boylan 2016) and practicality as they relate to the practice of mathematics. Thus, shifting the curriculum to more sociopolitical contexts (Gutiérrez 2010/2013[ii]), what some would refer to as teaching mathematics for social justice (Frankenstein 1990; 1995; Gutstein 2006), could broaden the service of mathematics beyond economics and warfare.

However, attending to *when* and *how* mathematics is in the service of sustainability or ethics may be a necessary but insufficient step towards new relationships between humans, mathematics, and the planet (Gutiérrez, 2002). This, for me, has been one limitation of social justice mathematics (Gutstein 2003; 2006; 2007), as it tends to assume we will keep intact as "classical" what I refer to as "dominant" mathematics rather than challenging whether that version or any single version should remain central. In the social justice mathematics tradition, students are taught to use classical mathematics as a tool to read and write the world, in order to develop their sociopolitical consciousness and mathematical proficiencies. But, in general, the tool itself is not questioned. Recognizing the limitations of using the master's tools to dismantle the master's house (Lorde 1984) leads me to argue that we must also be willing to question and reconceptualize what counts as mathematics in the first place, thereby taking up issues of epistemology and ontology.

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I am not alone in suggesting we need to reconsider our definitions of mathematics in light of our current state of global crises. For example, Appelbaum (2016) suggests a different approach through curriculum, where a key component is questioning what counts as mathematics.

> …one key curriculum question that can no longer be pushed to the side is how very narrow, Western, "rational" conceptions of what mathematics "is" have continued to be wielded implicitly as tools of epistemicide, obliterating alternative epistemologies of number, size, quantity, possibility, shape, algorithmic problem solving, analogic representation, and other extended components of mathematical thinking and living. (p. 5)

Similarly, Boylan (2016) considers the role of mathematics in relation to the planet and argues,

> An ecological ethics calls not only for an environmentally informed critical mathematics education but also for a critique of the social construction of mathematics itself as separate and disconnected from the earth (p. 9).

The Program Ethnomathematics offers a useful starting point for broadening the definition of mathematics, something I will discuss later in this article.

Not only must we: a) be conscious of the ways mathematics can dominate and b) constantly question what counts as mathematics and who decides, we must also c) think about how we, as living beings, practice mathematics as we interact with others and ourselves. As we begin to reimagine mathematics, we have the opportunity to reimagine the mathematician—who is considered a mathematician as well as how are mathematicians influenced by the mathematics they do? Many of the current efforts to reconsider mathematics and its role in our global society tend to rely upon a utilitarian version of mathematics that allows us to better survive on this planet. I am suggesting that a form that describes moving through the world and relates to all living beings is more likely to change our relationships with each other in this universe or in others. We need a definition that acknowledges mathematics as a verb and how that practice relates to our bodies, minds, and intentions. For that, we might consider our philosophical stance.

Much of the philosophical research produced in mathematics education centers on European thinkers. For example, we are abundant with theories of postmodernism, poststructuralism, and psychoanalysis that regularly draw upon such writers as Deleuze and Guattari, Ranciere, Foucault, Lacan, Badiou, Derrida, and Freud. As a Chicanx scholar, a cis gender female with Rarámuri[iii] roots, I seek to decenter the field's overreliance on Whitestream views. I use the term Chicanx (as opposed to Chicano, Chicana/o, or Chican@) as a sign of solidarity with people who identify as lesbian, gay, bisexual, transgender, queer, questioning, intersexual, asexual, and two-spirit[iv] (LGBTQIA2S). Chicanx represents both a decentering of the patriarchal nature of the Spanish language whereby groups of men and women are normally referred to with the "o" (male) ending as well as a rejection of the gender binary and an acceptance of gender fluidity. The "x" signifies a variable to represent any gender form. My choice to use this term reflects my respect for how people choose to name themselves.

In this article, I introduce three Indigenous concepts that have guided my work over the years—In Lak'ech, Nepantla, and reciprocity—and suggest they can serve as guiding principles of a new practice of mathematics.

Indigenous Epistemologies

Why privilege Indigenous concepts when considering the relationship between mathematics, humans, and the planet? The answer to that question lies partly in the way (Western) mathematics is viewed as universal (being able to explain everything in reality) and highly valued in society. When challenges of discontinuity or undecidability arise, mathematicians often protect the universal view

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by suggesting that mathematics still holds true if we simply begin with different axioms (Barrow 1992). Yet, no knowledge could fully describe or attend to our universe and our relations with/in it. If we look to the role that Aboriginal[v] knowledges have played in the reading of signs of distress from the land (i.e., predicting the global crises we face), the preservation of biodiversity, and the role of survival in general, we see the limits of Western mathematics/science practices as a means for intervention (Berkes et al. 2000; Brayboy and Maughan 2009; Cajete 1999; Deloria 1979; González 2001; Heinrich, et al. 1998; LaDuke 1994; Little Bear 2000; 2009; Tallbear 2013; Watson-Verran and Turnbull 1995). I claim neither that all Western thought is colonizing/hegemonic nor that all Indigenous thought does not have the ability to dominate. However, modern Western thinking has been hegemonic in ways that erase Indigenous thought. In this way, I use the term "Western" to refer to the modern version that has tended to colonize and "Indigenous" or "Aboriginal" to refer to the version that has tended to be erased throughout history.

Acknowledging the limits of Western mathematics is not to discount the value of mathematical knowledge in other realms. However, such limitations suggest that, in contrast to the global push to get more students to enter Science, Technology, Engineering, and Mathematics (STEM) fields in order to deal with the complexity and challenges in our world, we cannot fully address our problems through a reliance on Western mathematics/science.

Santos (2007) suggests that the problem of domination may lie not in *which* knowledge is authoritative, but rather in our overreliance on any single knowledge as authority. As such, he suggests an epistemology of knowledges, underscoring the view that all knowledge is legitimate, partial, and interdependent. In fact, with respect to ignorance, learners do not just lack knowledge, they have "misknowledges" (i.e., stereotypes, incorrect knowledge) about others (Kumashiro 2001). And, those misknowledges may not easily be replaced by the introduction of new knowledge because desconocimiento (ignorance) can be a "refusal to know" when what is new disrupts what was previously believed to be true (Anzaldúa 2000).

Yet, from a postcolonial perspective, it is important to unlearn what one thinks one knows, both to recognize a form of epistemological arrogance (thinking that one's ways of knowing are superior to others') and to learn to see oneself in relation to others (Andreotti, Ahenakew, and Cooper 2011). Such a perspective acknowledges that our ignorance is our own, not a general form that cannot be known or is not yet known (Santos 2007). That is, just as there is no unity of knowledge, there is no unity of ignorance. Each of us has knowledge and ignorance that is, to a certain extent, unique. Consistent with this epistemological pluralism, some scientists have argued against trying to develop a theory of everything (Gleiser 2015).

Ecology of knowledges does not follow a single abstract universal hierarchy among knowledges. Rather, it sees knowledge practices as context dependent. In that sense, it recognizes that different knowledges can address our understanding and ability to relate to one another depending upon our different purposes (e.g., the ways we aim to connect, the problems we seek to solve, the ways we invite joy into our lives) (Little Bear 2009). For example, by seeking to be predictive, generalizable, reductionist, and quantifiable in nature, Western perspectives tend to privilege knowledge as a form of (re)presentation and explanation of reality (Aikenhead and Michell 2011). Yet, given the global crises we face, we might be better served by knowledge as action—a form of intervention (Santos 2007; Andreotti 2011).

Given these different purposes, it is important to create inter-knowledges, whereby learning another's knowledge does not negate knowing one's own knowledge (Santos 2007). In this way, learning how other living beings perform mathematics does not eliminate what is known in terms of academic mathematics. But, it does help us know what we do not know. Recognizing these inter-knowledges can go a long way towards embodying humility and establishing the need for responsibility, and therefore reciprocity, *toward* another, as opposed to *for* another (Spivak, 1987).

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While Santos is referring to an epistemology of knowledges that would include scientific/mathematical versus social scientific, I am arguing that within mathematics, we might acknowledge and value an epistemology of knowledges. That is, mathematically, we might come to see that different ways of knowing, different knowers, and different forms of knowledge are all legitimate, partial, and interdependent. Epistemological pluralism recognizes that there will be tensions, contradictions, and politics in translating Indigenous knowledges into Western categories/languages (Andreotti, et al. 2011). As such, an epistemology of knowledges is destabilizing because it interrogates the politics of knowledge and, unlike Western knowledge, does not presume causal outcomes—that is, that we can know the potential from any given actual. Therefore, the production of knowledge is an ongoing process that is not cumulative but relational.

Centering Indigenous Knowledges

To be clear, there is no universal "Indigenous worldview." Within the US, alone, there are 567 peoples federally recognized as American Indian and many more that are not recognized. Within México, there are 62 peoples recognized as Indigenous, comprising 13 percent of the nation's population. Within Canada, there are 634 peoples recognized as First Nations, plus peoples who are Métis and Inuit, all accounting for 5.6 percent of the nation's population. And, these populations cover only North America, not the globe. The use of particular languages and ties to particular lands create unique views held by Aboriginal peoples throughout the world and by individuals within those groups. And, many Aboriginal writers refuse to refer to themselves as Indigenous, Indian, or First Nations, as those categories are reflections of a colonizing history that blurs specificity. Even so, at times, "strategic essentialism" (Spivak 1987) is important for joining peoples and advancing common resistance tactics. As such, I speak of commonalities across the range of Indigenous knowledges. The perspectives I share are my view and do not necessarily reflect the views of others.

Indigenous knowledges recognize that we are part of a system of intelligent and sentient beings, also referred to as persons, with interconnected spirits, including rocks and bodies of water. Plants, for example, have lived on this planet for millions of years before humans. In that sense, plants are our older brothers/sisters and have developed ways of efficiently using space, relating with other living beings, and sustaining life not just for themselves but for others, often with few resources at any given moment. They have been able to withstand long droughts, communicate about impending dangers, and collaborate in order to protect others in the community in ways that appear to be selfless acts. They have much to teach us; and we may have something to teach them. Breaking with a human/non-human binary is consistent with queer theory, which recognizes the violence that is justified when some are viewed to be more human than others (Chen 2012).

Our choice to destroy the planet to serve our immediate/capitalistic/technology needs is a form of settler colonialism that perpetuates violence. That is, because a Western worldview does not consider plants, animals, and rocks as living beings of equal value with the same rights to this universe as humans, the result is that plants, animals and rocks suffer the same treatment as Indigenous peoples have endured throughout time. For example, like American Indians who were stripped of their lands and communities and forced to live in boarding schools, plants are yanked from their families and forced to assimilate into Western ways of doing things (e.g., to become suburban gardens). By respecting animals, plants, and even rocks as living beings, we can avoid some of the human/material binary that has plagued the sciences in the past.

By referring to humans as a young species, I do not mean to imply a sense of posthumanism or transhumanism. That is, I am not looking to make humans better or into a fuller version of themselves by combining with technology, fiction, or art (Haraway 1990; but also Chela Sandoval's extension). An Indigenous perspective, for me, seeks not to transform humans into another form of being; rather it serves to help us recognize our place in this world as the younger brothers/sisters of

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animals, plants, and rocks who have much to teach us about making sense of and remaining connected to this planet and possibly other planets. In this sense, by changing our world view—how we move through this world and possibly into others—we will necessarily change ourselves, but not in a way that is separate from other living beings, not in a way that is necessarily tied to technology. There may be things we cannot yet access or understand because we are a young species. Other persons may have ways of accessing information that can be helpful for us.

While our Elders have long spoken of the sentient capabilities of plants and rocks and of the collective spirit they/we share, only recently have modern scientists begun to acknowledge that claim with experiments that prove this to be the case, suggesting trees are sentient and intelligent (Haskill 2017; Jahren 2017; Wohlleben 2016). For example, tracing isotopes of carbon dioxide gas offered to sample trees shows they turn that carbon dioxide into sugars that travel down through the trunk and use a complex system of roots, fungi, and mycelium to share that resource with other trees nearby, even trees of a different species (Simard et al. 2012). Similarly, when a tree is injured or attacked by pests, it is able to communicate by way of pheromones to nearby trees to tell them to start changing the chemistry of their leaves to be unfavorable to the intruder (Wohlleben 2016). And, mother trees are able to both reduce their root system to make room for their offspring as well as send defense signals through their mycorrhizal network to increase the resistance of their offspring to future stress (Teste, et al. 2009).

Beyond embracing the intelligence and sentience of other living beings, Indigenous epistemologies connect place, body, spirit, and consciousness. They reflect understandings of land, history, culture, identity relationships, and therefore, politics (Deloria 1979). Many Indigenous knowledges have been developed with roots in survivance; that is, not surviving in the colonialist depiction of escaping catastrophe or being positioned as victims, but resisting dominance in a way that renews Indigenous knowledges that are particular and have always been present (Vizenor 2008). While there are many Indigenous concepts that could be fruitful to revisioning mathematics, I present three that have been important in my upbringing. I do so in order to set the stage for an epistemology of knowledges that can guide our practice of mathematics.

In Lak'ech

The Mayan definition of human being (huinik'lil) translates to "vibrant being" in recognition of the idea that all human beings are part of a universal vibration (Arguelles 1987; Paredez 1964). Acknowledging that all beings are connected, Mayan philosophy includes the important concept of *In Lak'ech* woven into everyday thought and action. When a person meets another, they begin with the saying In Lak'ech (You are the other me), to which the receiver responds with Ala K'in (I am the other you). This greeting highlights for all persons (human and other-than-human) their connection with each other and the need to protect each other. Consistent with Indigenous knowledge, I use the terms "living beings" and "persons" interchangeably, as each term refers to all things living.

Seeing a version of oneself in other living beings or persons is a powerful reminder to move through the world with compassion, gratitude, and interdependence. For me, In Lak'ech suggests that if we look closely, we can see ourselves in others and others in us, but not in a way that implies an erasure of our uniqueness, even while recognizing that uniqueness does not imply a sense of self without others. To be clear, In Lak'ech does not translate to "I am you; You are me." Seeing a version of oneself in others and others in us is a kind of mirror, an affirmation; while the concept also recognizes we are not exactly the same. In the same way that a mirror refracts light, produces words that are backwards, and has imperfections from the glass, In Lak'ech reminds us that each person is unique. In this sense, other persons also serve as a kind of window, a way of viewing another world, another self, another (possibly better) you.

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Over time, Chicanx scholars have brought the concept of In Lak'ech into poems and theater as reminders of how we should move through the world.

> Tú eres mi otro yo.
> You are my other me.
> Si te hago daño a ti,
> If I do harm to you,
> Me hago daño a mi mismo.
> I do harm to myself.
> Si te amo y respeto,
> If I love and respect you,
> Me amo y respeto yo.
> I love and respect myself. (Valdez and Paredez n.d.)

Through this poem and other writings (e.g., Valdez 1971), Valdez highlights the ways in which Chicanx might relate to others in order to move with the cosmos. The meaning of In Lak'ech is similar to the Lakota saying Mitakuye Oyasin "we are all related" (Cajete 1999 cited in Hatcher et al. 2009). The idea that we are all related can, in some ways, bring us joy, a simultaneous affirmation of self and others. Building upon the idea that we are all interconnected, an Indigenous production of knowledge to benefit others is in opposition to knowledge production as performance that benefits mainly oneself and that is seen in most White institutions or places that value Western thought. Brayboy and Maughan (2009) remind us,

> Indigenous communities have long been aware of the ways that they know, come to know, and produce knowledges, because in many instances knowledge is essential for cultural survival and well-being. Indigenous Knowledges are processes and encapsulate a set of relationships rather than a bounded concept, so entire lives represent and embody versions of IK (p. 3).

Reflecting these relationships, In Lak'ech focuses not on description of reality but on movement through the world and metaphysics. By metaphysics, I simply mean a set of first principles by which we make sense of the world around us (Deloria 1979).

Reciprocity

Extending the idea of In Lak'ech, the second concept upon which I draw is reciprocity. The concept of reciprocity highlights the idea that different persons have different strengths and needs, and thus must rely on others for what they lack. More than simply recognizing that reciprocity enables persons to do things they could not otherwise do alone, it underscores a kind of ethic that is valued in maintaining harmony of the cosmos. In this sense, reciprocity is not only the productive thing to do, it is the right thing to do. Whereas In Lak'ech acknowledges the nature of the relationship between self and others, reciprocity highlights the actions that should result.

As a botanist and a member of the Citizen Potawatomi Nation, Kimmerer (2013) weaves the view of a scientist with an Indigenous view on the role of reciprocity and suggests that when we honor other living beings (e.g., plants), it changes our relationships with them. She says,

> When I speak of the gift of berries, I do not mean that Fragaria virginiana has been up all night making a present just for me, strategizing to find exactly what I'd like on a summer morning. So far as we know, that does not happen, but as a scientist I am well aware of how little we do know. The plant has in fact been up all night assembling little packets of sugar and seeds and fragrance and color, because when it does so its evolutionary fitness is increased. When it is successful in enticing an animal such as me to disperse its fruit, its genes for making yumminess are passed on to ensuing generations with a higher frequency than those of the plant whose berries were

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> inferior…what I mean is that our human relationship with strawberries is transformed by our choice of perspective…when we view the world this way, strawberries and humans alike are transformed. The relationship of gratitude and reciprocity thus developed can increase the evolutionary fitness of both plant and animal. (p. 29-30)

Can we come to understand mathematics as a living practice that needs actors and can respond to their needs? Are there already ways in which these concepts play into mathematics?

Kimmerer highlights how in the Thanksgiving Address, humans are reminded of the importance of balance and harmony, "We have been given the duty to live in balance and harmony with each other and all living things" (p. 107) and she asks the non-Native reader, "What would it be like to be raised on gratitude, to speak to the natural world as a member of the democracy of species, to raise a pledge of *inter*dependence?" (her emphasis, p. 112)

This is very similar to Cajete's notion of laws of interdependence. What might it look like to view mathematics (what it is, how we practice it, who is considered a mathematician, what knowledge we produce) as having a basis in interdependence? Kimmerer expands,

> Cultures of gratitude must also be cultures of reciprocity. Each person, human or no, is bound to every other in a reciprocal relationship. Just as all beings have a duty to me, I have a duty to them. If an animal gives its life to feed me, I am in turn bound to support its life. If I receive a stream's gift of pure water, then I am responsible for returning a gift in kind. An integral part of a human's education is to know those duties and how to perform them. (Kimmerer, p. 114)

If we keep in mind our duties to others, might we think about the forms of mathematics we are producing and practicing as well as how those forms impact other persons, not just ourselves or other humans?

In describing the relationship between beans, corn, and squash, referred to collectively as Las Tres Hermanas (the Three Sisters), Kimmerer highlights, for me, the particular way in which these sisters perform mathematics.

> The corn stands eight feet tall; rippling green ribbons of leaf curl away from the stem in every direction to catch the sun. No leaf sits directly over the next, so that each can gather light without shading the others. The bean twines around the corn stalk, weaving itself between the leaves of corn, never interfering with their work. In the spaces where corn leaves are not, buds appear on the vining bean and expand into outstretched leaves and clusters of fragrant flowers. The bean leaves droop and are held close to the stem of the corn. Spread around the feet of the corn and beans is a carpet of big broad squash leaves that intercept the light that falls among the pillars of corn. Their layered spacing uses the light, a gift from the sun, efficiently, with no waste. The organic symmetry of forms belongs together; the placement of every leaf, the harmony of shapes speak their message. Respect one another, support one another, bring your gift to the world and receive the gift of others, and there will be enough for all. (p. 131-132)

Phyllotaxis, the study of the ordered position of leaves on a stem, highlights the fact that many plants grow in ways that mirror "Fibonacci[vi]" numbers and the ratios of two consecutive numbers tend towards the golden ratio (Douady and Couder 1992). Interestingly, scientists who have studied Las Tres Hermanas have documented that when grown together, they out-produce what the plants would if cultivated individually (Mt. Pleasant 2006). That is, the corn makes light available; the squash reduces weeds; and the beans turn atmospheric nitrogen into mineral nitrogen fertilizer. Reciprocity is modeled in their relationship. This form of reciprocity is also present in research methods used by indigenous scholars and scholars of color (e.g., Dance, Gutiérrez, and Hermes 2010; Kovach 2009; Rigney 1999; Smith 1999).

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Drawing upon ten years of teaching integrative science that acknowledges both Western science and Indigenous sciences, Hatcher et al., (2009) argue that knowledge is only passed on from one living being to another when a relationship between the two is formed and when the receiver is ready. In this sense, knowledge is a verb; teacher and learner both play constructive parts in it, highlighting the role of reciprocity. In fact, the Mi'kmaq word netukulimk means to "develop the skills and sense of responsibility required to become a protector of other species." While a Whitestream view might privilege the problem solving/utilitarian aspect of reciprocity, I see reciprocity (along with In Lak'ech) as related to experiencing connections and joy—knowing that one's actions are positively affecting oneself and others.

The overall point I am making is for us to live in harmony, without domination, as a form of metaphysics, and to continue to note the similarities and differences between our modes of being and those of other-than-human living beings. Recognizing other persons as having something to "teach" us is not to begin with a stance that other living beings are a means to our end, in order to better ourselves and our time on this planet or in our multiverse, though that can be a byproduct. Rather, this stance is simply reflective of a deep belief that we must show respect for others, a form of ethics, because in doing so, we are showing respect for ourselves, a frame of mind consistent with In Lak'ech.

Nepantla

Nepantla is the third concept upon which I draw. Nepantla is the Nahuatl (Aztec) term for the interstitial space between worlds. Gloria Anzaldúa explains,

> Nepantla can be seen in the dream state, as well as in transitions across borders of class, race, or sexual identity. Nepantla experiences involve not only learning how to access different kinds of knowledges—feelings, events in one's life, images in-between or alongside consensual reality. They also involve creating your own meaning or conocimientos[vii]. (Anzaldúa 2000; p.267)

In many ways, Nepantla serves as a space of tensions, of multiple realities. Anzaldúa highlights those tensions, explaining how as a lesbian Chicana poet, she is neither fully accepted by her White feminist colleagues who do not acknowledge her Indigeneity nor by the Chicano community who does not recognize her as a lesbian. She is neither and both at the same time; she is in Nepantla. The same could be said for people who identify as two-spirit, a translation of niizh manidoowag, the Anishinaabe (Ojibwe) term for spiritual people who walk in two worlds, one foot in female and one foot in male. In fact, Nepantla has been compared to the action of walking, whereby one is constantly in motion and where each step shifts the center of gravity so there is no solid grounding. Anzaldúa highlights this movement and potentiality,

> Nepantla, where the out boundaries of the mind's inner life meet the outer world of reality, is a zone of possibility. You experience reality as fluid, expanding and contracting. In Nepantla, you are exposed, open to other perspectives, more readily able to access knowledge derived from inner feelings, imaginal states, and outer events, and to "see through" them with a mindful, holistic awareness. (Anzaldúa and Keating 2002, p. 544).

For Anzaldúa, being able to see through human acts of identity, knowledge, and construction allows us to question when/if the actions of some violate the actions of others, thereby attending to issues of dehumanization.

It is not simply the "space" of Nepantla that is powerful, but the power of being a Nepantlerx[viii]-one who chooses to live in a place of tensions—as a border crosser, so as to birth new knowledge.

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> For Nepantleras[ix], "to bridge is an act of will, an act of love, an attempt toward compassion and reconciliation, and a promise to be present with the pain of others without losing themselves to it." (Anzaldúa and Keating 2002; p. 4)

Bridging between two different views requires deep intellectual and emotional work. It means being willing to hold two or more contradictory views in one's mind at the same time with the goal of not quickly coming to a conclusion that subsumes both ideas under an umbrella but maintains some of those views and reaches a third space that is neither and both of those views. The idea of Nepantla is consistent with Aboriginal knowledge of the metaphoric mind where we have the ability to hold two completely different thoughts simultaneously (Cajete 2000).

Nahua metaphysics recognizes the shared collective consciousness of the cosmos. As such, a person is both *in* Nepantla and *is* Nepantla. That is, I am situated within a space of tensions and multiple realities that is called Nepantla. And, by virtue of being in that space, I am also the thing called Nepantla; I contribute to its essence. Therefore, Nepantla dictates how we move through the world. We are conscious of the multiple realities and energy in which we participate and to which we contribute as well.

Elsewhere, I have argued that Nepantla can help mathematics education researchers think differently about knowledge (Gutiérrez 2012) and provide a guiding principle for teacher education (Gutiérrez 2015). Here, I am suggesting that Nepantla can help us interrogate the idea that mathematics is both a universal endeavor and not a universal endeavor. That is, the practice of mathematics is not universal in the sense that it is always localized and particular to the needs of those who practice it (e.g., D'Ambrosio 2006; Ascher 2002; Gerdes 1997; Powell and Frankenstein 1997; Knijnik 2007; Restivo 2007). Yet, many of the forms that are practiced throughout the world have been identified as falling within six general forms: counting, locating, measuring, designing, playing, and explaining (Bishop 1988).

For Hatcher et al. (2009), this is two-eyed seeing, learning to see with one eye through Indigenous ways of knowing and the other eye on Western ways of knowing.

> The principles of Two-Eyed Seeing are used for the purposes of collateral learning or colearning where Western Scientific concepts are constructed side by side with minimal interference and interaction with Indigenous Scientific concepts (p. 149).

Unlike Hatcher's goals, I choose to privilege the view of a Nepantlerx—seeing the interconnectedness between Indignenous and Whitestream knowledge of mathematics. I choose the term Whitestream instead of European American to highlight the role of global White supremacy in the enterprise of mathematics education. Like Hatcher et al., Ogawa (1995) advocates for a kind of multi-science teaching, seeing from multiple views. Aikenhead (2017) echoes this focus on seeing more than one reality, saying,

> Indigenous cultures, for instance, generally share presuppositions characterized as value-laden, contextualized, cultural, ideological, mostly subjective, and embracing multiple truths. (p. 29)

In embracing these multiple truths, he suggests that students need to learn to be "cultural border crossers" (Aikenhead 1997), reminiscent of Anzaldúa's Nepantleras.

I choose to talk about knowledge from the point of view of a Nepantlerx because it highlights metaphysics and the choice for persons to stay in tensions rather than choosing one view over the other. A critical theorist might suggest an omnipotent perspective from above, a single version of mathematics that would be necessarily less oppressive and best at addressing ethics. In contrast, a post-structural view might suggest a relativist position where there is no one truth and all possibilities are viable for addressing ethics. For me, neither of these options is productive, as each requires a form of collapsing under one umbrella. From the view of a Nepantlerx, one is always trying to find

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ways of staying in the tensions long enough to birth new knowledge. The value of Nepantla is reminding us to seek multiple realities and to hold those in view because they help us generate new knowledge.

Embracing Nepantla would mean allowing these differing views to remain separate but in relation. Anzaldúa refers to this state of interdependence and solidarity as nos/otras,[x] meaning us/them intertwined. [See Gutiérrez (2012) for an explanation of nos/otr@s as it relates to mathematics education.] Like Nepantla, mathematics is always in motion and embodying principles that could be considered contradictory. Mathematically, the relationship between abstraction and contextualization is an example, as the definition of each relies upon the other.

Mathematx

Combining the views of In Lak'ech, reciprocity, and Nepantla allows us to raise new questions about a vision of practicing mathematics that might move past previous notions of Western versus other mathematics, past an idea of mathematics as either oppressing or liberating, beyond a mathematics that is either discovered or invented, towards an idea that allows us to deal with today's complexity and uncertainties. Towards that end, I am calling for a radical reimagination of mathematics, a version that embraces the body, emotions, and harmony.

Seeking/Performing Patterns for Problem Solving and Joy

Mathematx is a way of seeking, acknowledging, and creating patterns for the purpose of solving problems (e.g., survival) and experiencing joy. Beginning with the principles of recognizing self and/in others, responsibility towards others, and valuing tensions, several things stand out as different from the typical way Western mathematics is conducted or experienced by students in school. First, although some mathematicians experience pleasure as a result of solving previously unsolved problems, that aspect of joy is often a very small percentage of the time and almost always absent from the "mathematical product" (e.g., new theorem, new proof) that is valued by the community. Yet, mathematics education researchers who study aesthetics highlight this domain as essential to human meaning making and to the insights that mathematicians develop (Sinclair 2009).

Aesthetics join emotion, pleasure, and understanding for humans as they relate to their world (Dewey 1934). For mathematicians, aesthetics may serve as a precursor for intuition, whereby they do not rely upon a sense of logic and deduction but upon some general sense of how things connect together (Burton 1999), often illuminating a unity of meanings and values. In this sense, intuition and wonder may lead to joy and discovery (Sinclair and Watson 2001). That is, we seek what is surprising and wonderful, yet events must fit into a broader scheme; the parts must fit with the whole (Gadanidis and Borba 2008). In fact, because humans have had to discern patterns in their world in order to survive, we may be predisposed to attend to just "enough complexity to engage the mind but…not overwhelm it with incomprehensible irregularity or diversity" (Sinclair 2009, p. 52). Although much of this intuitive/aesthetic work remains at the subconscious level for many mathematicians, mathematx is intricately tied to what is pleasing and rewarding in a connected way, not just a utilitarian or "problem solving" manner. This perspective is consistent with Boylan's (2016) call for putting passion and pleasure at the heart of mathematics education. For me, "pleasing" includes not just the playful way in which many "pure[xi]" mathematicians invent new workspaces by beginning with different axioms, (e.g., 8-dimensional space) but also how other persons perform mathematx for/with us. This version of play deviates from Bishop's definition surrounding games because play does not necessarily involve an organized game, but includes a kind of frivolous activity with value perhaps only for the one performing it.

Like plants, humans also have a way of expressing ourselves (our tastes, our values) and our sense of beauty through patterns (e.g., braiding hair, creating symmetry in our surroundings, walking,

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dancing, speaking, dressing, creating balance in a home). These patterns are both playful (useless) and purposeful (useful) at the same time because they have the potential to connect us with others. Reviewing the work of Dissanayake, Sinclair (2009) highlights that this form of expressing ourselves through aesthetics helps indicate that we are special. In terms of patterns, it might not be just regularity that matters for persons. Biologists have noted that the ability to embody opposites (Nepantla) is consistent with living systems that show simultaneous stability and plasticity, incomplete separation between internal and external topology, prolonged stages of criticality, and the co-existence of future and past (Soto et al. 2016; Longo and Montévil 2011; Montévil et al. 2016). Again, broadening our definitions of living beings may yield insights for mathematicians who seek to discern, appreciate, and reciprocate patterns.

Current versions of what count as "beautiful" in mathematics tend not to reflect the diversity in our world. Instead, they tend to relate to truth (Stewart 2007), implying universals rather than uniqueness/expression that would align with performance or a plurality of epistemologies. If we can recognize that cultural theses of modes of living are aesthetic choices (Popkewitz 2002; 2008) and some aesthetics are not superior to others, then the means for controlling or dominating is lessened. The opportunity to appreciate another's values is the embodiment of In Lak'ech. In other words, approaching life in this way of appreciating and looking for similarity is what helps us grow and also recognize difference. Ethics and aesthetics join in mathematics when we have guiding principles like In Lak'ech, reciprocity, and Nepantla.

Intervention in Reality

Second, whereas mathematics tends to be thought of as a noun (e.g., a body of knowledge, a science of patterns, a universal language), mathematx is performance and, therefore, a verb. Just as identity is not something that you are, but rather something you do (Butler 1999), mathematx emphasizes the guiding principles and the process as opposed to the product. Drawing upon the concept of reciprocity, mathematx is an intervention-in-reality (action) as opposed to a representation-in-reality (explanation) (Santos 2007). The starting point for Western mathematicians would be to begin with embracing the joy/emotions and seeking In Lak'ech, reciprocity, and looking for opportunities to be a Nepantlerx while doing mathematics. Let us consider an example. A common theme in combinatorics is to start with an object P, and define some sort of counting function to P, which makes sense for taking in positive values because it results in a polynomial. Then, negative values are substituted into the counting function and it is recognized as a new counting function for a different/new mathematical object. For mathematicians, this work is known as combinatorial reciprocity (Meléndez 2017). In fact, Beck and Sanyal (2017) ascribe animacy to the process by referring to it as moving from "your world" to "my world." The new counting function has offered something that the original counting function could not. Is the mathematician grateful for the offering of this new counting function? Is there some joy in noting that functions can give back to each other? How might that starting point extend to other forms of reciprocity in doing mathematics with other persons?

The idea of mathematx as verb is consistent with many Aboriginal languages that are largely verb-based and may relate to how persons practice mathematics (Lunney Borden 2011). Mathematx is an activity that cannot be extracted from the living being(s) in the process of solving problems and/or experiencing joy--the mathematxn. Although ethnomathematics tends to take into consideration the idea that different cultures do different mathematics, the unit of analysis normally remains at the level of the group and what they have produced, possibly promoting the unintended message that all members of that culture do the same things for the same purposes. Mathematx acknowledges this group relation, but recognizes the meaning that each person ascribes to what is being experienced.

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The x at the end of the word signifies movement, an openness, the x being a variable that could be represented by anything. In this sense, mathematx is constantly evolving, depending upon what is represented with that x. This framing is consistent with the choice to use "x" as an ending (e.g., Latinx) to represent any gender performance instead of privileging a patriarchal view or ascribing to a binary of male/female.

I choose mathematx instead of mathematix in order to distinguish between the two when spoken aloud. In Nahuatl, the "x" is pronounced "sh." So, the word is pronounced mathematesh. The x is also political in the sense of Malcolm X, the human rights activist who took on the x to represent all of the unnamed ancestors and their cultures that had been lost through slavery. For me, mathematx is a political statement about reclaiming the persons who have been lost when humans remain at the center. As such, mathematx seeks to intervene in the status quo of mathematics.

Living Mathematics

The title of this article suggests a vision of living mathematx. What might it mean to live mathematx? Living mathematx means both that we live a version of mathematx as well as we are a living version of mathematx. This framing is consistent with Nahua metaphysics that suggests one is both in Nepantla and one is Nepantla. Living mathematx means moving through the world with other living beings, acknowledging, appreciating, and reciprocating the patterns produced. If we look to animals and plants for some insight, we see that Brassica oleracea (Romanesco cauliflower) performs itself in both utilitarian (compact) and non-utilitarian (pleasing) ways that may get us to pay attention to its form and to continue to cultivate it. On the one hand, Romanesco cauliflower performs a version of the "Fibonacci" sequence that maps onto Western mathematics, and the elegance of the pattern brings joy while at the same time solves problems of space. Yet, like all persons, every brassica oleracea, performs itself in a way, and over its lifetime, that shows variance and suggests a departure from a pre-determined set of possible outcomes programmed by genomes (Montévil et al. 2016). We might ask ourselves, why is a grove of trees, each with similar but not perfect versions of fractals more pleasing than a computer-generated version of a grove of trees that precisely follows expanding symmetry? Is there something more in our relation that triggers a sense of pleasure, appreciating the aesthetics that plants perform? Are we able to discern and appreciate asymmetry along with symmetry? And, in what way(s) might this relate to aesthetics, intuition, or insight? Are there patterns in the ways in which our pleasure is communicated back to plants, for example, through pheromones or other means we are not yet able to understand or describe?

Do other persons remind us of the importance of beauty in imperfection, of not relying upon a defined algorithm? That is, although they offer good approximations of such things as shorelines of oceans, fractals in Western mathematics do not map perfectly onto the universe around us. Moreover, not all symmetry is inherently beautiful or "natural." Marcelo Gleiser refers to this phenomenon as the aesthetics of the imperfect. He notes that while synthesizing amino acids in a laboratory setting, biologists achieve approximately 50 percent right-handed chiral[xii] formations and 50 percent left-handed formations. Yet, in living creatures, virtually all amino acids are left-handed. This asymmetry is critical for protein folding and reproduction. The same is true for the asymmetry of occurrence in matter and anti-matter in physics[xiii]. So, asymmetry, not just symmetry, may be a form of performance by living beings to which we need to pay greater attention. Perhaps this asymmetry has aspects of a pattern that are complex enough without being overwhelming to initiate surprise or wonder.

Can our older brothers and sisters in this universe (and others) teach us something based on how they have developed and organized themselves to relate with each other to please and solve problems? From a practical point of view, are there ways in which we can organize our living spaces to draw upon visions such as the Three Sisters and other geometric formations that our older brothers

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and sisters use? In some respects this idea of learning from our older brothers and sisters is not new. Researchers have begun to rely upon biomimicry, copying the forms observed in "nature," in order to solve complex problems of space, design, and efficiency. For example, termites have taught architects in Harare, Zimbabwe, how to erect buildings with patterns that create effective internal climate control systems; Kingfisher birds have taught engineers how to construct high speed trains that will move through the air with less noise; plants and insects are teaching aerospace engineers about miori folds in order to tightly package and then deploy enormous complex origami versions of sun shades to block the light and allow telescopes to take more accurate pictures; similar folds in the universe are helping physicists understand neighboring galaxies. However, all of this biomimicry is taking place in research labs, not in schools with students. We are missing an opportunity to expose students to plants, animals, and other persons as our teachers, and perhaps also our opportunity to reciprocate actions.

In terms of recognizing and performing patterns—living mathematx—marine creatures such as salmon, sea turtles, trout, and eels have the ability to read magnetic fields in the earth and use them in migration (Pennisi 2017). Animals such as bears, dear, elk, great apes, macaws, lizards, and fruit flies are able to read (communicate with) plants in order to self-medicate when they have diseases (Shurkin 2014) or develop high levels of toxins in their skin and use other chemical signals to communicate and ward off predators (Hagelin and Jones 2007). Several tree species such as oak, spruce, and beech are known to communicate among themselves and with each other in order to ward off disease, share resources, and protect each other (Wohlleben, 2016). Like Las Tres Hermanas (corn, beans, squash) mentioned earlier, many of our cousins seem to recognize/acknowledge patterns and create new ones while collaborating and valuing reciprocity. To date, many researchers rely upon Bishop's (1988) classification of six forms of mathematics: counting, locating, measuring, designing, playing, and explaining. I urge us to consider what forms of classification might we develop in looking to other-than-human persons and the ways in which they live mathematx in their local contexts? Which new forms of mathematics might arise?

From a philosophical perspective, perhaps it is neither that we have come to appreciate the "natural" patterns present in plants, animals, and rocks, as Platonists would have us believe (i.e., that they have taught us patterns that were programmed within them or that they developed), nor that we simply project our own aesthetics onto our living cousins (i.e., that we see the mathematics we want to see in our environment) as Realists would have us believe. More likely, our relations and the tensions between us provide the multiple lenses on reality and instability. We are constantly in motion like a Nepantlerx. This is consistent, though different, from Barad's (2001) notion of "intra-action." If, instead of perpetuating a human/non-human binary, we consider the shared consciousness between all living beings, the greater unity to which we belong, we are more likely to value mathematx for what it offers us. We can acknowledge both the potential for domination between living beings while also opening up the possibility of harmony and reciprocity in the practice of mathematics.

As we look for new structures and forms of mathematics to help solve the global crises we encounter as well as to experience joy, we might consider how other living beings might offer lessons and insights. We have developed new structures and physics concepts by studying intently such things as symmetry and conservation laws in the physical world. Even using a narrow definition of living beings, biologists have noted that all organisms (uni-cellular or multicellular) do not simply follow prescribed rules or programming. They develop their own norms/rules in a way that balance between plasticity and robustness; that is, they show spontaneous organization and variance that does not appear in physics (Soto et al. 2016). If we broaden our understanding of living beings beyond the organism, we might find even further insights.

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Reflecting an Ecology of Knowledges

Building upon Andreotti, Ahenakew, and Cooper's epistemic plurality (2011) and Santos' (2007) call for a new ecology of knowledges, I suggest that mathematx guide our work in mathematics. Because mathematx acknowledges that all persons will seek, acknowledge, and create patterns differently in order to solve problems and experience joy, multiple knowledges are valued and sought. These multiple knowledges are important, given that all knowledge is partial and each offers us a different angle and understanding on the world. The goal is not to work towards a summative understanding, as if by simply adding the different knowledges we will have a complete or perfect view. Rather, our work is to locate ourselves in others and others in us, as we attempt to understand our world through patterns. Doing mathematics in this way offers us the opportunity to unlearn our epistemological arrogance. The concept of reciprocity draws upon complementarity in recognizing that different knowledges contribute something others do not. Mathematx nurtures a view of mathematics that always considers strengths and limitations for particular purposes. For example, we might ask ourselves: which forms of mathematics can our brothers/sisters perform for which we do not have a way to express? In looking to other persons, might we be more open to multiple versions of knowing that are constantly open to new axioms and even non-axiomatic mathematics?

While others have noted that Western mathematics—sometimes referred to as Platonist mathematics or European mathematics or European American mathematics—is in opposition to Indigenous mathematics, I am not seeing that mathematx would be in opposition; rather it would include Aboriginal mathematizing. In the same way that Latinx rejects the gender binary, mathematx rejects the epistemological binary. Mathematx allows for a variety of expressions without suggesting one is "normal," superior, or the reference point for erasing other epistemologies. However, mathematx is not everything and anything. It privileges a particular way of moving through the world that acknowledges and produces patterns that align with the collective consciousness and energy of the cosmos and respects other persons. Mathematx is less a way to describe how we currently do mathematics and more a goal for how to approach our relations with each other in the practice of mathematics. In this sense, mathematx is a quest for intersubjectivity and systems thinking, not unity.

Moreover, mathematx acknowledges Nepantla by underscoring the fact that there is no absolute universalism or absolute relativism. That is, there is no umbrella term under which all forms of mathematics can collapse and explain everything in reality. When we move from a global universal mathematics to a form of mathematx, whereby we acknowledge epistemological pluralism and are guided by first principles of In Lak'ech, reciprocity, and Nepantla, we are likely to see changes in not only mathematical activity (and products) but also in mathematxns.

Philosophers, sociologists, and anthropologists who study mathematics have long argued that "school mathematics" is but one small version of the many forms of mathematics practiced in the world and that such mathematics does not operate outside of individuals, morals, or politics (Brown 1994; Clarke 2001; Ernest 1994, 2000; Fitzsimons 2002; Restivo 1994; 2007; Turnbull 2000; Verran 2001). Often, in making these claims, researchers point to the field of ethnomathematics to highlight the fact that all cultures do mathematics in localized ways. In some respects, I am arguing for an extension of ethnomathematics to include animals, plants, rocks, bodies of water, and other persons. Mathematx is consistent with a focus on peace, education as relation, a recognition of the imprint of Western thought in dominant mathematics, and a language through which people could be more creative (D'Ambrosio 2007; Francois and Van Kerkhove 2010; Gerdes 1988; Powell and Frankenstein 1997). Even so, I choose mathematx as opposed to "ethnomathematics with the inclusion of other-than-human persons" because I aim to avoid some of the pitfalls of previous understandings and implementations of ethnomathematics (Cimen 2014; doCarmite and Pais 2009; Vithal and Skovsmose 1997). For example, I am not looking to use Western mathematics or a Platonist view as the standard by which we judge other persons to live mathematx or to suggest a

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kind of essentialization of humans (Gutiérrez 2000; Francois and Van Kerkhove 2010). Moreover, I do not wish for the knowledge of our older brothers and sisters to simply be acknowledged/sanctioned and shared (Mesquita and Restivo 2013); I want such knowledge to be valued and applied. Although D'Ambrosio broadened his definition of "ethno" to include "all culturally identifiable groups with their jargons, codes, symbols, myths, and even specific ways of reasoning and inferring" (p. 17, cited in Francois and Van Kerkhove), people have continued to think about ethnomathematics as practiced by ancient ethnic (non-Western or non-White) cultures[xiv] or collapsed it into a form of cultural appropriation. By introducing mathematx, I also seek to decenter the notion of "tics" (technologies), which, for me, do not capture the body/spirit (feminine) and the ways we move through the world in the same metaphysical manner (Haraway 1988; Harding 2008). Mathematx is more than explaining and understanding in order to survive (D'Ambrosio 1990); it attends to aesthetics and the body.

Implications for Teaching and Learning

Elsewhere, I have argued that the practice of school mathematics in the US regulates the child by privileging: algebra/calculus over geometry/topology/spatial reasoning; rule following over rule breaking; Western mathematics (culture free) over ethnomathematics (recognizing that even academic mathematicians are a culture); the "standard algorithm" over invented or international algorithms; abstraction over context ("just pretend this is real world"); mind over body; logic over intuition; and encouraging students to "critique the reasoning of others" over appreciating their reasoning (Gutiérrez, in preparation). Not only can these repeated practices over a lifetime serve to dehumanize students and teachers in classrooms, the narrative about mathematics being a pure discipline, reflective of the natural world around us, universal, with an almost unilaterally positive relationship to society's advancement, leaves many humans unable to challenge this narrative to consider other ways of doing mathematics. In this way, school mathematics comes to normalize and valorize particular practices and to make others seem deviant and in need of fixing (Skovsmose 1994; Walkerdine 1994). By continuing to privilege data analysis and probability over other kinds of spatial patterning, even if that data analysis concerns itself with issues such as climate change, we run the risk of limiting new ways of doing mathematics and our relationships to the practice.

In contrast, what might teaching and learning look life if mathematx were embraced? First, students need time to relate with other-than-human persons in order to develop a familiarity with the kinds of patterns that exist outside of themselves—things that are both another version of us and yet not exactly us—so they can provide mirrors onto ourselves and windows onto another's world. Rather than education happening within school walls, students might be asked to head outdoors. In lieu of a purely dominant mathematics curriculum (Gutiérrez 2002), students might be asked to investigate: How do we acknowledge, understand, and relate to the patterns in bird song? What are the patterns/signs/codes that allow some animals to relate to their plant relatives for the purpose of self-medication? What are some of the patterns that occur as insects package their wings and bodies? And, in what way(s) might those forms solve problems and bring joy? How do those packages of wings and bodies relate to other packages in humans, in other species, in the imagination? Where does the search for patterns fail to capture other meanings in these practices? These are all questions for which most teachers will not have answers. Therefore, different from the portrayal of the math teacher as the credentialed professional who has acquired the "knowledge base" and who is inserted into the child's life in a coercive relationship whose success is conditional upon pre-set performance measures and criteria, living mathematx would involve the passing of knowledge only when the knowledge receiver is ready and a relationship is formed between giver and receiver, as suggested earlier by Hatcher et al. (2009).

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In some respects, seeking to understand how we and our older brothers and sisters live mathematx can serve as both a problem solving exercise (in mental manipulation, spatial reasoning, and other things that might map easily onto current forms of humans doing mathematics), but it is also likely to deviate from the language we have to understand or describe. In this way, students will be learning how to be open to other forms of being and for recognizing the tools necessary for reading and responding (reciprocity) to those forms and also being fully present in the beauty of such performances. Such an education would shift the dynamics from an objectifying description and problem-solving manner towards one that includes joy, respect for the person, and the desire to act (reciprocate) in a way that is responsive to the particular situation at hand, thereby changing the individual learner in the process. In the same way that we might see traditional mathematics classrooms move away from students being taught to "critique" the reasoning of other students, as is called for in the Common Core State Standards in Mathematics (National Governors' Association 2010) towards what I refer to as "appreciating" the reasoning of other students (i.e., being able to stand in their shoes), we might see that process occur across all persons.

Some researchers have started to bridge the gap between aesthetics and mathematics through the online game *Fold It* where players find pleasure in folding proteins in compact ways and earn game points (Cooper et al. 2010). The players' unique folds are analyzed by researchers who then apply puzzle solutions to real world problems in the medical industry. In fact, this form of crowd sourcing has developed insights and answers to problems concerning the AIDS epidemic that researchers and computer-generated approaches alone had failed to solve. Researchers involved in the project are studying the intuition of players and how they approach the folding process in order to improve algorithms generated by computers. This form of pleasure and "learning" occurs outside of the school walls. However, combining versions of exploring the world to relate with other persons and then playing such games may help us identify certain trends that would have been difficult using our eyes alone. That is, there may be ways in which relating with plants, animals, rocks, or other persons inspire us to develop intuition in approaching the visual display of computer-generated objects that can be both pleasing for us as well as build upon the mathematx that other persons live in order to generate biomedical solutions to health problems.

Learning through mathematx accedes that all knowledge is based on particular worldviews and ways of knowing that close down other possible choices; that is, knowledge is a political process, not a neutral product. Rather than mathematics being seen as the pursuit of truth in the sense of a unifying theory of reality (e.g., the unique solution to string theory) and, therefore, the means to control, learners embracing mathematx might come to see that the mathematics performed by humans is but one form that describes part of our world, but not all. Through living mathematx, teachers and students would practice walking alongside of other living beings, revising their understandings based upon their relations with them. In this sense, students would have opportunities to unlearn their epistemological arrogance. Teachers would focus upon helping create opportunities for learners to engage in an aesthetic experience—seeking surprise both in how similar something is, but also how it differs—to wonder about how other living beings seek, acknowledge, and perform patterns for their own survival and joy. Teachers might also encourage students to search for patterns that are felt/experienced (at the macro level), not just conceptually identified (at the micro level). What are the aesthetic preferences that help us define and understand the concept of pattern? Through mathematx, learners are likely to become more reflective about their learning and their relations in the world—what they know, what they do not know, as opposed to what can be known.

Because mathematx involves the Nepantla state of both/neither when discussing problem solving and joy, learners will need to become comfortable with such uncertainty. In other words, they will come to know and practice mathematics as neither purely problem solving, nor as purely joy, but also

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not both in a cumulative sense. Learning mathematics in this way means being able to, at times, acknowledge one side over the other, but always seeing the two in relation.

Teachers' roles would necessarily shift from telling/showing and towards living alongside of students and other persons. Teachers should be asking themselves, "Am I conducting mathematical activity with an eye towards reciprocity, Nepantla, In Lak'ech? Am I doing mathematics to see myself in others and others in myself, to give and to receive from my universe, to acknowledge multiple ways of knowing and multiple kinds of knowers?" Students would be learning to move through the world, appreciating, noting the forms, packages, and connections that plants, animals, rocks and other persons develop. In a sense, we are apprenticing learners to become "mathematxns" by providing guiding principles—In Lak'ech, Nepantla, and reciprocity. We are preparing them to look for what we already acknowledge/sanction as some humans doing mathematics with how other persons (human and other-than-human) live mathematx. In doing so, we must recognize that ignorance might not just be a lack of knowledge but an active refusal to know because it disrupts one's previous beliefs. If we start early with young learners, it may be easier to disrupt what humans have come to consider normal in the practice of mathematics. That is, like learning a new language, young students often are able to absorb new ideas and new ways of gaining knowledge.

Mathematx is not a rival body of formal knowledge to mathematics. Rather, mathematx is a worldview that surrounds and guides whatever it is that we are trying to accomplish mathematically. However, because of the performativity of mathematx, this new approach is likely to produce new structures and forms that academic mathematicians might acknowledge as new mathematics. Indigenous epistemologies value context and relationships, recognizing that our strength comes from understanding ourselves not with universal principles but in relation to particular lands and particular living beings. One could argue that the individual cannot be extracted from its environment and understood in any meaningful way. Biologists would agree, suggesting that because biological systems operate under different theoretical principles, a focus on living beings is likely to require different forms of mathematical modeling (Montévil, 2017). For example, breaking something down into its parts in order for study does not necessarily lead to anything meaningful about the results of a model when inserted back into its context. We saw this was the case with synthesized amino acids versus ones occurring in nature. So, our definition of a "useful mathematical model" may need to be reexamined when we include all living beings as performers of mathematx, including ones that would not be classified as organisms.

I am not suggesting that humans have gotten it all wrong and that by turning to other-than-human persons, we will get it right. My goal is not to get closer to some absolute truth about our world. Rather, learning with other persons opens the door for us to have different lenses for viewing and relating with our universe and others. And, in doing so, we have the opportunity to learn how different approaches (mathematics or mathematx) make im/possible certain forms of knowing the world, recognizing that all of these forms are provisional, local, and legitimate. Even so, given the history of particular knowledges, knowers, and ways of knowing that have dominated in our history with respect to mathematics, it is important to give greater focus to the ways other-than-human persons live mathematx.

I recognize the potential limitations of attempting to use a term like mathematx that is difficult to both say and spell, even if one understands conceptually what it can offer. The term ethnomathematics, even when being explicit that all cultural forms of mathematics are "ethno" has not prevented many researchers and teachers from continuing to use Western mathematics *in opposition to*, instead of *as a version of* ethnomathematics. That is, neither do we tend to refer to Western mathematics as such nor do we refer to other mathematics as Eastern, Mexican, Northern, or American. Ethnomathematics seems to encourage researchers and teachers to create a binary between Western and Indigenous, rather than recognizing a variety of forms, some with overlapping goals and

Galindo, E., & Newton, J., (Eds.). (2017). *Proceedings of the 39th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education.* Indianapolis, IN: Hoosier Association of Mathematics Teacher Educators.

principles. Moreover, ethnomathematics also has not been well incorporated into the school mathematics curriculum. So, some might wonder, what is to prevent the same phenomena with mathematx?

To avoid these potential pitfalls, I have suggested we expand our view to all living beings, thereby providing us with the ability to consider how some humans live mathematx differently from each other as well as from other persons, creating new lines of solidarity (In Lak'ech) or difference (and the need for reciprocity), or contradiction/tension (Nepantla). By expanding to other living beings, mathematx can avoid the trap of Western versus "other" mathematics and open the door for new categories to be drawn. For example, in what ways do humans live mathematx that are consistent or compatible with how trees live mathematx? And, how are individual humans affected by considering trees to be simultaneously another version of us (In Lak'ech) and not a version of us (Nepantla), but in need of our reciprocity? In what ways are we incompatible? What are the new knowledges and sensibilities we need to fully develop to live in harmony? Moreover, because mathematx is not a description of the world, but rather a set of first principles in doing mathematics, it differs from ethnomathematics in that it sets out a form of intervention.

Although the vision of living mathematx that I have outlined may sound outlandish, we need only remember Clarke's (1973) third law: "Any sufficiently advanced technology is indistinguishable from magic." In fact, I argue that mathematics as a field and as a human endeavor need only look to other sciences to see it is late to evolve. The field of physics used to promote the idea that there was a single time-space continuum. Then, Brian Greene (2011) introduced the concept of infinite parallel universes and physicists are now imagining how humans could participate in more than one space at one time. Moreover, the cosmologist Alexander Vilenkin has proposed a theory of our universe sitting within a bubble of other universes (Vilenkin and Tegmark 2016), the implication being that other universes may have different laws of physics. In a similar vein, I am suggesting that we may have different forms of mathematx in which we participate, but to which we are largely blind and numb. When we move [l]through the world seeking connections and reciprocity, our views of ourselves and of others change. I ask us to open our minds to envision how such a view could change the relationship between humans, mathematics, and this universe with/in which we currently live.

Endnotes

[i] I am grateful to Federico Ardila-Mantilla, Kimberly Seashore, Andrés Vindas Meléndez, and Diana Zambrano at San Francisco State University; and Brandon Singleton at the University of Georgia for providing helpful comments on an earlier version of this article.

[ii] I cite this article as 2010/2013 because it was published online through JRME in 2010 and some researchers began citing it as such then. It was not released in print until 2013, and some researchers have cited it as such since. Because the focus of the article is on a particular point in history, the work should reflect the earlier date.

[iii] My maternal grandmother was a woman of Rarámuri (Tarahumara) descent. My ancestors are located in the Copper Canyon region of Northwestern México.

[iv] Two-spirit is an Aboriginal term.

[v] I use Indigenous and Aboriginal interchangeably. US authors tend to use the term Indigenous, whereas authors from Canada, Australia, and New Zealand tend to use the term Aboriginal. In Canada, Aboriginal includes First Nations, Métis, and Inuit peoples.

[vi] I place Fibonacci in quotes to highlight the presence of settler colonialism. That is, although the Italian Leonardo Pisano (Fibonacci) receives credit for the pattern, many cultures and persons throughout the world, including Pingala in 200BC in India, had already known/performed the same pattern many years earlier. In fact, if humans are no longer the center, we might credit nautilus

pompilius (Nautilus shell), pinus coulteri (pinecone), or helianthus annus (sunflower) with the "discovery."

[vii] Conocimientos translates to "knowledges" in English.

[viii] Similar to the use of Chicanx, Nepantlerx indicates solidarity with people who identify as LGBTQIA2S. In the Spanish language, the –ero/-era ending of a word typically signifies "one who…" As such, a Nepantlerx is one who chooses to reside in Nepantla.

[ix] Anzaldúa's terms do not reflect the "x" because she was writing before such language was common. She used a version that privileges a feminist perspective and therefore ends in "a" instead of "o."

[x] Anzaldúa's terms do not reflect the "x" because she was writing before such language was common. She used a version that privileges a feminist perspective and therefore ends in "a."

[xi] I place pure in quotations to suggest that there is no such purity to mathematics. When we use terms like pure mathematics or fundamental mathematics, we are "othering" different forms of mathematics in ways that make them sound primitive or deviant. An Aboriginal stance would call into question whether any form of mathematics could be seen as pure, as it will always have a purpose and a grounding—cultural context—to start.

[xii] Chirality refers to the geometric structure of a molecule, in particular how four different entities connect to a carbon center. Like hands, chiral molecules cannot be superposed onto their mirror image.

[xiii] See, for example, Paul Dirac's prediction of anti-matter that contradicted classical quantum physics where systems were thought to only have positive energy.

[xiv] Noted exceptions include the work of Gelsa Knijnik (2011), who has chronicled the Peoples Land Movement in Brazil.

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