

## Toward Indigenous Making and Sharing: Implications for Mathematics Learning

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In this chapter, we explore the “Indigenous making and sharing” that occurred in a project called Indigenous STEAM, an ArtScience participatory design research project. The project involved Indigenous youth, families, community artists, and scientists in a summer program designed to cultivate Indigenous ways of knowing, being, and making complex socio-ecological systems through a focus on pedagogies of walking, observing, and talking about lands and waters as the foundations in making activities. We will draw from a case study that utilizes interaction analysis of ArtScience making spaces, more specifically clay work. This work seeks to expand our understandings of issues of equity in making and in mathematics learning by considering how making is necessarily a cultural activity that reflects particular epistemic practices that have consequences for how we think about and design mathematics learning environments. We specifically explore the ways in which clay making (as an embodied form of mathematics) can engage youth in humanizing mathematics and science practices as well as other disciplines as part of the making process.

### ■ Our Starting Point

We start by communicating our intentions for writing this chapter and by acknowledging the historical erasure of Indigenous people across continents. We begin with erasure because any conversation about equity in society, the world, education, or mathematics education needs to be situated as part of an ongoing historical, political, and social context or, in the case of Indigenous people, the project of settler colonialism (Wolfe 2006). By starting here, it is possible to consider the limitations of existing/imposed frames of learning and equity and to then consider more appropriate approaches that draw from Indigenous worldviews and cosmologies. Within this work, we position ourselves as Indigenous scholars and educators, one from the territories of central México and one from the Great Lakes, who challenge Western frames and are working to develop Indigenous-based solutions. In addition to living our lives and raising families in Indigenous communities, each of us has spent important time and effort working in both school- and community-based contexts with families and communities to develop learning environments that are transformative for our communities. Sometimes this work has been in the form of research, sometimes

not, but all of it has shared a commitment to Indigenous resurgence and educational justice. An important part of this work has been the deliberate exploration and/or learning of ways to enact Indigenous-based pedagogies in various contexts—both formal and informal—with an eye toward understanding how such ways might inform and transform one another. It is from this perspective that we narrate the work undertaken in the Indigenous Science, Technology, Engineering, Arts, and Mathematics (ISTEAM) camp and consider the ways in which such work can offer expansive forms of equity and inform the field of mathematics education.

Historically, the contributions and contemporary practices of Indigenous people in mathematics have either been forgotten (erased) or positioned as deficient relative to Eurocentric conceptions of mathematics. That is, the mathematical practices and contributions of Indigenous people and other traditional cultures have largely been described as lacking the complexity or sophistication to merit higher status in the field of mathematics (Powell 2002). For example, one example often cited or acknowledged as a contribution of Indigenous people (e.g., Mayan civilization) is the concept of “0.” While the conceptualization and understanding of the concept of “0” demonstrates the development of a number system and the computation of sophisticated astronomical counts (Closs 1986), such contributions remain marginal and are often excluded or devalued as major contributions to the broader field of mathematics. Such exclusion often suggests to practitioners and to learners that few cultures (mainly the Greeks) produced or developed the mathematics that are taught or practiced today in school and in society. In addition, when the contributions of Indigenous people are acknowledged, such contributions are framed as the mathematical and scientific production of Indigenous people of the past with little or no connection to the Indigenous people of today.

In the last thirty years, some researchers have attempted to make more visible the ways in which Indigenous people across continents have used mathematics and continue to do mathematics in culturally embedded forms (D’Ambrosio 1985; Eglash 2001). One area that has emerged as a productive space, both in mathematics and in mathematics education, has been ethnomathematics. Multiple definitions of ethnomathematics have been developed, but D’Ambrosio (1985) defined it as the “mathematics which is practiced among identifiable cultural groups such as national-tribe societies, labor groups, children of certain age brackets and professional classes.” Bishop (1988) articulates ethnomathematics as a cultural product, whereas D’Ambrosio makes reference to cultural groups. Ethnomathematics has made explicit the relationship between culture and the development of mathematics by countering the commonly held and false assumption that mathematics is universal and culture free (D’Ambrosio 1985). From an ethnomathematics perspective, mathematics is the production of human beings and emerges from cultural activity (Bishop 1988; Lipka and Adams 2004). In addition, ethnomathematics presents a direct challenge to Eurocentric conceptions of mathematics that have been imposed and reproduced in colonized territories (Powell and Frankenstein 1997). In this chapter, we build on this ongoing research in ethnomathematics but chart another pathway that accounts for the ways in which making spaces based in youths’ epistemic ecologies can enable expansive forms of making that include mathematics and are reflective of Indigenous forms of human-nature relations (Gutiérrez 2017). Put differently, our intention is to articulate ways to restore Indigenous nature-culture relationships as a direct refusal of Indigenous erasure and to uphold the epistemic authority (Booker and Goldman 2016) of Indigenous ways of knowing in mathematics learning.

## ■ Why Making and Sharing? Centering Indigeneity through ISTEAM Camp

We focus our attention on making because making has taken on particular meanings in the U.S. context. In the United States, a dominant view of the maker movement narrowly defines such activity as the work of individuals and groups engaging in “uniquely American activity focused on technological forms of innovation that advance hands-on learning and contribute to the growth of the economy” (Vossoughi, Hooper, and Escudé 2016, p. 207). A major assumption of this conception of the maker movement is that it privileges the creation of products, generally dealing with electronics or modern technologies, in ways that are representative of normative White culture and activities (Vossoughi, Hooper, and Escudé 2016, p. 208). We build on Vossoughi and colleagues’ (pp. 213–26) critique of the maker movement to articulate Indigenous making and sharing. They suggest that the following four dimensions are critical in developing pedagogies of making that can support equitable and transformative learning for nondominant youth:

1. Critical analysis of educational injustice
2. Historicized approaches to making as cross-cultural activity
3. Explicit attention to pedagogical philosophies and practices
4. Ongoing inquiry into the sociopolitical values and purposes of making

These four dimensions are critical in developing transformative learning environments because they help to refuse approaches that reify the dynamics of erasure we mention, and they shaped how we approached our analysis and narrative. Further, the dimensions resonate with design principles Bang developed for repatriating Indigenous technologies (Bang et al. 2013) that shaped the design of the STEAM camp and guided our pedagogical practice. Since the summer of 2014, we have engaged in an ArtScience participatory design project (Bang and Vossoughi 2016) titled ISTEAM Camp. We have engaged over eighty first- to twelfth-grade Indigenous youth in complex ecological systems learning in field-based settings utilizing ArtScience pedagogies during two-week summer camps. The project was developed to engage Indigenous youth in understanding the changing lands and waters in the Pacific Northwest through direct engagement with phenomena in the world. Pedagogically, the project aimed to cultivate epistemic heterogeneity (Rosebery et al. 2010) and onto-epistemic navigation between Indigenous ways of knowing and western ways of knowing in sense making and embodied practice. The Indigenous youth participating in the camps represent a wide range of Nations across the continental U.S., Canada, and México. Such groups include Washington State tribe members from the Puyallup, Yakama, and Upper Skagit Nations (to name a few), as well as members of Nations originating outside of the state of Washington (e.g., Ojibwe, Diné, Lakota, Kiowa, Chippewa, Paiute, P’urhépecha [México]). In total, over twenty Nations are represented.

We have worked to evolve an understanding of Indigenous making and to consider the ways in which Indigenous making may afford transformative and humanizing learning opportunities for Indigenous youth. In the context of the ISTEAM camp, rehumanizing means to directly refuse Indigenous erasure by centering Indigenous knowledge systems (Cajete 2000; Kawagley 1995; Meyer 2001) as a way to counter assumptions embedded in western conceptions of knowing and knowledge production. These assumptions include an emphasis on universalism and

compartmentalization of knowledge. We center Indigenous knowledge systems by historicizing the practice of making as a longstanding cultural practice with deep nature-culture relations that are enacted within the context of family and communal responsibilities.

As Indigenous scholars, we have engaged with Indigenous youth, families, and community artists by centering Indigenous nature-culture relations (as an explicit counter to western human-dominated views) to cultivate ways of knowing, being, and making through the pedagogies of storytelling and walking (observing) the lands and waters (Cajete 1999) as the foundation for the making activities. Storytelling involved communicating meanings, feelings, and ways of being, including elder storytelling. Walking (observing) entailed noticing and being present with stories in places. Finally, clay making involved the direct use of natural materials as a vehicle to contribute to and manifest the continuity of Indigenous practices and people. In the camp, the activity of making (in this case, clay work) has been established as a millenarian practice that Indigenous communities have developed as a technology in the past and in the present. Within this conception, Indigenous making is the enactment of relationships with animate materials that have life courses to fulfill communal responsibilities and as a process of knowing, being, and doing.

To document the various activities throughout the camps, we have collected video, audio recordings, and field notes of the making activities, as well as interviews with youth and adults; these materials form the basis of the data for this study. The data were logged in five-minute intervals across each summer and tagged with key markers of making, Indigenous knowledge systems, and practice configurations. The episode we present in this chapter represents a slice of a broader analysis where we examined the making activities that took place in the ISTEAM camp during the summer of 2016. As part of the analysis, we looked for instances when stories and storytelling were shared or retold in the context of the making activities. In addition, we also identified moments when youth and/or artists referenced ideas or concepts from the walking activities in the making activities. Across the data, we identified significant relationships between the storytelling, walking, and making activities; however, in this study we highlight the relationships that emerged from the clay making.

### ■ Making and Sharing from an Indigenous Perspective: Emergent Understandings from ISTEAM Camp

In order to understand why making and sharing reflect particular epistemic practices, it is important to understand how Indigenous communities have drawn from their own ways of knowing and relating with the world by reaffirming such relationships in daily practice. One such technology that continues to be a source of continuity, reclamation, and reaffirmation is the use of clay as one of the original technologies. Clay work continues to be used in a variety of community contexts and for varied purposes. In some contexts, like Indigenous communities in central México, clay work and the activities around it remain a central part of a community's social organization and play a strong role in the transmission of cultural practices and knowledge systems. For some Indigenous communities, clay work (most often pottery) is part of a community's specialized system of production. In these communities, families contribute to collective making, with women generally taking up key roles in the making of pots, incense burners, and other ceremonial pieces.

Clay making, as an Indigenous-based practice, involves a range of activities that integrate a variety of disciplinary domains throughout the process of making and sharing. Being in relationship with clay means understanding the science of what constitutes moldable clay throughout the

mixing process. This includes an understanding of the types of organic materials (e.g., plant medicines) used, the different types of clay, the need to evenly distribute moisture through kneading and wedging, and the ways in which the elements (e.g., water, fire) come into play at different parts of the process to make a clay piece possible. In the elaboration of the clay piece, several mathematical activities also occur as embodied mathematics (Hall and Nemirovsky 2012). Nonstandard measures and proportions are used to approximate the amount of water needed to mix with dry clay. In addition, mathematical modeling is used to translate from two-dimensional (2-D) sketches to the three-dimensional (3-D) art piece. Here, the designing of the 2-D sketch allows the clay maker to conceptualize into the “real world” (i.e., the 3-D piece), somewhat similarly to the way that engineers develop models as part of an iterative process to test whether a product will work as desired (Dym 2004). The major distinction between this approach (model-based prediction) and Indigenous clay making is that the “final” clay piece (which is the only iteration) is viewed as a physical representation that captures the meanings, feelings, and ways of being that are part of the process of making and sharing.

Below, we describe one episode that highlights aspects of clay making and sharing that privilege epistemic practices that are founded on the practice of walking and clay making. It is important to note that the focus on clay emerged in the ISTEAM camp from the students’ own discovery while exploring tidal pools as part of the study of beach relatives and changing waters (ocean acidification). It was there that students came in relation with a clay deposit that then prompted student-generated inquiry and a focus on clay work in year two of the camp. In our initial efforts to come in relation with clay, we approached clay work by drawing from ceremonial practices originating from Indigenous communities in central México. The ceremonial practices are the accumulation of thousands of years of oral and making transmission that are deeply based on storytelling and apprenticeship relationships. We worked to intertwine youth experiences with making relations in the natural world with processes of clay making. For example, the beach was about a half-mile walk from the community center that served as the base of the ISTEAM camp. We designed inquiries into the mathematics of the natural world for the youths to explore during these walks. In the walks, the students attended to deep observation of plant relatives and to understanding patterns in plants from various scales and perspectives. They explored symmetry, shapes, angles, tessellations, lines, and curves in plant relatives native to the Pacific Northwest. The walking episode below shows one way in which the students began to make connections between the activities of storytelling, walking, and making. In the walking episode that follows, we narrate how one nine-year-old Ojibwe/Diné youth, Dawn, began to make these connections.

*Dawn:* I saw many patterns and shapes.

*Clay artist:* You were telling me you saw many patterns and shapes. Your question was, how would I include it in clay? What are some—can you give me an example of a pattern you saw?

*Dawn:* This is one pattern where the leaves were kind of forward, kind of like a clover and then it would do that for like every branch.

*Clay artist:* Why might it all be growing out like that?

*Dawn:* Like sunlight. It spreads out and gets more nutrition.

*Clay artist:* Is that the only one [pattern] you saw or were there others?

*Dawn:* There was. I remember when we were telling my team and nettle goes like that and that and that.

*Clay artist:* So the nettle, how it was going in one direction. Cool—that's another good example.

*Dawn:* Oh, also I noticed that on the horsetail there would always be like a bunch around the stem and then wait and then do it again. So it's kind of over and over.

*Clay artist:* I noticed that too. You know what I remember about that. I actually went around and counted. And I noticed they were in groups of three and then another group of three. They were closer than I'm drawing it. I don't remember how many groups of three but about seven or eight. So this is the horsetail, the nettle, and this was some kind [*inaudible*].

In the episode above, the interaction demonstrates how children's observations/noticings of patterns in nature are conceived as part of the process of clay making. In the design of her clay piece, Dawn drew from patterns in nature (observed and noticed in the nature walks). This was a practice that paralleled one of the regional stories that was retold by an elder Indigenous storyteller on another day during a storytelling circle. In that story, a young Yakama girl persists to overcome feelings of incompetence by learning to make baskets from a cedar tree. The cedar tree guides the Yakama girl to do patterns and designs by observing nature (e.g., the rivers, the mountains).

In the walking episode, Dawn recalled the types of growth patterns that she observed between two plants. In deciding the type of design to incorporate into her clay piece, Dawn compared her observations of horsetail and nettle. She counted the branching that she observed in each of the plant relatives. Dawn also began to conceptualize why particular plants grew the way they did (e.g., exposure to sunlight) and to explore the type of relationships the surrounding plants had with each other. Furthermore, Dawn's engagement throughout the walking activities was grounded in reestablishing relationships with plant relatives with an aim to understand the knowledge (stories of reciprocal relations), medicines, and foods that plants can impart and provide to each other and for humans. As a whole, the episode demonstrates how Indigenous youth can engage in meaningful nature-culture relationships where scientific and mathematical knowledge can be constructed as part of an Indigenous knowledge system. The episode also demonstrates the role of story as an integrative part of making practices where multiple relations—such as, among others, the fulfillment of the purpose that Indigenous people have in relation to the physical world, connections to ancestors, engagement in a millenary practice, and noticings of patterns in nature—can be established.

In the post-camp reflections and interviews, Dawn and many other of the students described the meaning of their engagement across the walking and making activities as being formative experiences. For many Indigenous youth, the practice of making as a continual cultural practice and the enactment of nature-culture relations provided opportunities for youth to assert culturally based ways of being and doing. By engaging in historically rooted Indigenous practices of making, clay making was reclaimed as an original technology that continues to play a central role in the way Indigenous people manifest their relationship with the land. Indigenous youth remarked that engaging in clay making, in the same form as their ancestors had done, gave them a greater sense of responsibility for maintaining strong cultural ties through Indigenous-based making activities.

From our perspective, we interpreted this to mean that the making and observational practices represented a resurgent and humanizing form of contributing to the physical and spiritual well-being of their own communities.

It is also important to note that through Dawn's engagement with making she engaged in a variety of academic disciplines. For example, through the walking activities and her ongoing observations of plants, she also deeply engaged with mathematical concepts (e.g., patterns, symmetry) as part of her observations. This contrasts significantly with school-based western conceptions of separate academic domains, which suggest that academic disciplines can be learned separately from each other. While making, more broadly, may afford this kind of interdisciplinary work, we note that this is particularly important for Indigenous ways of knowing, causing making to be potentially fertile ground for such learning.

Figures 1.1 and 1.2 provide visual examples of clay work that demonstrate such learning. A clay bowl made by a ten-year-old Yakama girl named Lisa (fig. 1.1) shows the patterns mentioned in a Yakama Nation story. In the story, a young Yakama girl learns to make baskets from grandma cedar. The young girl in the story also learns to incorporate patterns from animals and the lands. The clay piece shows the diamond pattern learned from a snake and the triangle shapes from the mountain.



Fig. 1.1. Lisa's bowl with patterns from a Yakama Nation story

Rachel, a twelve-year-old who is Kiowa, Creek, and Cherokee, made a clay piece (fig. 1.2) focused on narrating the presence of otters in waters where otters had not been seen for many years. The first iteration of the otter was conceived as a storyboard on a two-dimensional flat piece of clay representing a linear story progression, but by the third day the concept of the otter story had evolved into a three-dimensional piece (e.g., an otter incense burner) that would be used to retell the story of otters (e.g., the elimination and return of otters in the region) and for the purpose of family and community prayer for living things including animals, plants, and water.



Fig. 1.2. Rachel's piece relating the story of otters

## ■ Indigenous Making: Implications for Equity and Mathematics Learning

The work that has taken place in the ISTEAM camp and our efforts to document youth restoring relationships with land, water, and communities serve as an initial articulation of how Indigenous making can expand understandings of equity and mathematics learning. We have presented an example of how making is a cultural activity that reflects particular epistemic practices that have consequences for how Indigenous youth engage with materiality and nature. Furthermore, we have made explicit the ways in which young people draw from walking and storytelling pedagogies in making. From our perspective, Indigenous making is about living nature-culture relations to establish futurity and as a direct refusal to Indigenous erasure.

In light of the design of the clay making and walking activities, engagement with Indigenous making practices suggests that scientific and mathematical knowledge is not separate or divided from a cultural activity, as seen in western thought and practice. That is, the construction of mathematical knowledge is an embodied practice in making and a part of a knowledge system. For us, engaging in mathematics learning in this way removes the imminent threat of erasure that educational spaces often impose on Indigenous people. Compared to school-based approaches to teaching mathematics, which is taught as its own discipline, productive disciplinary engagement from an Indigenous perspective can do more than teach children mathematics. Indigenous-based conceptions of making can also establish the permanence of Indigenous people as continual producers of knowledge by creating opportunities for Indigenous people to engage in interdisciplinary activity within a knowledge system that embraces nature-culture relations.

As we envision what it means to humanize mathematics, we need to be cautious of the foundational relationships that are implied or enacted in humanizing paradigms that reinscribe western forms of nature-culture relations. We also caution that trying to fit or impose Indigenous knowledge systems into western conceptions of knowledge means maintaining asymmetrical power relations and reproducing inequities and dominance. In closing, equity in mathematics education is more than providing access to normative conceptions of mathematics. Equity in mathematics education, from an Indigenous perspective, means creating spaces that contribute to the “collective continuance” of Indigenous communities (Whyte 2004). While this may include ensuring Indigenous youth can master dominant forms of mathematics, it must also mean that they are not

dominated by them and that they have opportunities to engage in mathematics that contributes to our own ways of knowing and making mathematics.

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