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SIGHTS AND SIGNS OF TRANSDISCIPLINARITY: DISRUPTING DISCIPLINES THROUGH ART AND SCIENCE INQUIRY

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Abstract

Sights and signs of transdisciplinarity: Disrupting disciplines through art and science inquiry

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Recent critical literature on science and art education highlights a shift from engagement with disciplinary canons toward expansive, equity-oriented disciplinarity. Efforts to integrate the science and art disciplines, especially under the acronym STEAM (Science, Technology, Engineering, Art and Math), have not sufficiently engaged with such within-discipline critique. Left unchallenged, proposals for disciplinary integration cannot meet the transformative potential to which they aspire. Therefore, this 3-paper dissertation adopts an anti-colonial lens to explore conceptualizations of art and science inter- and transdisciplinarity as a collection of interconnected stories of disciplinary reimaginings. Drawing from multiple theories and methods, this dissertation aims to demonstrate the possibilities of transdisciplinarity conceptually, methodologically, practically, and personally.

The first paper critically examines current discourse trends that mention transdisciplinarity efforts in K-12 schools, specifically in curricular activity that seeks to expand science learning through the arts. It offers a critique against flattened ways of being and knowing present in schooling and aims to put forward considerations for critical and creative transdisciplinary curriculum development. The second paper presents a vertical case study that investigates how the purposes of art and science transdisciplinarity are defined by multi-level actors: from the macro national and city policy level to that at the microlevel of an art and science museum. Using critical discourse analysis alongside Bakhtin's concepts of centrifugal and centripetal forces, this study identifies how the purpose of transdisciplinary learning is

reproduced and reimagined through discourse at multiple scales. Tensions arose in the pull of how transdisciplinarity was conceptualized, particularly between board members and staff who felt different responsibilities for aligning with national discourse. Finally, the third paper is an autoethnographic study weaving together personal narrative, theory in the arts and cultural studies, and student work from one summer art and science program. Grappling with the art/science disciplinary dichotomy, this last paper troubles framings of the human-nature divide through material inquiry into place. In the discourse of critique and iterative making, the class community follows one student's movement in a relational encounter with an ant as a disruption of enduring dualisms that signify Cartesian logic.

In memory of my Grandma Faye and mi abuela Mireya
two creative *makers* who persevered out of love for their family

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I love hands. In fact, it gets me in trouble. Instead of listening sometimes I am just taking in your hands – your fingers, their expressive punctuation to what you are saying, the meatiness or delicate lines, the chosen polish or grit. There's also something to the open palm, ready to accept an offer or quickly grasp tight. I thought this drawing from my sketchbook a fitting metaphor for all those that have taken my hand over the years. Some gently placed a tool in it, or a book, or a kiss. Some pulled me from here to there by holding on tight and leading the way, and others held it in comfort. I have been touched by so many and there is no way to thank everyone because this journey does not begin with enrollment and end with graduation. It began many years ago, and already I am feeling the tug of tomorrow. This next section is therefore extremely partial.

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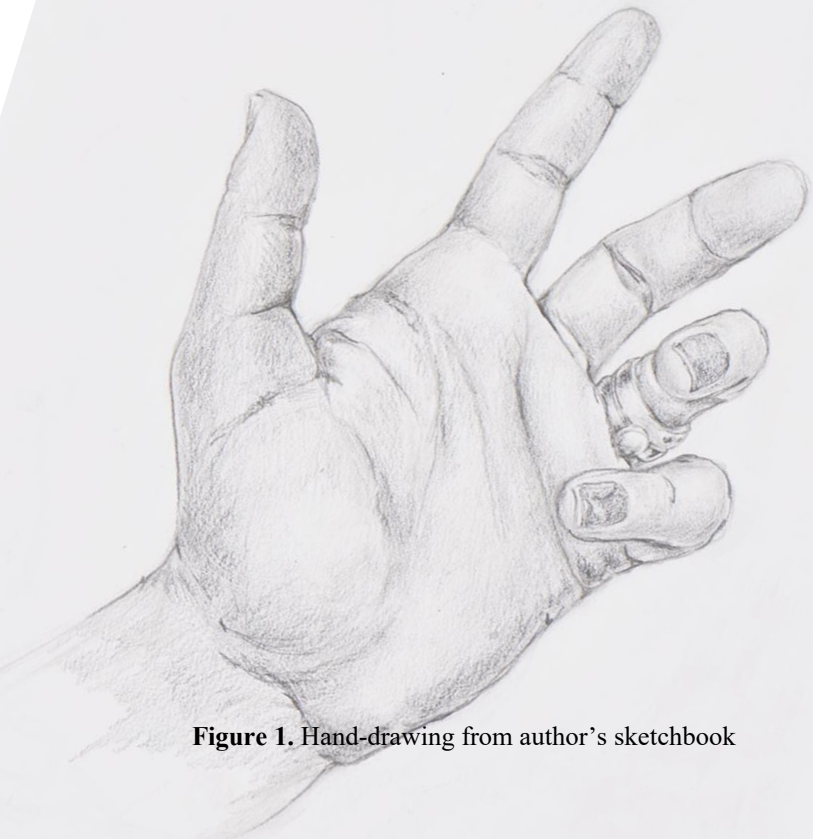

Figure 1. Hand-drawing from author's sketchbook

My beautiful family, you all inspire me so much. Mom and Papi, you two helped me love teaching and making things and responding to the world in continual alignment to an ethic of love, care, and compassion. Mireya, Esther, Jonathan, David, Daniel and Christopher - I have no doubt I chose you all to be my teachers and guides and I have much still to learn from you. Our differences made up my earliest moments of understanding multiplicity and learning how to both love hard and disagree. Thank you for your patience as I grow with you into our adult selves and families. Your kids help me learn everything all over again. They give me hope and motivation to keep working toward a world of justice and freedom. And for a life in harmony with the more-than-human world that I hope they can enjoy too.

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in gratitude for the chance to do research

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heartfelt experiences. Richard, "essential for some, good for all". It's simple but seems to take all our efforts to get us there.

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Chapter 1 – Introduction

Thomas King, in *The Truth About Stories*, tells us, "you have to be careful with the stories you tell. And you have to watch out for the stories that you are told" because within those stories are relationships that "define the nature of the universe and how cultures understand the world in which they exist" (King, 2003, p. 10). We, as educators, are tellers and makers *of* stories. We share stories about why we are in schools, who schools are serving, and why they are important. We share stories about learning, what it is and how we measure success. We also tell and are told stories about the problems in the world and how education – through formal institutions and informal contexts – might address them. Whether implicitly or explicitly, our stories construct the cultures of institutions and frame knowledge systems, such as what comprises legitimate science and the elements of beautiful art.

This dissertation extends from the story of disciplinarity, a story that really only begins for us when we go to school. Disciplinarity did not exist for me as a child, and I'm sure it did not for you either. We picked things up, stuck them in our mouths as children do, and began our learning journey with our bodies, through our senses, our hands, and our minds growing together. But as we grew, that discovery process became fractured, stratified, and hierarchically organized – our bodies positioned as distinct from our minds. In schools, how we learned about the world became *disciplined,* organized into separate and siloed, independent departments, compartmentalizing knowledge processes through discrete and unrelated blocks in the day (Dixon-Román, Jackson, Jr., & McKinney De Royston, 2020; Leavy, 2011; M. Takeuchi et al., 2020). These blocks also build a version of learning and knowledge that points to larger

sociocultural values and priorities (Bang, Warren, Rosebery, & Medin, 2012; Vossoughi & Vakil, 2018).

Recent critical literature on science and art education highlights a shift from engagement with disciplinary canons toward expansive, equity-oriented disciplinarity (Bang, Marin, & Medin, 2018; Gaztabide-Fernandez, Kraehe, & Carpenter II, 2018; Na'lah Suad Nasir, Rosebery, Warren, & Lee, 2014; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). Efforts to integrate the science and art disciplines, especially under the acronym STEAM (Science, Technology, Engineering, Art and Math), often do not sufficiently engage with such within-discipline critique and possibility. For example, in an introduction to a special issue on arts integration in the Learning Sciences, Halverson & Sawyer (2022) write, "STEAM is a newer and more sophisticated version of arts integration; the new acronym describes pedagogies that transform classes in science, engineering or math by integrating arts practices such as dance, theater, or visual arts" (p .3). Left unchallenged, proposals for disciplinary integration are unable to meet the transformative potential to which they aspire. Such arguments do not engage with whose disciplinary knowledge is legitimized or how institutional hierarchies across disciplines impact design for classrooms where deep learning can occur. Therefore, this 3-paper dissertation adopts an anti-colonial lens to explore conceptualizations of art and science inter- and transdisciplinarity as a collection of interconnected stories of disciplinary reimaginings.

Telling a different story about how we might organize learning and consider knowledge generation will require that we think across disciplinary process and production boundaries, as well as account for the political and ethical dimension of how and for whom that knowledge is produced (Philip, Bang, & Jackson, 2018). Jasanoff (2015) states, "our sense of how we ought to organize and govern ourselves profoundly influences what we make of nature, society, and the

'real world'" (p. 3). A deep understanding of global issues – even when examined at a local scale – necessitates awareness and critique of the ideologies which create, contribute to and maintain such issues in society. Yet doing so calls into question White, Eurocentric relational orientations which organize ways of learning and creating knowledge (Bang & Marin, 2015; Guyotte, 2020; Mignolo, 2009; Mignolo & Walsh, 2018; Warren, Vossoughi, Rosebery, Bang, & Taylor, 2020; Zavala, 2016). Hence, through this lens, transdisciplinarity becomes a pursuit of knowledge across disciplines examined first through a historicization of disciplinarity.

Overview of Dissertation and Research Questions

In this dissertation, I work across time and scale, from changes in the theory over time and place to the vertical alignment between national policy and one non-profit to the micro-interactional moments of an art and science class. I propose that reaching the expansive horizons of possibility promised by transdisciplinary teaching and learning will require pedagogical practice centered on heterogeneity and attuned to entangled historical, cultural, political, and value-laden ideologies (Patel, 2016b; Rosebery, Ogonowski, DiSchino, & Warren, 2010; Stetsenko, 2018; Warren, Vossoughi, Rosebery, et al., 2020). Through the three papers that comprise this dissertation, I investigate where and when disciplinary tensions and contradictions arise, how they are negotiated and by whom, and what aspects of program design commitments create openings and disruptions to hegemonic disciplinarity. Additionally, I work from the presupposition that transdisciplinarity does not only happen between science and art. It can and does happen across all disciplines. For this dissertation, however, I look specifically at science and art as they represent an archetypical dichotomy of ways of thinking and because they are the spaces with which I have most consistently been in conversation.

The first paper, "Critical and creative transdisciplinarity: Making arrangements for multiple ways of knowing and being," critically examines current discourse trends that mention transdisciplinarity efforts in K-12 schools. I focus on curricular activity that seeks to expand science learning through the arts. It offers a critique against flattened ways of being and knowing present in schooling and puts forward considerations for the design of critical and creative transdisciplinarity.

The second paper, titled "Changing the word or changing worlds? A vertical case study of art and science transdisciplinarity," presents a vertical case study that investigates how multi-level actors define the purposes of art and science transdisciplinarity. In it, I shift perspectives between the macro national and city-specific policy level to that at the microlevel of an art and science museum. The central question I focus on in this paper is: *How do educators, staff, and board members at SAIM reflect and reimagine broad policy discourse about the purposes and potentials of transdisciplinarity?* Taking up critical discourse analysis alongside Bakhtin's concepts of centrifugal and centripetal forces, this study identified how a neoliberal purpose of transdisciplinary learning is reproduced and reimagined through discourse at multiple scales.

Finally, the third paper, "Disciplinary Disruptions in time and place: An autoethnography of Art-Science Learning," is a study that collages personal narrative and theory in the arts and cultural studies with student work from one summer art and science program. In it, I asked: *How do I and others experience transdisciplinary nature-culture encounters associated with art and science inquiry?* Through material inquiry into place, this last paper troubles framings of the human-nature divide by grappling with the art/science disciplinary dichotomies. In the discourse of critique and iterative making, the class community learns together from one student's movement in a relational encounter with an ant.

Coming to terms with terms

In the three papers, I center considerations for pedagogical design grounded in assumptions of how I understand learning to happen. I include the following section on terms as it is important not to assume shared understandings of such words as learning, culture, art, and science. The ways we as researchers and educators conceptualize art, science, and transdisciplinarity impact the work it does in the world. Our conceptualizations are also entangled with a linked set of values. I ground my study of transdisciplinarity in sociocultural theories of learning and cognition, which consider participants' cultural, contextual, and everyday sense-making.

Sociocultural theory of learning, culture and learning

My beliefs about learning are founded on critical sociocultural theories that emphasize the importance of the cultural contexts in which activities and learning occur (Cole, 1995; Esmonde & Booker, 2016; Nasir et al., 2014; Rogoff & Lave, 1984). By cultural contexts, I follow Nasir et al. (2014) to mean the practices that communities have developed and are continuously changing across time through joint activity organized around shared beliefs and values. It includes the varied ways we engage in the world and make sense of our experiences across the many spaces in which we live our lives, including both at school and our everyday spaces beyond school (Warren & Rosebery, 2011). We develop cultural repertoires based on "where you show up and within which local communities of practices you participate most actively" (Erickson, 2020, p. 570). It is important to note that I do not mean that individuals are culturally uniform across social categories, such as through membership across nations, religions, race, or ethnicity – what is often referred to as essentialism. Rather, culture is dynamic and variable within and across groups who share history, language, and cultural identification

(Medin & Bang, 2014). What this means for this dissertation is that I understand learning in the science and art disciplines as connected to the values and knowledge-building practices of the communities through which students maintain central positions of participation.

Sociocultural theory makes critical moves away from an understanding of human development that focuses on habituated responses to one's environment or genetically inherited behavior patterns (Bang, 2015; Cole, 1995). Rooted in Vygotsky's theory of learning as situated and distributed, sociocultural theory emphasizes that cultural (conceptual and material) artifacts mediate human activity by altering the relationship between people and their world (Esmonde, 2017). This significant move expands ideas found in cognitive psychology of learning and knowledge residing in an individual's head. Cognition, in this sense, is "a public, social process embedded within a historically shaped material world" (Goodwin, 2000, p. 49). Importantly, learning and cognition are tied to contexts and the everyday experiences and practices in which they are put to use (Vossoughi & Gutiérrez, 2017).

Additionally, researchers working through sociocultural theory acknowledge learning is connected to the values and knowledge-building practices of the communities through which they centrally participate (Gutiérrez & Rogoff, 2003; Nasir & Hand, 2006). Hence, I see learning as a culturally mediated activity with roots in social life. There is a dynamic relationship between an individual's goals, values, beliefs, and practices activated through interaction with their surrounding environment. I recognize that students come to know the world through cultural forms of participation that are inseparable from ways of being in the world (Stetsenko, 2018; Warren, Vossoughi, Rosebery, et al., 2020). Researching the design of learning environments, thus, requires attending to interactions between individuals in everyday contexts, as well as the tools, language, and artifacts that mediate participation. Art and science environments have the

potential to offer knowledge-building resources different from singular disciplines alone that make room for unique types of learning to unfold.

Science, Art, and Making

I regularly use the words science, art, and making throughout each paper. These words come with histories of language in use (Bakhtin, 1981) and are dynamic, representing different ideas in varied contexts and cultural discourse. As traditionally carried out in schools, science practice embodies the subject-object separation of Western Enlightenment. It is grounded in epistemological orientations and practices that privilege rationality, precision, formality, deductive reasoning, detachment, and objectivity as imperative for finding universal truths (Stetsenko, 2018; Warren et al., 2001). Many have written about how science education fails to account for the sociocultural aspect of learning. Instead, there is often a "disconnect between scientific and social worlds," particularly what counts as science and who can be a scientist (Davis & Schaeffer, 2019, p. 367; *see also* Bang & Medin, 201; Nasir, Rosebery, Warren, & Lee, 2014). Many studies place accountability for disparities across different student populations in STEM courses and careers on restrictive science practices, particularly for Black, Brown, and Indigenous youth and women (Barton, Tan, & Rivet, 2008; Barton & Tan, 2018). Critiques of science education have also noted a lack of focus on sociopolitical contexts, suggesting that "the relationship between science and social justice is fraught" (Morales-Doyle, Childress Price, & Chappell, 2019). Much science education fails to account for the problematic contributions of science, such as legacies of measurements of racial difference, the devastation of land and culture through weapon development, and exploitative and extractive relationships with people and the more-than-human world (Bang & Medin, 2010; Morales-Doyle et al., 2019; Vossoughi

& Vakil, 2018). Generative work has begun among scholars actively working to account for the histories through which the disciplines have been and continue to be constructed.

The framing of science learning most closely allied with my efforts in transdisciplinarity work is grounded in onto-epistemic heterogeneity from a sociocultural perspective (Warren, Vossoughi, Rosebery, et al., 2020). I recognize that science learning happens beyond the institutional context *and* through varied subject-subject, subject-object relational arrangements. Resisting settled forms of science disciplinarity recognizes the contestation, variability, and venturing into the unknown that is integral to science.

The arts are distinguished in the learning landscape for their capacity to foster a connection between representation and communication of ideas that foregrounds the subjective experience of the world and personal inquiry. In schools, the arts typically involve visual analysis of masterworks and contemporary artists alongside opportunities to produce artifacts (Burton, 2000, 2016; Halverson & Sheridan, 2014). Additionally, this activity has often grounded the construction of meaning through the elements (i.e., line, shape, color, form) and principles (i.e., composition, harmony, balance) of art. It sometimes extends to the study of music, dance, theater, and media arts. Through form, concept, and materiality, the arts can provide an opportunity to individually and collectively explore relational knowing through identity and material-rich culture (Burton, 2016; E. R. Halverson & Sheridan, 2014).

Yet the arts, too, fall under scrutiny. What constitutes "the arts" has received thoughtful, critical attention in the last decade through the application of the tenets of critical race and anti-colonial theory (Castellano, 2019; Gaztabide-Fernandez et al., 2018; Gaztambide-Fernández, 2014). Dominant framings of arts education and what it means to be an artist prevalent in schools have been shaped by values and aesthetics dating back to the Renaissance, conceived (and then

exported) on Eurocentric terms. Gaztambide-Fernandéz et al. (2018), for example, writes that "'the arts' and what it means to be an artist are profoundly shaped by racial logics and racist assumptions (p. 2)". These are predicated on Eurocentric understandings of culture and culture production that become invisible through their dominance (*see also* Ahtone, 2019; Barajas-López & Bang, 2018; Vossoughi, Hooper, & Escudé, 2016).

Art educators (including teaching artists) often find themselves working in the tension between arguments working to frame the benefits of the arts. One view poses the contribution of the arts is to foster cognitive development in varied academic subjects. Another view suggests value is found in the inherent expressive and affective oriented processes that can build community, identity, and reflexivity through the arts (Burton, 2016; E. Halverson & Sawyer, 2022; Hetland, Winner, Veenema, & Sheridan, 2013). Gaztambide-Fernández (2013) cautions that arguments for the arts should be engaged discursively to "examine the ways in which claims are made, the assumptions that support such claims, and the social rules and relations that enable some people to make claims about particular kinds of practices to particular ends" (p. 215). In other words, arts education is a field that must reckon with the sociocultural practices of creativity and the political motivations embedded within different making activities. In my own work with arts learning, I work toward a pedagogy that creates opportunities for students to engage with personal modes of symbolic creation as individual and collective meaning-making, particularly those alienated by a framing of the arts as primarily sanctioned through institutional discourse.

Making has been taken up in science and education literature, growing from informal learning environments into formal school settings. It is often presented as a tool for engaging non-dominant populations in material-rich STEM-oriented learning activities (Barton & Tan,

2018; Wohlwend, Keune, & Peppler, 2019). It tends to involve either analog (i.e., cardboard, recycled materials) or digital (i.e., 3D printing, laser cutting, electronics) tools and materials to address real-world problems through a constructionist approach to sense-making. *Making* has also received critical attention given its rise from and popularization in and through the Maker Movement. For example, Beuchley (2013) critiques early introductions to Makerspaces in schools that failed to engage with how making upheld primarily White, male, middle-class values. Beyond who is included as a maker, Vossoughi, Hooper & Escudé (2016) interrogate what is recognized as making, citing limited conceptualizations of ingenuity and technology presented in "maker literature". By putting the purpose of making activities secondary to process, they also demonstrate how corporate and military ideologies can be overlooked.

The people engaged in this dissertation's science and art learning spaces did not all refer to their efforts as transdisciplinary. They interchangeably used *arts-integration*, interdisciplinarity, transdisciplinarity, STEAM (Science, Technology, Engineering, Art and Math), and *making.* Yet all were clear to mark the experiences created as distinct from science or art learning. Figure 1 is a typical representation used to designate how transdisciplinarity differs from mutli- or interdisciplinarity. Transdisciplinarity tends to be distinguished from a) disciplinarity that remains within the established practices, beliefs, and values of a single discipline, and b) multi-disciplinarity that involves multiple disciplines but remains grounded in the methods and practices of each respective home discipline. Interdisciplinarity also approaches topics from multiple disciplines yet brings the methods of one into the other, working at the edges or between the disciplines (Marshall, 2014; Leavy, 2011; Takeuchi et al., 2020; Nicolescu, 2010; Klein, 2015).

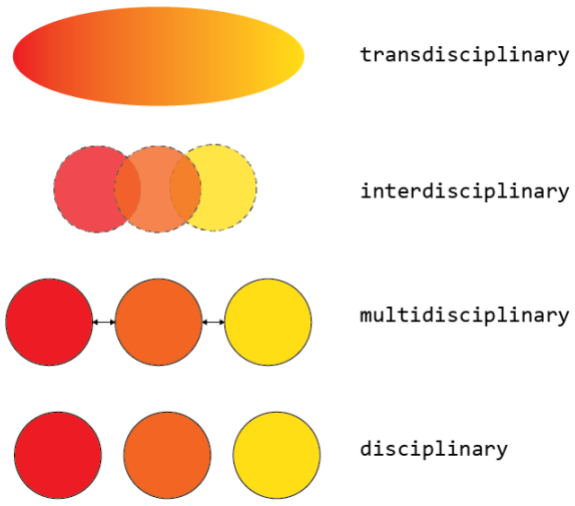


Figure 2. Representations of Multi-, Inter-, and Transdisciplinarity (variation of image credited to Emily Nastase, nature.com, and found in Darian-Smith & McCarty, 2016)

Art and science – as distinct disciplines – are often invoked to delineate a timeless knowledge binary, with one end of the spectrum as objective and rational, and the other as subjective and interpretive (Dixon-Román et al., 2020). Much of the literature on art and science inter- or transdisciplinarity takes on disciplinary definitions aligned with institutional framing. Work is presented as equity-oriented in that taking up the arts, most often as *making*, opens a pathway to engagement with science practices (Barton, Tan, & Greenberg, 2016; Bevan et al., 2019; Kafai & Peppler, 2011). A second body of literature explores the convergence of skills required for successful participation in the arts and the sciences (Blikstein, 2013; Marshall, 2014; Root-Bernstein, Pathak, & Root-Bernstein, 2017). For instance, Root-Bernstein et al. (2017) highlight twelve art/design practices that bridge to science practices, including what they call mental skills such as observing, imaging, abstracting, pattern forming, modeling, transforming, and experience with materials, tools, and methods. While I engage with these ideas in greater depth in the dissertation papers, I want to state that I follow literature that works explicitly to desettle disciplinary structures through integration, dislodging normative practices in ways that

can expand within and across disciplinary ways of knowing and being (Warren, Vossoughi, Rosebery, et al., 2020).

A Reflection on Responsibilities

In-between spaces have long drawn my attention. I explore this more extensively in the third paper of this dissertation. The blurred lines of dichotomies that emerged for me – through experiencing racialization, classism, and disciplinary narrowing – caused me to question the implications of who and what such categorization serves, how categorization can violently divide and destroy, and what it means to live well together into the future. As I grew to understand constructions of society that manufacture difference with a negative valence, teaching and learning became a political act for me, a conscientización (Freire, 1970), and a desire to counter hegemony with complexity, and flatness with an always uneven texture.

As I spiral into greater self and world awareness, I have further confronted that my whiteness, my English-language-first, my navigation of upper- and middle-class worlds – foreign as they might have been to me – have granted me a fluidity to move in powered spaces. I have been allowed into spaces closed off from others, labeled both as a white woman and as a person of color. This, for me, has increasingly become a great responsibility. Tuck and Yang (2012) emphasize that being a multi-ethnic, minority status citizen in an imperial nation is a privilege. They describe a *move to settler innocence* as taking a stance of "the other" within efforts at decolonizing work, either through claims to a mixed ancestry or immigrant status, while simultaneously enjoying the benefits of settler privilege (citizenship). This furthers the suppression and erasure of Indigenous voices and knowledge, and most importantly, efforts for land sovereignty. In this study, I situate my responsibilities in learning to break institutional cycles that are harmful to students, teachers, and researchers, particularly the populations whose

ways of knowing and being have been delegitimized in powered institutional settings. I ask, *How do we bring together values, beliefs, ideas, and knowledge systems within a powered and pluralistic world*? To answer this question includes working to understand what kinds of learning are made possible through the conditions I am a part of setting in motion. It includes revealing how the purposes for learning are framed in different contexts such that the dignity and thriving of all human and non-human beings are valued. It includes maintaining vigilance to the tendencies toward erasure and appropriation of non-Western cultural resources, including scholarship, that exist in precarity with anti-colonial research.

This dissertation is an effort to work against a colonial narrowing of knowledge. In writing, I take up the language, ideas, and research of Indigenous, Black feminist, diaspora, and Latinx scholars. In some ways, this is to become a subordinate settler, as described by Tuck and Yang (2012), neutralizing the aims and goals of such scholarship as I potentially benefit by staying within the boundaries and behaviors that have excluded the participation and recognition of those who are not white. With this complexity in mind, I hope to engage with the ideas to amplify versus replace, and to listen and learn. Mignolo's (2014) words resonate for me as he proposes:

> We, all of us in the world who have been educated at least at the level of secondary school, are trapped in the Western epistemic and hermeneutical vocabulary. That is not tragic. It is necessary to introduce new concepts, like Fanon's sociogenesis. But it is necessary also to work with existing ones in order to de-naturalize them or, if you wish, to decolonize them. Once you accept this fact, you work from given concepts and look behind and under them. (p. 202)

Looking behind, looking under, from a place of gratitude and also a place of politicization. Through this dissertation work, I hope to explore, interpret and expose the political present in conceptualizations of transdisciplinarity, noticing the spaces which can work against over-simplification, smoothing, and erasing.

Chapter 2 - Critical and creative transdisciplinarity: Making arrangements for multiple ways of knowing and being

Introduction

It does not take much to realize that existing disciplinary structures in schools suggesting how knowledge *should be* organized and categorized (e.g., science, English language arts, mathematics) are insufficient to address the complexity of the world we live in. A pandemic such as COVID-19 makes it impossible to ignore the interconnected nature of our lives. Such global issues reach across distinct knowledge domains to impact the fields of microbiology, politics, economics, criminal justice, education, and, of course, health. Consider another example from my home state, the forest fires that burned through California. Online, former President Trump tweeted it was due to not cleaning the forest floors. There was a shortage of firefighters to fight forest fires on the ground. The shortage was due partly due to fact that the state relies on the labor of people who are incarcerated to fight wildfires, a population highly impacted by federal response for access to healthcare during the COVID-19 pandemic (Fuller, 2020). Others linked fire surges to record high heats connected to climate change. At the same time, an amplification of activist voices called out the suppression of Indigenous knowledges that could manage fire, such as the local Muwekma, Pomo and Ohlone, knowledge that has been lived and elaborated on intergenerationally through years of living as stewards of the land. A singular disciplinary perspective limits our capacity to see the interconnection of many systems, as well as the ways of thinking required to address the complexity of issues such as forced migration, poverty, water scarcity, climate change, and pollution.

Over time, there have been multiple education efforts to reform learning by combining disciplines so that young people can address local and global issues (Mansilla & Lenoir, 2010).

Yet these reforms have not altered the dominant structures of siloed disciplinarity at the heart of school learning (Stevens & Ramey, 2020). A deep understanding of global issues – even when examined at a local scale – necessitates awareness and critique of the ideologies which create, contribute to and maintain such issues in society. Transdisciplinary pursuits are often presented as an antidote to singular disciplinary modes as a means to address complex problems. Yet such propositions leave out the construction of disciplinarity itself as a focus of analysis, a critical element that can contribute to the stories of liberatory possible futures. Such omission effectively upholds hierarchical assumptions about the organization of knowledge systems (construction, production and expression) and their associated axiology. For transdisciplinarity, in any form, to be transgressive, it will require a disruption to hegemonic narratives about structures of knowledge production. This includes examining how we come to know, what has been canonized as essential to know, the physical and theoretical place of schooling, and the pedagogies that constitute teaching and learning within multiple contexts.

In this paper, I address how transdisciplinarity, when left as an ill-defined construct, can be mobilized for varying purposes, often in contradiction to the transformative goals put forward. I begin by highlighting conceptualizations of transdisciplinarity that have emerged in the field of education. I then and further how it is being taken up in science and art education literature today, particularly given the growth and ubiquity of the rhetoric of Science, Technology, Engineering and Math (STEM) in schooling contexts, and from that STEAM (add the arts). I then propose a set of considerations that frame transdisciplinarity through an anti-colonial lens as a prerequisite to reaching for the expansive and liberatory goals of transdisciplinary efforts (Warren & Rosebery, 2011; Warren, Vossoughi, Rosebery, et al., 2020).

At one time, I may have considered this a project of epistemological decolonization. Yet Tuck and Yang (2012) warn of the too-easy adaptation of decolonizing discourse that results in the enclosure and further perpetuation of colonization. They write, "decolonization specifically requires the repatriation of Indigenous land and life. Decolonization is not a metonym for social justice" (p. 21). In describing an ethic of incommensurability, Tuck and Yang (2012) focus on recognizing what is distinct about projects of decolonization versus aligned or allied, in order to actively unsettle efforts in research and practice that become enclosed as normative and assimilative. To that end, I situate this paper in scholarship from the arts and sciences that position their work through decoloniality and anti-colonial understanding of schooling.

From Disciplinarity to Transdisciplinarity

As a model of modern education, the Western university is based on the creation and maintenance of disciplinary borders. Disciplinarity, as it is commonly defined in schools, suggests an organization of tools, processes, and language grouped based on ostensible similarity, which allows humans to "participate in complex conceptual and representational practices" (Takeuchi et al., 2020, p. 1463). In this sense, disciplinarity can be argued as productive in allowing for continued deepening of specialized communication about and within a singular system of knowledge (Leavy, 2011). Disciplines operate as sites of knowledge production with rules for knowledge-building practices that are constructed through shared assumptions and worldviews. Over time, some disciplinary codes and processes become normalized through repetition and are taken as natural (e.g., the scientific method). Specialization further narrows disciplinary structures as subdisciplines (i.e. microbial genetics) create more specified language within the broader domain.

While shared disciplinary language allows for efficient communication, it is also limiting and requires maintenance. Disciplinary borders are defined and patrolled by disciplinary members who ensure a specific "ritualized or coded way of building, evaluating and disseminating knowledge" (Leavy, 2011, p.16). Disciplines can be hegemonic, constraining and controlling non-normative forms of knowledge production. Ways of knowing (epistemologies) and ways of being (ontologies) that fall beyond or contest what has calcified as central tenets of a discipline become further marginalized and devalued from the dominant practice (Leavy, 2011). McKittrick (2021) states, "Disciplines stack and bifurcate seemingly disconnected categories and geographies; disciplines differentiate, split, and create fictive distances between us" (p.36). As a function of the modern university and schooling system, disciplines are an organizational structure that should not be taken as natural or inevitable.

Transdisciplinarity, as it is often used in K-12 settings, suggests a *new,* emancipatory way of thinking beyond disciplinary structure. "Only in a transdisciplinary classroom can learning be fundamentally changed—the types of questions asked, the representations made, the materials and practices used, and the way answers are found to those questions would all be expanded by integrating the intellectual frameworks of multiple disciplines" offer Finch, Moreno and Shaprio (2020). Disciplinarity suggests study that remains within a single discipline's established practices, beliefs, and values. Multi-disciplinarity involves separate disciplines in conversations yet remaining apart in their approach to methods and practices of each respective home discipline. Interdisciplinarity works at the edges of disciplines, suggesting a weaving of methods at the overlap between the disciplines (Takeuchi et al, 2020; Leavy, 2011; Marshall, 2014; Nicolescu, 2010; Klein, 2015).

Consistent Calls for Transdisciplinarity

In contrast to the gloss of newness, moving beyond disciplinary boundaries is an enduring critique in the history of formalized schooling in the United States (Mansilla & Lenoir, 2010). For example, at the turn of the 19th century, a group of educational scholars, the Herbartians, pushed for a version of curriculum that prioritized the interrelationships between branches of education. They supported using a "concentration" (i.e. history) as a focal point for other subjects to create unity in curriculum (Kliebard, 2004). Tenets of progressive education in the early 20th century foregrounded learning as a sensory and aesthetic experience that moved beyond passive intake of information and connected to how to live together in democratic society (Dewey, 1934). Alternatively, from the mid-20th century on, transcendence of disciplinary structures and synthesis between knowledge systems within schools emerged in relationship to heightened interest in science and technology. First, the historic moment of the Soviet Union's launch of the satellite Sputnik triggered fear of falling behind in space superiority (M. A. Takeuchi & Marin, 2022; Vossoughi & Vakil, 2018). Competition drove waves of government investment to address what was perceived as an education gap between the US and other countries, spawning efforts to increase the numbers of trained scientists and engineers (Bernstein, 2015). Second, discoveries in quantum physics and mechanics gave rise to theories of complexity and uncertainty, challenging classic models of distinct and separate roles in the relationship between parts and whole systems (Nabudere, 2012). These few examples demonstrate transdisciplinarity, mobilized for multiple ends, are not new, rather they are reoccurring.

Outside of the school context, social critique and conflict in the mid 20th century also fostered motivations for getting beyond the rigid boundaries of school disciplines. The civil rights, second-wave feminist, and the gay rights movements, all sought to disrupt categorical,

often binary, social classifications by placing them in relationship with structures of power and oppression (Leavy, 2011). In the academy, ongoing examination of methods in research design amplified the ways in which non-dominant populations were subjugated and othered by university-based knowledge production (Smith, 2012). These tensions gave rise to transdisciplinary domains outside the sciences that grew in opposition to the Eurocentric academic canon. Programs in fields such as ethnic studies, gender studies, and urban studies amplified non-Eurocentric knowledge systems, working across traditional disciplinary boundaries such as law, philosophy, anthropology and psychology to demonstrate, for example, how constructions of race were created and maintained through social practices (García, 2019; Klein, 2013; Leavy, 2011). Critical movements brought to transdisciplinarity the idea of transgression, a speaking-back to the purity and truth that rigid structures of disciplinarity espoused. These movements named the mechanisms which shaped and controlled access to them as social in origin (Nabudere, 2012). It is important to highlight that educational histories of schooling practices are incomplete. They often do not stretch far enough into educational pasts and presents to examine teaching and learning unbound by the Enlightenment as a starting point for schooling, examining transdisciplinarity tied to alternative ways of being and knowing about the world.

Threads of Transdisciplinarity in the Sciences

Two often-cited schools of thought around transdisciplinarity that emerge from literature in STEM can be traced through a 1970 seminar on interdisciplinarity, sponsored by the French Ministry of Education and the Organization of Economic Cooperation and Development. The conference was prompted by interrogation of how the academy should be organized for new research and knowledge development methods, given growing complexity of global issues

resulting from industrialization (Martin, 2017). One conceptualization of transdisciplinarity that emerged was through the work of Jean Piaget, who conceived of transdisciplinarity as a more developed stage of knowledge production (Bernstein, 2015; Klein, 2007; Nicolescu, 2010). Piaget (1972) elaborated that,

> …we may hope to see a higher stage succeeding the stage of interdisciplinary relationships. This would be "transdisciplinarity", which would not only cover interactions or reciprocities between specialised research projects, but would place these relationships within a total system without any firm boundaries between disciplines" (Organisation for Economic Cooperation and Development, 1972, p. 138).

Much like his stages of development in a child, Piaget imagined hierarchical stages of disciplinary maturity (after interdisciplinarity), resulting in thinking across knowledge structures to lead to a *superdiscipline*. Through his ongoing efforts at the International Center for Transdisciplinary Research and Studies (CIRET), physicist Barab Nicolescu carried forward Piaget's ideas of transdisciplinarity, developing a theory that suggested a shift in the ontology, epistemology, and logic of a disciplinary paradigm. His ultimate aim was to develop a theoretical approach to epistemological synthesis toward a new universality of thought and type of education informed by complexity in science (McGregor, 2015a).

For Nicolescu, trandisciplinarity is a break from modern Western science. He suggests that "the quantum revolution" required a radical rethinking of complete subject-object separation and holds that there are multiple levels of reality, constituted by relationships between those realities (Nicolescu, 2010). Between the level of the subject (interior) and the object (exterior), Nicolescu proposes The Hidden Third – a mediating interface between the first two levels, between information and consciousness (McGregor, 2015a, 2020; Nicolescu, 2018; Augsburg,

2014). Nicolescu suggests that through transdisciplinarity, we might find our way to an education that:

> …could become the privileged place of apprenticeship in the transcultural, transreligious, transpolitical and transnational attitude, of the dialogue between art and science, which is the axis of a reunification between scientific culture and artistic culture. A renewed University would become the place for welcoming a new kind of humanism. (p. 77)

Those who follow a Nicolescuian definition of transdisciplinarity name it as a theoretical approach to challenging the hierarchical relationships of Western universities. They also suggest transdisciplinarity is an attitude cultivated or nurtured in an individual, enabling them to move beyond dichotomized thinking.

Moving in a different philosophical direction, at the same 1970 OCED conference mentioned earlier, Erich Jantsch (1972) proposed trandisciplinarity as a coordination of disciplines linking education to innovation targeting social issues, especially those framed as issues of sustainability. He highlighted that the separation and isolation of knowledges were not enough to foster effective response to complex and dynamic global changes (Klein, 2007; Leavy, 2011).By taking up existing methodologies in the sciences as the primary, essential knowledge system in society, stakeholders and researchers formed partnerships in and outside academia to address global issues and local impact (García, 2019; McGregor, 2015b; Gibbons et al., 1994). The central argument forwarded by what came to be known as the "Zurich School", suggested that traditional disciplinary production of knowledge (called Mode 1 research) has little need for collaboration between scientists and non-scientists (Augsburg, 2014). Rather, the audience is the highly specialized field within which one works. In contrast, Mode 2 research "transcends the boundaries between science and society, integrates disciplinary paradigms, and is strongly

sensible to societal needs" (Martin, 2017, p. 13). In contrast to Nicolescu's more theoretical approach, it was popularized as a more pragmatic approach to addressing complex problems.

The Zurich School's main critique was that disciplines within institutions were driving the study of problems, rather than problems being generated and addressed in specific and local contexts. Weingart (2010), for instance, states, "The emergence of disciplines in the modern sense…implied the shift from occasions arising externally to science for the collection of experience and data to problems for research generated 'within' science itself" (Weingart, 2010, p. 6). The Zurich School emphasized that Mode 2 transdisciplinarity involved trans-sectorial collaboration working on solutions to concrete social problems carried out in the context of application. In describing Mode 2 knowledge production, Klein (2004) cites a project by Fry & Jurt (2000) in which scientists reconciled their views on soil quality and biodiversity with that of local farmers. The work of the Zurich School was not to establish a method, but rather to focus on application and dissemination of transdisciplinary research practices within specific, localized contexts.

The Nicolescian and the Zurich School thread resonate with two of the prevailing schools of thought most commonly invoked when discussing the origins of transdisciplinarity in STEM learning, both explicitly and implicitly. They are certainly not, however, exhaustive. As a whole, use of the word transdisciplinarity is shaped by differing philosophical outlooks, contexts of practice, and views of the sociopolitical function of science and the educational system. Leavy (2011) works toward a synthesis of definitions to highlight that transdisciplinarity (a) involves the collaboration of multiple disciplinary sets of knowledge, (b) is problem-centered, (c) involves stakeholders outside of academia, (d) allows for emergence of new conceptual frameworks outside of any one disciplinary perspective as needed, and (e) requires openness to new ideas.

While these ideas might seem revolutionary for a system deeply entrenched in structures of disciplinarity, there are critical aspects in which these two ways of framing transdisciplinarity fall short of reaching a definition of transdisciplinarity that is truly disruptive.

Epistemological visibility

In critiquing contemporary instantiations of transdisciplinarity, García (2019) offers a critical and decolonial stance that emerged through ethnic studies on the historicization of disciplinarity. He frames that the major issue of literature on the origins of transdisciplinarity can be read through "scholarship visibility," highlighting that "that issue at hand is epistemic absence in mainstream transdisciplinary discourse in relation to critical and decolonial scholars and literature" (García, p. 34). He details the rise and fight for legitimization of transdisciplinary fields such as Ethnic Studies as a disruption to regimes of truth, arguing that Indigenous, Chicana and Black decolonial scholars have long worked as transdisciplinarians. García (2019) cites Parris' (2018) deployment of *creolization*, Rabaka's (2010) transdisciplinary *critical social theory-organic intellectual activism* in Africana Studies, and Anzaldúa's (2002) conception of *nepantla* as transdisciplinary methodology made invisible by siloed forms of knowledge production in the university. García seemingly works toward an answer to a question posed by Patel (2017) "What if a course addressing theories of society studied the work and lives of disciplinarily defiant scholars including Sylvia Wynter, Gloria Anzaldúa, Cedric Robinson, and W.E.B. Du Bois rather than sequencing through theologies?" (Patel, 2017). Independent from one another and collectively, each of these scholars challenges Western, science-centered transdisciplinary discourse. They confront the assumed epistemic inferiority and disciplinary settledness that is the underside of epistemic privilege, a violently ordered, surveilled and continuing ideological project at once pervasive and invisible.

In what follows, I turn first to how transdisciplinarity is being taken up in K-12 education, specifically through scholarship in art and science integration. From there, I build on Garcia's (2019) critique of transdisciplinarity to propose a set of considerations that are necessary to explore in moving toward the liberatory possibilities reached for through transdisciplinary projects.

Science and Art Transdisciplinarity in K-12 Education

In the last two decades, work across disciplinary silos is emerging with force once again in K-12 education research, with early work being called SciArt or ArtScience learning. Root-Bernstein et al. (2011) write, "ArtScience is a new way to explore culture, society and human experience that integrates synesthetic experience with analytical exploration. It is knowing, analyzing, experiencing and feeling simultaneously" (192). With the rising popularity and funding attached to STEM, art and science transdisciplinary curriculum is more recently associated with STEAM learning. Transdisciplinarity is often taken up in a way that suggests a *new,* emancipatory way of thinking about knowledge, inquiry-based learning, and teaching. Without focusing on the limitations of transdisciplinarity as new just yet, it is important to understand that what constitutes transdisciplinary learning experiences remains vague. Forwarding one conceptualization of transdisciplinarity, Guyotte (2019), drawing from Lattuca (2001) states, "Through transdisciplinary education, disciplines 'become subordinate' (p. 7) to broader frameworks and…the boundaries between STEAM give way to the overarching challenges, questions, and discourse" (p. 775). Liao writes that, "the focus is applications to social practices" (Liao, 2016, p. 45). Such arguments highlight a common understanding that transdisciplinarity inquiry begins with complex, real-world problems versus disciplinary content. As a pedagogical practice, disciplinary principles and techniques are activated for the purpose of

solving complex issues. Such arguments echo the Zurich school's pragmatic approach to transdisciplinarity as a problem-focused space in which are instrumentally oriented to solution finding,

Alternative definitions of transdisciplinarity highlight its potential as method for employing tools and practices from different disciplines in physical or abstracted integrated space. For example, Mejias et al. (2020) define transdisciplinarity as "a coequal and holistic integration of theoretical and systematic approaches" that "bring about new ways of knowing that are enabled by deeper integration of knowledge and methods" (p. 212). Marshall (2014), similarly, designates that transdisciplinarity means "a practice or domain that rises above disciplines and dissolves their boundaries to create a new social and cognitive space…where deep integration can be achieved" (p. 106). Mejias et al. (2020) and Marshall (2014) put forward a conceptualization of transdisciplinary as moving toward a new synthesis of research and knowledge creation, a way of thinking about the world. This is made even more explicit by Siler (2018) who writes,

> Advancing the practice of integrative thinking entails realizing the principle of connectivity: that all things (data, information, knowledge, wisdom, ideas, experiences, events, etc.) can be integrated to increase their meaning, purpose and usefulness. That basic realization is one of many keys to unlocking endless innovation. (p. 419)

Transdisciplinary spaces, in an attempt to dissolve disciplinary boundedness, are for many an opportunity, a freedom from rigid scientific procedures or aesthetic judgement. Such conceptualizations echo the Nicolescuian thread that works toward universals, finding commonalities in processes between science and art that can be unified as a new comprehensive

system of knowledge production. Yet what is being considered new often remains grounded in a history of knowledge production that remembers only disciplinary schooling.

At this nascent stage of research on transdisciplinarity as a formal construct in education, much of the literature aims to establish frameworks for understanding an integrated art and science epistemology (Bevan et al., 2019; Costantino, 2018), further develop a typology for different type of transdisciplinary STEAM collaborations (Mejias et al., 2020), or advance pedagogical practices for carrying out transdisciplinary projects (Marshall, 2014, Liao, 2016). Bevan et al. (2019) establish a set of epistemic practices for STEM derived from the National Research Council's NGSS (investigating, sense-making and critiquing practices), and a set of epistemic practices for arts learning (technical & critical, creative and ethical practices). Together they yield epistemic practices at the intersection of art *and* science (exploratory, meaning-making, and critiquing practices) as a combinatory epistemology. Mejias et al. (2020), alternatively, work to map a typology of transdisciplinary STEAM across quadrants (e.g., *instrumental* to *non-instrumental*, *pedagogical* to *non-pedagogical)*. They endeavor to make explicit the theoretical and methodological expansiveness that "speaks to the possibility of elevating transdisciplinary pedagogy more broadly, but that also points directly toward strategies for 'desettling' structural boundaries of meaning-making that privilege in STEM education" (Mejias et al., 2020, p.226). These papers articulate a similar purpose for transdisciplinarity as a way to build "new cross-disciplinary epistemologies of arts and STEM" through approaches that hold "significant potential to increase efforts to decolonize learning spaces, elevate indigenous knowledges, and prioritize equity as policy means and ends" (Mejias et al., p. 226). Yet by not engaging with anti- and decolonial scholarship, they do not push the expansive horizons made possible by foregrounding stories with histories and powers present in an ecology of knowledges.

Further, such projects can reinforce dominant narratives by not explicitly engaging in deconstructing what constitutes science or the arts (Bang et al., 2012; Gaztabide-Fernandez et al., 2018).

In K-12 schools, attempts at transdisciplinarity in the forms of ArtScience, STEAM and making all vary in motivations from discovering universalities of knowledge (i.e. overlaps in process of observation and experimentation in the arts and sciences) as a master synthesis and a theoretical approach, to instrumental motivations extolling the innovative possibility for the purpose of advancing society and the nation or state (as defined by through a singularly Western understanding of progress and modernity) or the development of soft skills necessary for a information age. In order for transdisciplinary efforts, in any form, to be transgressive, they will require a disruption to the hegemonic narrative about structures of knowledge production, from who is an expert, how it is we come to know, what is essential to know and for what purpose, the physical and theoretical places of schooling, and the pedagogies which constitute teaching.

At this point, I turn to my main argument, specifically that a conceptualization of transdisciplinarity that introduces alternative possible futures has to consider its generative, creative potential alongside discussions about the political and powered structures of schooling. Further, a critical and creative transdisciplinarity requires the following: 1) recognition of the limitations of disciplinarity stemming from the legacy of epistemicide that has perpetuated narrowing epistemologies and suppressed ontologies; 2) engagement with onto-epistemic heterogeneity and attuning to heteroglossia of language; 3) engaging with critical interanimation in dynamic contact zones; and 4) valuing science and arts transdisciplinarity as culturally symbolic activity that happens in the many places we move in our lives. Rather than propose a framework, I offer that through such orientations we might together imagine new horizons of

possibility that emerge through complexity and dynamic emergence. I now extend these considerations below and later return to the arguments for transdisciplinarity offered above through the lens of a critical and creative conceptualization of transdisciplinarity.

A Critical and Creative Transdisciplinarity

Disrupting and expanding toward future possibilities of what learning and school *can* be, requires confronting ideas of coloniality, the trace and artifact of colonialism (Mignolo, 2009), and its work as an ongoing educational project. Mignolo suggests through "epistemic disobedience" we can unsettle the finiteness of knowledge and knowledge creation practices, decentering Eurocentric logics as a natural historical starting point (Mignolo, 2009, p.160). To look critically at science and art transdisciplinarity requires recognizing each discipline as value-laden, as actively and purposefully doing things through the set of assumptions that masks the compressed history of disciplinarity itself.

Narrowing epistemologies and suppressed ontologies

In any conversation concerning disciplinarity, it is important to consider the roots of its epistemic and ontological structuring as well as the historical developments that led to its formation and ongoing replication. Grosfoguel (2013) traces the development of a logic that undergirds the contemporary university as a history of the four epistemicides, or four genocides in which multiple onto-epistemologies narrow toward a singular a Eurocentric, Western epistemology. I take time with Grosfoguel's argument because of the persistent legacy of "two cultures" (Snow, 1959) that informs many efforts for integrating art and science. Grosfoguel's focus is on understanding the emergence of what is considered modern knowledge as a production of *the long 16th century*, the years which set the stage for the Enlightenment era, and usher in the rise of Cartesian logics. From there emerge ideas of the scientific logic as superior,

casting as inferior all other cosmologies, or ways of relating to the land, nature, each other and our bodies.

The first of these four epistemicides begins with the killing (physical genocide) or conversion (cultural genocide) of Muslims and Jews from the Iberian Peninsula, solidifying Christianity as the dominant religion in Europe and main source of knowledge. Beyond the killing and removal of people from land who were worshipping the wrong god, libraries were burned, libraries that contained 500 times the number of books than was held in the biggest Christian European library. This was not yet a racial hierarchy that called into question the humanity of its victims, rather it maintained a religious hierarchy – those of any race were accepted as social subjects of the monarchy as long as they converted to Catholicism, with the one goal of unification: "one state-one identity-one religion" (Grosfoguel, 2013). This surveillance and continued enforcement lead to dominance of a Christendom – an ideological position which Grosfoguel separates from the spiritual/religious practice of Christianity – and the logic of ontological and epistemological dualism. This paves the way for a Cartesian philosophy which structures knowledge in Western universities to this day. Grosfoguel writes that:

> This allows for the mind to be undetermined, unconditioned by the body. This way Descartes can claim that the mind is similar to the Christian God, floating in heaven, undetermined by anything terrestrial and that it can produce a knowledge equivalent to a God-Eye view.… not determined by any particularity, it is beyond any particular condition or existence. (p. 76)

A separation of humans from nature, a disembodied knowing/thinking became the basis of how truth claims could be made in the scientific knowledge hierarchy of university research.

The second epistemicide Grosfoguel (2013) describes is modeled after the first, with Christopher Columbus setting sail to the Americas nine days after the conquest of final emirate holding in Spain. Upon his arrival in the Americas, thousands of codices holding the knowledge of indigenous peoples in the Americas were burned, alongside human massacre. From the outside looking in, Columbus described the people he encountered as not having a religion. This becomes a critical point in shifting the religious hierarchy to the racial hierarchy in what is considered modernity. At the time, Christian beliefs supported the idea that all humans had religion, albeit a right or wrong religion. Yet to characterize a group of people as without religion was the equivalent of saying they did not have a soul, and the essence of what it meant to be human was to have a soul. The logic of the argument of humans with and without a soul established enduring beliefs about our separation from nature by setting up the following: 1) If you do not have religion, you do not have a god; 2) If you do not have a god, then you do not have a soul; and 3) If you do not have a soul, you are not human but rather animal-like. Who did or did not have a soul became a first tool of racial domination in the Western/Christian/capitalist new world.

Columbus' writings sparked a debate in Europe during the 16th century to solidify whether or not Indigenous people had souls. At stake in this debate was a justification for enslavement. Enslavement of human beings was understood as a sin in the eyes of God. But without a soul, enslavement would not defy Christin beliefs. Indigenous ways of being were also invoked in this debate. Relationships with the land that didn't involve property and ownership, and markets that sustained reciprocity and distributed wealth over individual accumulation were framed as a deficit and articulated as a lack of sophistication. The question over whether Indigenous people of the Americas did or did not have a soul, or rational thought, was argued in

a Christian theological tribunal called the Valladolid debate (1550 – 1551), the outcome of which would determine Spain's moral right to not only land, but also the labor of those who lived there (Wynter, 2003). Bang (2017) writes of the argument by those in favor of enslaving indigenous people saying, "Indigenous peoples' heterogeneity was collapsed into the category Indian, and simultaneously Indians became expelled from the category of human because of the absence of a god and therefore a soul" (p. 121). What became the winning argument in the Valladolid debate was that the Indigenous people did have a soul yet they were in need of civilization, and it was up to the responsibility of the Church to Christianize them. The logics of religious superiority became the logics of racial superiority: a false Eurocentric geographical orientation homogenized and labeled the Indigenous people of the Americas as "Indians", the first racial identity categorization. Additionally, the first argument in the debate became the underpinning logic that moved from the inferiority of people practicing the wrong religion, to questioning the humanity of people through a community's proximity to nature and religious practice.

The third epistemicide brought the conceptualization of human to a new colonial front, built on the logics of the debates for a soul in Western Europe. Africans, whose land and labor was required by a white and western population for the expansion of a capitalist economy, was also assigned a classification at this time. It was conveniently determined that Africans did not have a soul, which allowed for the ongoing kidnapping and enslavement and system of slavery in the Americas, a replacement for the labor of indigenous peoples. The capture and transport of human beings was not only a genocide, but also an epistemicide as enslaved Africans in the Americas were not allowed to practice their cosmologies, and pass on their knowledges and world views. Through the rise of the natural sciences during the Enlightenment, a supposedly objective biology was used to classify Africans as "below the line of humans" (Grosfoguel,

2013, p. 84). In ways similar to the treatment of Indigenous peoples, African and enslaved peoples were rendered inferior and primitive through their supposed *soul-lessness*. Dixon-Ramón et al. (2020) suggest this constitutes the "racialized logics of colonialism" (p. 321) which continue to plague our society through biological/cultural dualities that reinforce knowledge hierarchies within Western institutions.

Grosfoguel locates the final epistemicide in the persecution of Indo-European women in the 16th and 17th century. Drawing on the work of Silvia Frederici (2004), he parallels the aforementioned suppression and erasure of Indigenous and African peoples' ways of knowing and being, with women who had mastered and passed on ancient Indigenous knowledge, of anatomy, biology, medicine and astronomy, often existing in commune-like economic communities. Their knowledge and economic organization directly contradicted that of Christian authority and early global capitalism based on the accumulation of property/product and the labor force to support its production (Grosfoguel, 2013).

Laid out as such, the four epistemicides effectively erase the onto-epistemologies that are not Christian, Eurocentric and male. This becomes clear in the privileging of subject-object dichotomies rooted in mind-body, human-nature separation, and epitomized in the Western scientific method. Cartesian logics became an exported and universal truth, locking in the soundness of objectivity and the mistrust of a subjectivity governed by the affect of a body in a material world. Art as subjective and interpretive was positioned in contrast to science as neutral and objective. I have taken considerable time on this as a way to understand two points: 1) the narrowing of onto-epistemologies that carry with them worlds and worldmaking; and 2) how a definition for one's humanity, one's soulfulness, became entangled with science practices, science as truth, and the enduring narrative of art and science as cultural dichotomies.

Examining the zero-point

The history of disciplines is the organization of knowledge in the westernized university, moving from one controlled by a theological institution to a post-Enlightenment, secular academic organization. Mignolo (2009) offers that the creation of a geo-historical and bio-graphic starting point set up a racialized "colonial matrix of power" which hierarchically positions and maps the world from first to third, setting up places of thought and "places of non-thought (of myth, non-western religions, folklore, underdevelopment involving regions and people)" (p.161). Universality and domination, entangled with ways of being and knowing, became the officiate of what it meant to be a fully thinking and knowledgeable human. Smith (2012) illustrates the project of coloniality as the outpost of imperialism, stating:

> One of the supposed characteristics of primitive peoples was that we could not use our minds or intellects. We could not invent things, we could not create institutions or history, we could not imagine, we could not produce anything of value, we did not know how to use land and other resources from the natural world, we did not practice the 'arts' of civilization. By lacking such virtues, we disqualified ourselves, not just from civilization but from humanity itself. In other words, we were not fully human. (p.26)

The categorization of who could be counted as human, connected to ideas of who could be educated and molded into the European ideas of "civilization," was the foundation upon which people, and their ways of knowing, were and continue to be subjugated. Mignolo, interviewed by Gaztambide-Fernández (2014), clarifies that "coloniality describes the hidden process of erasure, devaluation, and disavowing of certain human beings, ways of thinking, ways of living, and of doing in the world" (p.198). Imperialism, knowledge, and research became linked through the ways science has been used to justify hierarchies of knowledge and valuation of different

knowledge systems, and has further become a "regime of truth" (Smith, 2012) which forms the boundaries of what is accepted and passed on in schools.

This disciplinary endurance remains with science framed as objective and true and neutral, while art (and the humanities more broadly) are subjective and felt, tainted by the interference of an embodied, subjective context. It forms the basis for how and what continues to be taught in school, through what Escobar (2016) refers to as a one-world world (OWW), with all other possible worlds subjected to one world view. This is what Sousa Santos (2014) calls monocultures of knowledge linked to "linear time of progress, naturalized inequalities, the dominant scale, and the productivism of economic growth and capitalist development" (p.21). Modernity is tied to disciplinarity and disciplinarity is treated as a *zero point epistemology* (Mignolo, 2009), or the illusion of a singular, natural starting point of our capacity to progress as a society. Coming up with new solutions to complex problems requires recognition of the ways knowledge organization has been disciplined to move into possibilities that bring dignity to all human and non-human entities.

Onto-epistemic heterogeneity and the heteroglossia of language

Warren et al., (2020) position their work for expansive disciplinarity against the backdrop of *canon building*–the construction of hierarchies that privilege some knowledge over others–that is inextricable from institutional political systems (*see also* McKittrick, 2021). Since the early era of schooling in the United States, through determination of what is in the disciplinary cannon and what is not, schools have participated in an exclusion, assimilation and erasure of knowledge that operates as ongoing violence against marginalized populations (Barajas-López & Bang, 2018; Mignolo, 2009; Patel, 2016a). Warren et al., (2020) pose that in order to imagine school being a place of anything more than a continued form of colonialism, settled

understandings of knowing and learning must be agitated to achieve goals of liberatory education. Warren et al., (2020) offer a conceptualization of *onto-epistemic heterogeneity* as a way to conceive of building an "equitable, dignified and just" practice by highlighting two key ideas: "that knowing and being are inextricably tied," and that liberatory education must "be rooted in pasts, presents and futures that sustain and imagine multiple values, purposes and arcs of human learning" (p. 278). Onto-epistemic heterogeneity is one way to embody an intersubjective awareness and responsibility for the amplification of non-dominant perspectives in the design and facilitation of learning.

Liberatory education begins with political and ethical pedagogical commitments in the design of conditions for learning, and a reflexive engagement of deliberation and action. Warren et al. (2020) build from the work of many scholars to arrive at a set of ethical and political commitments. These are (1) critique and refusal of settled forms of disciplinary knowledge and practices (Tuck, 2009), (2) attunement to the linking of epistemology to forms of power (Mignolo, 2009), and (3) collective reimagining of alternative possibilities for learning and relations in learning (Espinoza, 2009) (p. 278). Such commitments allow educators (and designers of educational spaces) to move away from the myth of value-free, neutral universals, while rejecting an essentialized framing of "the other," and othered knowledge systems, as primitive and unsophisticated. Rather, "othered" epistemologies can offer new possibilities for the ways we teach, learn, and create, possible futures. Warren et al. (2020) offer three sensibilities through which one can consider the formation of a just pedagogical practice: *multiplicity, horizontality*, and *dialogicality*. Education settings rooted in sociocultural and sociopolitical understandings can practice vigilance toward onto-epistemic heterogeneity through the commitments to multiplicity (many ways of doing science and making/doing art),

horizontality across settings of activity (the power of community, library and informal school spaces), and dialogicality (being explicit about what meanings drive transdisciplinary efforts).

Attention to the multiplicity of ways of knowing and being does not imply a new hierarchy of knowledge. As Bang et al., (2018) highlight, Western epistemologies are not to be disregarded or discarded. Santos (2014) suggests that a primary feature of attending to the *ecology of knowledges* is that "it constitutes itself through constant questions and incomplete answers" (p.329). Knowledges, offers Santos, have histories of unequal relations, and that history must be recognized as an integral part of the present. Santos (2014) furthers that addressing the disasters caused by the exclusive use of science might be avoided if, "nonscientific knowledges, which circulate in subordinate form in and out of scientific practices, are valorized along with the social practices they sustain" (p.325). Recognizing such layers when working with ecologies of knowledges requires a process of *intercultural translation,* a moving between attuning to the existing hegemonic relationships and moving toward a reconstructive possibility beyond such relations. Importantly, emancipatory transformations in understanding the world will come neither through the limitations of Western framings of the world, which leave out massive amounts of social experience, nor Western-centric critical theory that takes Western modernity as a starting point. Rather, it must come from spaces which make room for critiquing the axiology of encounter and reduction of what we can know through one system of ideas, perspectives and values alone. They must be spaces of creation and emergence, where what we don't know is addressed by working with and through multiple ways of knowing and kinds of knowledge.

Attuning to the heteroglossia of language

In discourses – verbal, visual, written and more – our voices take up language through past formulations of meaning. We simultaneously impact and shape the meanings words can have in the future through our conversations with others and present utterances in the world. Hence, words enter the world from the middle, a dynamic space of how they have been used and the meanings into which they will grow. This is what Bakhtin calls the *heteroglossia* of language, and the ideologically saturated presence of the multiple that lives in discourse (Bakhtin, 1981). We exist in a world of socially constructed languages, systems which we simultaneously live in and move through. Attending to the heteroglossia of a word, such as science or art, can reveal the underlying configurations of society constructed through the geographies of the discourse within which it is used. Words do things in the world. They contribute to the formation of what futures are made possible, through the associated organization of relationships and values.

Articulating the multiplicity of language and the aliveness of words opens to the idea that meaning, far from an intrinsic quality, is made and remade through a re-articulation within and across specific discourse communities. As such, it can become entrenched and associated with power and hegemony. Vossoughi (2014) proposes a coupled analytic as a way to attune to the vibrancy of language in use, and to recognize dominant discourses. *Heteroglossic attunement* attends to the multiple voices present in a spoken or written text "with special attention to historical and ideological echoes" (Vossoughi, 2014, p. 359). *Semantic sharpening* is the act of refining one's language use for alignment with greater "analytic and political clarity" (Vossoughi, 2014, p. 359). Taken together, these tools help identify the historical voices and power present in discourse, and respond to utterances through critique, or taking a stance on

naturalized or conventionalized speech. In this paper, I offer it as a way to think about what is being forwarded in particular motivations and conceptualizations of transdisciplinarity.

Critical interanimation in dynamic contact zones

Bakhtin offers that an awareness to our words and the worlds and worldviews brought with them can be made possible by looking at one language, one discourse through the lens of another. An example of this is thinking about the language of science through the language of art, or vice versa. As such, "a critical interanimation of languages" can occur as "the inviolability and predetermined quality of these languages [comes] to an end, and the necessity of actively choosing one's orientation among them [begins]" (p. 296). Through the concept of *critical interanimation*, Bakhtin (1981) centers the dynamism of language, saying an utterance "cannot fail to brush up against thousands of living dialogic threads, woven by socio-ideological consciousness" (p. 276). An awareness of the vibrancy of words and their associated "points of view, conceptual horizons, systems for providing expressive accents [and] various social "languages" (p. 276) brings with it the realization that the languages we inhabit through the course of a day – connected to social discourses such as our institutional voice, our family voice – may not be compatible with each other. As we wrestle with contradictions and potentially disequilibrium when becoming awake to the multiplicity of social languages, we also are confronted with a need to choose one's orientation to the multiplicity among them. An example of this is when one's practices of doing science in an out of school context are reframed as primitive or lacking sophistication in an institutional context, implicitly or explicitly made visible through the dominant valuing system in place. Transdisciplinarity can be seen as a critical rethinking-feeling of difference through an understanding of critical interanimation, always in motion and grappling with ways of rethinking many worlds possible.

The heteroglossic complexity of words-in-use lives in all spaces, at all times, yet can also be assembled more consciously through the intentional juxtaposition of ideas, perspectives and values (Rosebery et al., 2010). Pratt (1991) offers the concept of the *contact zone* as a "social space where cultures meet, clash and grapple with each other, often in contexts of highly asymmetrical relations of power" (p. 39). In such spaces of rich tension, cultures – built through shared understandings and orientations to the world – collide. Pratt (1991) more broadly suggests development of the "pedagogical arts of the contact zone" (p.40), the activity and commitments that allow for identification, comparison, communication and mediation across different ideas, stories, attitudes and histories. Transdisciplinarity, when conceptualized as an active refusal of disciplinary discourse, has the potential to open up a space for critical interanimation. When explicitly brought to the foreground, learners, alongside educators and researchers, have the opportunity to recognize the "variegated languages" associated with disciplines, but also make room for disequilibrium as the ideologies and approaches to the world invoked contradict or remain incommensurate with each other. The complexity is critical for imagining differently.

In the un-fixing of words, or attention to critical interanimation which makes one question normative assumptions about language, orientations and understandings can be made and remade through participation in the contact zone. Shotter (2008) writes of the dialogic encounter of various subjects that:

> It is this entry of the voice of an 'other' into the shaping of our 'own' utterances that makes our focus on *joint, dialogically-structured* events so crucial. For it means in such events, something *unique* can occur, a *first-time* event, instead of an event occurring as an outcome, as the product of an already existing, logical system or framework – the continual reproduction of sameness. (p. 52)

As Shotter describes, letting multiple voices animate an event creates a space in which the creation of something new is possible, a *first-time* event. It is a move toward what has not yet existed but might be possible. Designing for transdisciplinarity, through this lens, is more than the topical combination of two disciplines. It can also be a place to listen and reflect on what emerges, to engage with what is opened up (or closed off) within the contact zones of art and science. Importantly though, it is also a possibility space to engage in creative action.

Science and arts-integrative activity as culturally productive activity

When thinking through conceptualizations of transdisciplinarity as both critical and creative, looking at within discipline heterogeneity is essential. This is particularly important in considering activity that deals with complex issues of society and amplifies the goals of anti-colonial or decolonial education. For projects at the intersection of art and science, clarity around whose science and for what ends, whose art and for what ends are essential elements to hold if spaces of possibility are to be opened up. As an example of what it means to agitate within discipline knowledge, I offer an example. In a project weaving together Indigenous science and sustainability science, Whyte et al. (2016) discuss ways in which Indigenous protocols differ from a Western scientific approach. Contrasting a "resource-circulating society" grounded in the premise of reducing, reusing, and recycling within the manufacturing processes, they offer a different relational starting point:

> Some Indigenous scientists express protocols that often represent humans as respectful partners or younger siblings in relationships of reciprocal responsibilities within interconnected communities of relatives inclusive of humans, non-human beings (i.e. plants, animals, etc.), entities (i.e., sacred and spiritual places, etc.) and collectives (i.e. prairies, watersheds, etc.). (p. 26)

In this example, Whyte et al. suggest that the very manner or approach of scientific (i.e. empirical) inquiry, and further science-based solutions to complex issues, defines how a group proceeds in a situation. Therefore, unless there is a meeting of multiple ways of coming to disciplinary knowledge and meaning-making from the outset, the integrative work remains lodged in singular considerations of what is possible in opening new cognitive space.

Turning towards onto-epistemic heterogeneity within the arts includes acknowledging how they are being framed. Arguments for the inclusion of the arts in education have extolled their intrinsic importance for, to name a few, identity development, problem solving, creative production, strengthening the imagination, divergent thinking, and communicating ideas to an audience/viewer (Halverson & Sheridan, 2014; Bevan et al., 2019; Burton, 2016; Constantino, 2018). Yet, the same processes of epistemic and ontological erasure that restricts what practices are included when referring to STEM, also narrow what it means to create art. Gaztambide-Fernández (2013), pushes back on the main threads, or *rhetoric of effects,* that justify arts education for either its intrinsic (art for art's sake as a purely aesthetic activity) or instrumental (serving the purposes of other disciplinary or political/economic goals) value. He extrapolates that:

> What this suggests is that every instance, event, experience, project, or intervention that mobilizes discourses of the arts is always-already situated in institutional contexts and social relations that impose particular constraints on what practices and products can be construed as artistic. (p. 224)

Rejecting a positioning of the arts within institutional discourses as holding a higher value than community practices, Gaztambide-Fernandéz (2013) suggests repositioning the arts as a practice of symbolic creativity. Dominant framings of arts education and what it means to be an artist

have been shaped by values and aesthetics dating back to the Renaissance, conceived (and then exported) on Eurocentric terms. Gaztambide-Fernandéz et al. (2018) write that, "'the arts' and what it means to be an artist are profoundly shaped by racial logics and racist assumptions (p. 2)," implicitly predicated on Eurocentric understandings of culture and culture production that become invisible through their dominance. By releasing the arts from universal notions that assume definition and value, contested disciplinary rights over creativity, and hierarchies of inquiry, can be connected to the practices and purposes of the activity rather than serving a broader economic agenda.

Making–as a practice aligned with processes and materials commonly found in arts classrooms–has similarly received critical attention given its popularity sparked by the Maker Movement (Barajas-López & Bang, 2018; Vossoughi, Hooper, & Escudé, 2016). For example, Beuchley (2013) critiques early introductions to Makerspaces in schools that failed to engage with how making upheld mostly White, male, middle-class values. An uncritical adoption of making and tinkering does not challenge the status quo of schooling. Barajas-López & Bang (2018) challenge that creating equitable and transformative through making requires attention to how "cultural variation in meanings of and relations to materiality are engaged and how dominant forms of material use are disrupted and transformed" (p. 9). Instead, Vossoughi et al. (2016) suggest we might look to settings which have long experimented with alternative pedagogical approaches in which the scientific and everyday are not pre-separated, such as the settings of working-class communities of color and women.

In detailing work from an ArtScience participatory design project, Barajas-López & Bang (2018) bring the materiality of making to the forefront. They state that through "clay making activities, youth and adults made sense of the relationships that they were developing with plants

and with sea life through the activities at the beach and in the forest. This in turn helped youth think about the possible stories they might narrate through their claywork" (p.14). The authors highlight that making engages cultural and political practice with the material in a relational process that allows community members to bring "old technologies" into the present while offering visions and desires for the future through their stories and artifacts. Tzao et al. (2019) reinforce this work in an engineering project building robotics in such a way that recognizes Indigenous presence, ingenuity, and innovation through storytelling and making. Eglash et al. (2020) emphasize the importance of localizing practices to people and places. They argue for connecting making to the values and practices important for participation within a specific community as a way to resist topical encounters that reinforce universalities. While stressing the potential of making, these authors assume a different set of logics undergirding the making activity that allows for understandings of the self to emerge from a particular place and landscape. Making, when not directed by distant and vague ideas of creativity and innovation for a market economy, has the potential to open to strengthening and sustaining relationships to community values, materiality and each other.

In summary, I have discussed considerations that I believe are required for a critical and creative transdisciplinarity. First, all projects stemming from disciplinary standards created in an institutional context alone are limited by narrowed forms of valued and sanctioned knowledge. Secondly, art and science integration efforts have the potential to be rich contact zones, animated by the onto-epistemic heterogeneity of learners. Third, in these contact zones, conversations that recognize the different powered relationships of language can be brought into dialogue for sociopolitical critique and reimagining. And finally, transdisciplinarity involving making must

also recognize making as a culturally symbolic activity that happens in the many places we move in our lives, expressed individually as well as collectively.

Ties to critical and decolonizing education has not always been at the forefront of combining art/making and science disciplines in new integrative efforts. Through the frame of epistemicide, onto-epistemic erasure, and zero point epistemology, we can begin to critique the normative ways transdisciplinarity – as a concept and practice – is framed. First, knowledge synthesis models, such as the one forwarded by Nicolescu, are totalizing, working to find a superdiscipline that unifies different meaning making practices into a singular set of principles and processes of application. As a move towards universals, especially one that does not contend with the powered ways disciplines have been constructed, such a conceptualization of transdisciplinarity fails to account for the complexity created through the presence of multiplicity. It also does not allow for emergence and critique, leading to the creation of yet another hegemonic and narrow construction of knowledge finding practices.

A second thread common in transdisciplinarity art and science integrative efforts understands it as a way to bridge science and society. Similar to the way the Zurich school puts forward, the university remains the locus of knowledge production, even when solution finding is extended to local communities. As such, transdisciplinary education begins in institutions "free from any ideological, political, or religious control" (Nicolescu, 2018, p. 80), which has never been the case throughout the history of education (be it in monasteries, palaces, academies, or universities). Creative practices and design are then entry points for producing better hard science through connections between universities and society (McGregor, 2015b). Through such logic, transdisciplinarity begins with disciplinary specialization as a natural developmental stage

without considering how knowledges outside the Western thought tradition were subjugated and erased as the academy became the center of learning.

A third thread suggests that art and science activity creates a space to shift subject-object dualisms, given the differences in their respective research processes. Contending that expressive elements are valuable to science learning works as a form of liberal humanism. It extends the bounds of what counts as knowledge building practices insofar as it still remains tethered to the truth building practices of science without accounting for the power associated with disciplinary knowledge structures. This conceptualization generally fails to contend with the living extensions of supremacy with lineage in the human-nature divide. Though expressed as a move away from scientism, the placement of the human being at the center of all life fails to engage with Cartesian dualisms (i.e., mind/body, human/nature) that claim knowledge universals without naming their genesis in specific place or perspective (Dixon-Román et al., 2020). Ultimately, this does little to rethink the racialized geographies of what it means to be human. The separation of the material from the cultural allows for the intellectual activity of solution finding to remain untethered to the political questions of for whom and for what purpose. Thus, in order for transdisciplinarity to be an enactment of onto-epistemic heterogeneity – which considers the ethical and political nature of learning environments – we also have to revisit the creation of the Western Man in the post-Enlightenment era (Wynter, 2003).

Through the concept of critical interanimation, Bakhtin (1981) centers the history and dynamism of language, saying an utterance "cannot fail to brush up against thousands of living dialogic threads, woven by socio-ideological consciousness" (p. 276). An awareness of the vibrancy of words and their associated "points of view, conceptual horizons, systems for providing expressive accents [and] various social "languages" (p. 276) is critical to the ways we

might move through explorations of transdisciplinarity. Negotiating the tensions within and across the disciplines is the work of transdisciplinarity, and what can lead toward other possibilities for learning, possibilities that point toward values that are not included within hegemonic nationalist and capitalist frames for education.

Concluding Thoughts

In engaging with the topic of transdisciplinarity, I center the ideas, action, and writing of anti- and decolonial scholars in an effort to desettle ways of thinking of transdisciplinary science and art education. Yet to this end, I am not, and will never be, fluent in the stories and world-views which have produced such lines of thought. I aim to explicate particular contradictions inherent in the words I use (i.e., art, making, science) and research I undertake (transdisciplinary learning) in order to confront conceptions of newness and difference which domesticate, and flatten complexity (Warren et al., 2020). In doing so I listen and respond to the critiques and orientations of scholars whose words and voices point to possibilities unimagined by the limits of Eurocentric hegemonic logics. Through an exploration of postcolonial framing of epistemicide, and further to its claim of school science and art as narrowly defined, zero point epistemologies I work to examine transdisciplinarity in ways that might lead toward educational experiences which support the dignity and knowledge of all students, and are purposeful in understanding the complexity of issues we face locally and globally. By starting from a place of modern disciplinarity, the scope of what is possible in reimagining our relationship to the world to address the complex issues is already limited. A transdisciplinarity that moves beyond colonial knowledge structures requires moving toward the multiple localities from which epistemic heterogeneity might emerge, to change the terms of how we can begin to address problems in their complexity and move toward solutions that don’t reproduce and replicate harmful systems.

Chapter 3 – Changing the word or changing worlds? A vertical case study of art and science transdisciplinarity

> *What is actually transdisciplinary in terms of concepts? What concept is a transdisciplinary concept? When the schools start picking up, it's like, "Oh, where is this idea going to go now?" That's when you got to start worrying. Who's backing it and what kind of nonsense are they talking? I always feel that it's much easier to come up with new words for things than it is to kind of really change the concept. It could just be like, "Oh yeah, we do art and we do science, that's transdisciplinary." You can change the word for what you're doing but that doesn't necessarily change what you're doing, you're just kind of calling it a different word. And then, if that means it's going to turn everything we do upside down – well, no, we'll just make the word mean something that we've already done here that fits it.* (Gordon, interview, 6.16.21)

As Gordon shares his conceptualization and hopes for what is made possible through *transdisciplinarity*, he points to the tension present when words become a veneer, a surface treatment that upholds the status quo of activity in schools. Gordon's hesitancy to prescribe a new term for art and science integrated inquiry implicitly links changes in educational language to the purposes and motivations behind them. Language shapes educational worlds. It creates a set of value-laden orientations and meanings that drive funding, valued knowledge, curricular resources, and measures of success. At the ground level, school and out-of-school administration, staff, and educators interpret, organize and implement learning activity based on policy discourse, often with constrained opportunities for critique or alternative formations.

Through a vertical case study at the Science and Art Inquiry Museum (SAIM), I examine how transdisciplinarity is framed and lived in practice by community members within the organization, as well as through discourse at the state and national level. I am interested in the design of learning environments which move beyond acquiring state sanctioned knowledge, skills, tools and processes alone. Moving from critique to creation, I am attentive to conceptualizations of art and science transdisciplinarity that work from the ground up and might

help us design with explicit political and ethical commitments. The central question I focus on in this study is: *How do educators, staff and board members at SAIM reflect and reimagine broad policy discourse about the purposes and potentials of transdisciplinarity?*

Theoretical Framework

In this study I look at the way language is both constructed and constructing. Language is never singular in form, meaning, or use. Yet it has reproductive tendencies, having been uttered and repeated in ways that are homogenizing through socio-ideological, powered relationships. Language is dynamic, open to infinite remixing by its voicing in specific contexts and by people with specific goals and purposes. Bakhtin (1981) refers to the vibrant multiplicity of meaning in words and their utterance as the *heteroglossia* of language. Each utterance is also world building. Bakhtin writes:

> All languages of heteroglossia, whatever the principle underlying them and making each unique, are specific points of view on the world, forms for conceptualizing the world in words, specific world views, each characterized by its own objects, meanings and values. (p. 292)

Critical to this study is how national policy exerts a *monologic* representation of the purposes of inter- and transdisciplinary projects. By engaging with discourse around understandings of transdisciplinarity at the local level of SAIM, the heteroglossic presence of language becomes visible in the ways different actors (e.g., board members, educators, and staff) discuss their beliefs and values about their activity. Pointing to Bakhtin (1981, 1986), Fairclough (1995) states, "Any text is part repetition, part creation, and texts are sites of tension between centripetal and centrifugal pressures" (p. 10). While Bakhtin is primarily a literary theorist, his work has

made significant contributions to the study of language and dialogue in educational settings (Montoya, 2000).

Centripetal and centrifugal forces

For the purposes of this study, I turn to Bakhtin's concepts of centripetal and centrifugal forces as a way to conceive of the pressures that push in (singularizing) and push out to alternative possibilities for the aims behind transdisciplinary projects. For Bakhtin, centripetal forces work toward a unifying and centralizing conceptualization of language. This is not just associated with definition but with the verbal-ideological, in that centripetal forces "develop in vital connection with the processes of sociopolitical and cultural centralization" (Bakhtin, 1981, p. 271). Centripetal forces are homogenizing and hierarchizing, flattening the many to one standardized, fixed or closed meaning (Ives, 2016). Centrifugal forces, alternatively, are deregulating, resisting a singular voicing toward the variety of individual voices always present and representative of multiple social belief systems. Bakhtin (1981) writes, "within these various systems…are elements of language filled with various semantic and axiological content and each with its own different sound" (p. 288). Language seeds the value dimensions of projects that work toward expansive disciplinary possibility through the discourse invoked. Both explicitly or implicitly, staff at SAIM demonstrate the *how, for what, for whom and with whom* at the heart of their art and science inter- and transdisciplinary design through dialogic response to outside forces (i.e. what shows up in marketing materials) and within organization discussions (Philip et al., 2018).

Language can be a vehicle for resistance and a resource, often seen at the micro level of interaction. Bakhtin's concept of forces in opposition have been taken up in educative settings as a lens to see the ways powered normative practices were disrupted or resisted by those

positioned by broader social structures as less powerful (i.e. teachers v. students, administration v. staff). Montoya (2000) applied Bakhtin's concept of centrifugal and centripetal force to describe moves made by law students from communities of color who used silence as a tool and a form of language resistance to destabilize assimilative power dynamics. Students' responses were in refusal of the centripetal force of legal pedagogy in a law classroom that reproduced hierarchies through dominant legal language practices which further operated to create socialized professionals that ignored the invisibility of race in legal language. Similarly, in a study of African American students' cultural and linguistic resources in a sixth-grade English Language Arts classroom, Ives (2016) highlighted a story of a student's practice that disrupted the monologic classroom. She described the tension between the teacher trying to meet her school's and state's policy mandates, and the student whose deep engagement with literacy practices was going unnoticed, at times even punished:

> This point at which centripetal and centrifugal forces collide is the locus of heteroglossic potentiality where possibilities for new meaning and new pathways are most open and immanent. (Ives, 2016, p. 41)

Ives attends to the interactions between a teacher and student as a push-pull between those knowledge practices at the center of the classroom, and hence valued by the teacher, and those at the margin, the lifeworld of the student outside of school. Looking at moments of collision brings to light the missed opportunities to embrace the heteroglossia present in the classroom and create a rich and culturally relevant (Madkins & McKinney de Royston, 2019; Ladson-Billings, 2017) space of learning that resists standardizing processes and practices.

I take up Bakhtin's concept of centripetal and centrifugal forces as a way to get at both critique and creation. In all the spaces we participate, we can look for the ways we are pulled

toward normalizing behaviors, or the voices that point in other possible directions. Centripetal and centrifugal forces are powered but not immobilizing. The multiple are always present, but the *authoritative word* exerts a hegemonic force over alternatives. Bakhtin (1981) writes that "we encounter it with its authority already fused to it", and further:

> Its authority was already acknowledged in the past. It is a prior discourse. It is therefore not a question of choosing it from among other possible discourses that are its equal. It is given (it sounds) in lofty spheres, not those of familiar contact. Its language is a special (as it were, hieratic) language. (p. 342)

The discourse of transdisciplinarity is multivocal yet also absorbed by the authoritative word through framings at the policy level. Given that non-profits are beholden to the language of those with funding power and goals and aims associated with a national agenda, focusing on the heteroglossia present, or the space where centrifugal and centripetal forces collide, brings to light contextualized moves away from a singular, unifying interpretation of the purposes of transdisciplinarity. In this vertical case study, I examine the language that frames the purpose and potentials of inter- and transdisciplinary learning curricular projects, and what other possibilities are enacted.

Transdisciplinarity in K-12 science + art integration

Scholarship regarding transdisciplinarity in K-12 education can be seen as moving toward a suppression of heterglossia. For example, (Bequette & Bequette, 2012) discuss the ways in which art educators should position themselves in parallel to the language Science, Technology, Engineering and Math (STEM) teachers take up to describe their goals. They suggest for engineering topics educators might use the language of functional design aesthetics, or move to frame the creative work of artists and designers through 21st century skills if the

purpose of integration is job-prep or innovation driven. They add, encouraging students to "be curious, experiment, and takes risks" gets at habits of mind that can be highlighted as critical to practices in the arts and the sciences (Baquette & Baquette, 2012, p. 46). Many art educators advocate for the arts through STEAM (STEM + Arts) in order to secure resources and establish their pedagogical expertise in spaces where STEM hierarchies eclipse valuing for the arts (Halverson & Sawyer, 2022; Mejias et al., 2020). Others have highlighted adding art and design to STEM subjects as a compelling educational approach that engages students in transdisciplinary inquiries through problem-based learning, creative inquiry, and solution finding (Costantino, 2018; Guyotte, Sochacka, Costantino, Walther, & Kellam, 2014; Marshall, 2014). Such convergence with STEM goals moves towards the monologic and is aligned with recent evolutions in national STEAM policy (Allina, 2018). As such, it advances a specific set of value propositions about the disciplines and the purposes of their integration, while sidelining others that are beyond the scope of national initiatives.

Much of the literature critical of the STEAM narrative as the dominant narrative of transdisciplinarity is emerging in literature on *making* and STEM transdisciplinarity. Elaborating on current critiques of the maker movement–popularized and framed as a form of STEAM–Vossoughi, Hooper and Escudé (2016) highlight how equity is conceptualized in the maker context, particularly as it aligns to existing research on the role of race, culture, epistemology, and power in learning (p. 201). They offer a set of principles for conceptualizing making which closely attend to what is made possible when "key learning goals and values are explicitly conceptualized through the lens of culture and power" (Vossoughi et al., 2016, p. 215). Eglash, Bennet and Babbitt (2020) also reorient making practices away from corporatizing and commodifying ends by highlighting culture-specific practices that build toward community

focused possibilities. The authors forward a generative justice framework through material agency as a refusal of STEM making projects that obscure ecological and labor value in the process of production. Both of these studies reframe the purpose of combining science (or STEM) subjects with processes of material inquiry (the arts) through a set of values that reimagines the authoritative word of national policy and opens to alternative, heteroglossic conceptualizations.

In what follows, I first turn to the methods and modes of inquiry that form the context of this research. Next, I attend to the ways art and science integration is presented in national policy documents. From there, I look at how the top-down authoritative word is reflected and reimagined at the local level of one museum of science and art. I particularly attend to the purposes and aims of transdisciplinarity as conceptualized at the educator and staff level as a challenge to a singular narrative and associated set of values.

Methodology

Given my desire to trace how discourse at the national level impacts inter- and transdisciplinary framings of those working in an art and science learning environment, this study was design as a qualitative vertical case study (Bartlett & Vavrus, 2014). I began with a critical discourse analysis (CDA) of national policy documents that included measures or recommendations for inter- or transdisciplinary learning. This included legislative documents produced by the United States Department of Education, such as the *Every Student Succeeds Act* (ESSA, 2015), as well as reports produced through federally funded research partnerships such as the National Research Council (NRC) or American Education Partnership (AEP). While much of the literature exploring transdisciplinarity in K-12 education has been written through the lens of STEM and STEAM, I focused here on mentions of disciplinary integration. To observe

national level discourse at the micro-level context, I then examined how transdisciplinarity was framed at SAIM. Through interviews with staff and teachers, as well as field notes, planning meetings, and strategic documents, I tracked how larger social forces shape local interactions (Vavrus & Bartlett, 2006).

Case study context

SAIM is a non-profit organization with a mission to cultivate curiosity and experimentation by combining practices and tools commonly found in science and art curriculum. The organization was founded in 2010 by a small group of scientists, educators and business owners as a mobile museum, offering art and science programming in schools, libraries and citywide events. In the early years of development, programs included activities centered around a collection of table top exhibits (e.g., a wind tunnel exhibit) and curricula combining elements of art and science study (e.g., kinetic sculptures inspired by Alexander Calder) (see Figure 1). Just before the 2020 COVID-19 pandemic hit, SAIM acquired a physical space, allowing the organization to rotate its interactive exhibits within a large warehouse room, host activities in their newly designed makerspace, and have a home-base for the supplies and administrative activity necessary for travel to schools and community partner sites.

Past programs through SAIM served a diverse demographic of students statewide through both onsite and offsite programs. Their offsite programming occurs in locations such as public and private school classrooms, after-school partnerships (e.g., After School Alliance) and libraries. They are also regularly contracted for activities through local citywide initiatives (e.g., through Department of Children, Youth and Family). Their youth population is generally grouped by elementary (K-5), middle (6-8), and high school programming but a majority of their participants are from 6th-8th grade. Depending on the venue, activities that SAIM offers can last

anywhere from one hour or one-day workshops to semester-long sessions. Early conversations with the Executive Director and founder of the organization, Beth, suggested that the organization was interested in addressing equity in their organization broadly (i.e., through board membership, educator hires, and outreach) as well as within the curriculum (i.e., artists and scientists highlighted, project practices).

Figure 3. Students engaging with exhibits at SAIM

Data Generation

My involvement with SAIM began when I was a Masters' student, working as a contract educator by offering their programming in after school settings. Given the part-time nature of the work, I found more consistent employment elsewhere, a common issue in many out of school time (OST) contexts. About five years later I reconnected with staff as my research led me back

to focus on art and science integration. Given the founder's desire to look more closely at disciplinarity as well as equity, we agreed on the site as a space of possible research. Desiring a relationship that shared active participation and mutual growth from the work, I made myself available to support ongoing programming, development of curriculum and strategic planning. Once official research for this study began (2020), my role shifted depending on the activity. During staff meetings I was predominantly an observer whereas at board meetings I participated as a board member. I was also invited to co-teach a number of SAIM programs, during which I wrote jottings which I later turned into field notes (Emerson, Fretz & Shaw, 2011). I also identified documents that were central to SAIM's interal and external (marketing) communications.

I conducted ten interviews with board members, administrators, and educators with the goal to gain insight into the multiple perspectives and lived experiences related to the purposes and understandings of transdisciplinarity. Following Vossoughi and Zavala (2017), I see interviews as a reflection and interpretation of past experiences versus a retelling, with the aim to find emergent understandings (p. 139). I chose board members with a range of expertise and reasons for which they were brought onto the board (such as a finance versus education background). This was particularly important given their recent shift toward a funding board. I interviewed all staff members that were integral to the operations of the physical space and education programming, and who regularly attended and reported out at staff meetings. I chose educators who had been with SAIM prior to COVID, were familiar with programming before the opening of the physical space, and had diverse disciplinary expertise (See Figure 2). Staff meetings, curriculum planning, and board meetings yielded field notes used to bring further

clarity to an emic representation of what the conversations and events meant to administrators and staff (Emerson, Fretz & Shaw, 2011).

Table 1.

Interview Participants

	Race/Ethnicity		Gender			Disciplinary background
	White	African American/Black	Male	Female	non-binary	
Founder & Board members	5		2	3		geology, business, entrepreneur, education, art administration
Staff	2		1	1		music, fine art
Educators	1	1		1	1	physics, music, art

Data Analysis

The choice to use a theoretical lens of centrifugal and centripetal forces is one that necessitates attending to the powered dimensions of discourse. The centripetal force that pulls towards one meaning or one understanding of a word is a felt presence that crystalizes into a correct or right interpretation of language. CDA considers how language is used to distribute power, and construct a concept–such as transdisciplinarity–in particular ways. Building on intellectual traditions of discourse studies, feminist poststructuralism, and critical linguistics (Rogers, 2003), CDA focuses on how "we make the world meaningful in certain ways and not in others" (Fairclough, 2012, p. 5). In order to challenge hegemonic beliefs regarding transdisciplinarity, I examined how the term is constructed and what it constructs through recent policy document discourses (Ingram & Elliott, 2020). One way into the data was to look closely at the value assumptions that exist in the described lived experiences (interviews & documents) and constructions of social reality created by the animation of ideas regarding art, science,

creativity and innovation at SAIM (Fairclough, 2012). CDA, as an analytic lens, reveals how power, status, and conflict function in local conversations as a reflection of broader sociopolitical ideologies framing disciplinarity and innovation in education (Gee, 2011). This focus helped to elicit aims and purposes that falsely suggest a common ground rather than open toward heteroglossia that is present in all contexts. Fairclough (2012) positions that the power of CDA "is its emphasis upon existing social realities as humanly produced constraints", and as such it also opens to re-framings that might "enhance well-being and reduce suffering" (p.10). CDA is useful tool for connecting how board members, staff and educators might express alignment or alternative visions for powered discourse regarding art and science transdisciplinarity.

CDA is a useful framework for recognizing conceptualizations of art and science inter- and transdisciplinary that don't just reside in a person's head but rather in the dialogic interactions and tensions between individuals, texts, institutions, and social worlds. In the dialogic are also the seeds of heteroglossia, what could be possible if given more weight or power. Hence, my analytic approach involved reading and interpreting text as choices, "operationalized as networks of systems of options which are selected amongst in the production of texts" (Fairclough, 1995, p. 5). I attended to the ideological assumptions read through a "presence-absence scale" (Fairclough, 1995, p. 6). This means remaining attentive to what was explicit and implicit in the text, and finding reoccurring themes in what was mentioned and what was assumed, what was brought to the foreground and what remained in the background. In doing so, the situated framings of inter- and transdisciplinarity at SAIM were interdiscursively brought into dialogue with national discourse.

My analysis of documents and interview transcripts as Discourse[1] began as an iterative process through ongoing reflection and refraction (Saldaña, 2015). Using inductive coding (i.e., codes derived from data), I looked systematically at the Discourse to identify how educator, staff, and board members conceptualized the purposes of art and science (trans)disciplinarity, as well as how such framings claim power and authority through larger social discourses. Analysis of observations, interactions and program implementation served as a way to validate meanings from interviews and clarify codes, particularly highlighting how beliefs and meanings were enacted through interaction with students and the broader community. Final themes were established that offered insight in how conceptualizations of (trans)disciplinarity functioned at SAIM, and how members reflect and animate national discourse, pointing toward alternative possible political and ethical dimensions of learning.

Analysis & Findings

The way an educational opportunity is framed impacts everything from the way funds are invested, the types of projects invested in, the assessment of programs, and the reform initiatives backed by policy measures. In what follows, I first present an analysis of policy documents that include measures for art and science integrated educational projects. I discuss four themes that emerge as the driving purposes framed at the macro level. I then turn to the ethnographic data from SAIM to better understand the ways educators, staff and board members

[1] It is important to note that when written in this thesis, "capital D" discourse indicates language, along with other multi-modal resources used to construct ideologies (Waring, 2017). When referring to text, Fairclough (2014) emphasizes: "I use the term 'text' in an extended way for the semiotic dimension of social events – the written documents and websites of government are 'texts' in this sense, as also are interviews and meetings in government or business organisations" (p. 93). A key idea in CDA is that texts both realize and reproduce social conditions, therefore serving as a mediator between abstract social structures and concrete social actions (Jimenez-Silva, Bernstein, & Baca, 2016).

understand the purpose of art and science transdisciplinarity, framed through their dialogue, programming, mission and marketing.

National level analysis of interdisciplinarity

"Wherever creativity goes–and, by extension, wherever talent goes–innovation and economic growth are sure to follow" states Richard Florida, writes in the Harvard Business Review, October 2004. In a move that mirrors the alarmist rhetoric of the National Commission on Excellence in Education's *A Nation at Risk* (NCEE, 1983), Florida, an urban studies theorist, frames what has become the driving discourse of interdisciplinarity in recent decades–specifically, our nation is at risk and "once unchallenged preeminence in commerce, industry, science, and technological innovation is being taken over by competitors throughout the world" (NCEE, 1983, p. 5). This time though, the crisis is linked to failing to provide opportunities to develop creativity in our schools and industries. The integration of art and science, especially linked to creativity to innovation, forms the backbone of current calls for inter- and transdisciplinarity in national policy documents. Driven by purposes that align with the past three decades of discourse on STEM learning in the United States (Mejias et al., 2020; Allina, 2018), support for inter- and transdisciplinarity is framed as a way to increase workforce development, promote the nation's economy through innovative products or business, ensure engagement and access to STEM learning, and solve global scale problems.

Interdisciplinarity to meet 21st Century STEM workforce needs

The discourse on bringing the arts into the sciences in education most often highlights evolving workforce needs due to technological development and production. The argument is as follows: Employers of the future will no longer demand skilled labor as such jobs can be mechanized and executed by robots. Rather, what is necessary is a creative workforce ready for

intellectual production and applied information (American Institutes for Research [AIR], 2016; Arts Education Partnership [AEP], 2019a). As such, the arts are seen as important for ensuring the development of 21st century "soft-skills" such as creativity, collaboration, cultural competency and innovation. These skills are often presented as transferrable and disconnected from content-based skills (Partnership for 21st Century Learning, 2009; Arts Education Partnership [AEP], 2019b). The *American Competes Reauthorization Act* (H.R. 1898, 2015) included the language:

> STEM graduates need more than technical skills to thrive in the 21st century workforce; they also need to be creative, innovative, collaborative, and able to think critically; STEAM should be recognized as providing value to STEM research and education programs across Federal agencies, without supplanting the focus on the traditional STEM disciplines (Sec. 204)

A passage found later in the same document calls for a workshop between the NSF and NRC. Among the goals to consider were:

> how arts and design-based education experiences might support formal and informal STEM education at the pre-K–12 level, particularly in fostering creativity and risk taking, and encourage more students to pursue STEM studies (Sec. 204)

Similar to language found in multiple policy documents, these two excerpts serve as advocacy by way of funding for art and design integration. But they also limit the scope of disciplinary purpose. The value for the integration of the arts is tied to bolstering STEM learning, suggested by the language around STEAM "providing value to STEM". STEAM learning is constrained in that it is not intended to "supplant" the focus on traditional STEM, maintaining an instrumental focus. The arts gain value only by helping to develop the skills STEM graduates need in the 21st

century. Additionally, the focus for the integration of art in science study is specifically to foster creativity and risk-taking, skills commonly mentioned as important for a 21st century workforce. This leaves out the possibility that the arts are a way of thinking and learning through materials in their own right. It is vectored, bringing art and design into STEM versus moving toward the creation of a new or emergent type of learning (Mejias et al., 2020). Finally, what is left in the background was that creativity is part of the new knowledge work needed for the workforce. This suggests that "so-called older types of work, are, by and large, mindless, 'neck down' rather than 'neck up'" forgetting that, "work of body and hand continues to create the material web of daily life (Rose, 2004, xix). The ways policy documents link to a changing workforce create a valuing for specific type of skills, devaluing others and positioning creativity as a new source of human capital.

Innovation as the end-goal. Innovation is often conceived of as a key feature of the advancement of a knowledge economy, and critical to scientific and technological revolution (Allina, 2018; Connors-Kellgren, Parker, Blustein, & Barnett, 2016). In education, innovation is commonly aligned with both product development and entrepreneurship. In a section of the STEM Education Strategic Plan (Committee on STEM Education, 2018) titled Engage Students Where Disciplines Converge, it was stated:

> Innovation and entrepreneurship are critically important to U.S. competitiveness and security. To keep pace with our competitors, U.S. companies must remain on the forefront of new discoveries and be able to efficiently transfer new technologies into products and services. (p. 16)

Innovation is here directly linked to "products and services" bringing the entrepreneurial aspect to the forefront as a primary value of innovative work. Yet the values of such innovation is

absent. For what purpose, or whose benefit do we innovate? In the excerpt above, innovation has the key purpose to maintain national competitiveness. The uptake and emphasis on innovation as it relates to transdisciplinary projects must be thoughtfully considered. For example, Barajas-López & Bang (2018) further that, "Frequently, technologies are rhetorically synonymous with the West and with newness and innovation as desired qualities. Technologies whose life courses are much older are often erased completely or positioned as antiquated heritage practices within settler-colonial paradigms" (p. 9). Possible innovative futures in policy documents are constructed primarily through technological advancement and, whether stated or not, underscore geopolitical and ethical assumptions about what is modern, sophisticated and desirable in products, people, and processes (Jasanoff, 2016; Tzou et al., 2019). It has been shown that the long-term effect of such neoliberal arguments do not result in designs that foster greater diversity, but rather, in many cases, heighten existing segregation based on existing and created value structures (Na'ilah Suad Nasir, Scott, Trujillo, & Hernandez, 2016).

Discourse around workforce and innovation at the macro national level was also mirrored at the meso state and city level. After decades of industrial decline due to cheaper means of production found in other locations (e.g., new globalized markets), the small New England city where this research took place has been rebuilding their postindustrial economy, making a transition from predominantly manufacturing employment to a consumer economy (Denmead, 2019). The turn of the century saw the local government invest in bringing artists and arts organizations into the downtown and surrounding areas, capitalizing on the population of local large universities and supporting the creation of arts-based non-profits toward an economically motivated revision of the city as a "renaissance project" (Salkind, 2013). Since the

early 2000's this city rebranded itself through its "Creative Capital," promoting an image of the urban creative and entrepreneur.

Legal benefits for arts organizations and development, such as incentivizing the creation of live-work spaces, were and continue to be mobilized, recasting this city as the Creative Capital of the state. Yet the form of renewal labeled *"creative placemaking"* (Markusen & Gadwa, 2010) has taken its toll, elevating a specific type of creative status, while simultaneously pushing nondominant communities further outside of the city center (Denmead, 2019). Such ideologies operate in the backdrop of conversations about learning in makerspaces in which the language of entrepreneurship guides product-driven explorations, reliant on models of interdisciplinary learning and values framed by corporatism and consumerism (Vossoughi & Vakil, 2018). Animating a legacy of colonialization, creativity *as* capital is linked to visions of innovation and progress dominated by a singular aesthetic and a singular economic model, and meant to service the needs of the dominant beliefs and values represented as the nation's interests.

Broadening Participation in STEM from Non-Dominant Populations

Another benefit of working across disciplinary boundaries that was taken up in policy discourse was the potential for engaging non-dominant groups in STEM fields, such as women, Black, Latinx, and working-class populations. In the STEM Education Strategic Plan (2018), it states, "organizations that are diverse in terms of gender, race, socioeconomic status, ethnicity, ability, geography, religion, etc., and provide an inclusive environment that values diversity better retain talent, are more engaged and productive, are more innovative, and generally are higher-performing organizations" (Committee on STEM Education, 2018, p. 5). Mirroring language found elsewhere in policy documents, this reinforces a critique offered by Takeuchi et

al. (2020) that inclusion by identity markers can reduce learners to sets of attributes or variables (e.g., gender, race, ethnicity) in ways that also erase "intersectional histories and experiences to deterministic categories" while obscuring "the heterogeneity of their histories, desires and experiences by disciplinary apparatus" (p. 236). Vossoughi and Vakil (2018) highlight Martin's (2009) critique which distinguishes an apparent interest in equity and diversity for an "enlightened" national interest – one which "organizes learning around the needs and political agendas of the state" versus a "deep moral concern" for youth and communities of color which center "the needs, capacities, values, identities, and possible futures of underrepresented students and communities" (p. 133). The interests of market forces (business, state or national economies) drive the desire for diversity demonstrate the weaving neoliberal interference in education.

Another way to interpret such an argument for diversity that seeks to lure linguistically and culturally diverse learners into STEM, constructs a particular kind of STEM learner (Sengupta-Irving & Vossoughi, 2019). Vakil and Ayers (2019) suggest that "persons devalued in society will be valued when they reflect what the market values" (p. 452). As long as people from marginalized communities choose to participate in what is valued by the dominant group, they are seen in their full humanity and granted access to certain rights. Such inclusion and valuing is conditional, positioning those in the dominant group with the power to deny or revoke entry given changing needs. It ties inclusion to increasing global competition, economic prosperity and military power in contrast to community interests or needs (Madkins & McKinney de Royston, 2019).

Boosting Achievement of Academic Standards

Many arts advocates highlighted the inclusion of the arts in the *Every Student Succeeds Act* (ESSA) (2015) as a great victory (Allina, 2018). In this document, ESSA specifies a

provision for the arts as part of a well-rounded education. The purpose of well-rounded education, as stated, is "To ensure that all children receive a high-quality education, and to close the achievement gap between children meeting the challenging State academic standards and those children who are not meeting such standards" (ESSA, Sec. 1006, 2015). This is reinforced with funding, stating local agencies should use "resources under this part to help eligible children meet the challenging State academic standards" (ESSA, Sec. 1009, 2015). In this document, the arts are framed as a way to support well-rounded education experiences, particularly for female, minority, English learners, children with disabilities, and low-income students "who are often under-represented in critical and enriching subjects" (ESSA, Sec. 4104, 2015). The naming of the arts in such documents opens funding streams that were previously non-existent, yet the value of adding the arts is defined by how exposure to a well-rounded education can help meet state standards. Such instrumental arguments do not challenge the structure of standards nor measurements of achievement as a potential precursor constraining critical engagement with STEM or the arts. This becomes especially clear in language such as "children who are not meeting such standards". Rather, such arguments uphold an educational framing based on meritocracy which highlights accountability for individual actors and deemphasizes the critical contexts of student learning (Nasir et al., 2016).

I am not suggesting academic success for all students is not important. Connecting arts and science integrated learning with standards limits the success of outcomes through a singular lens of academic achievement, as measured by test scores. There has been much research documenting how standards, especially science standards, uphold a canon of dominant Western knowledge systems as settled forms of disciplinary knowledge (Rosebery, Ogonowski, DiSchino, & Warren, 2010; Warren, Vossoughi, Roseberry, Bang, & Taylor, 2020; Lee, 2008) or

promote educational justice as an equality of educational outcomes (Matusov & Shane, 2018). Additionally, in the decades since *No Child Left Behind Act* (2001), increased accountability measures have not successfully prompted systems-level change required for educational equity across race, class, and gender difference. Additionally, instrumental arguments crediting the arts for academic success has been challenged within its own discipline. There remains ambiguity about the correlational linkages that don't account for the many variables that would be necessary to make such claims, as well as the limited ways participation in the arts is framed (Gaztambide-Fernandez, 2013; Hetland et al., 2013).

Inter- and Transdisciplinarity to Solve Complex Problems

A last major purpose found in the policy discourse on transdisciplinarity across science and art domains is the provision for educational opportunities that allow learners to apply creativity to real-world problems. The AEP introduces their report on STEAM learning by saying, "Including the arts in STEM learning can further enhance teaching and student achievement, and build upon existing approaches to STEM that encourage students to apply creativity to solving real-world problems" (AEP, 2019b, p. 1). Taking up the language of 21st century skills, creativity is foregrounded as essential to coming up with new solutions to existing problems at multiple scales. An American Institutes for Research (2016) report titled *STEM 2026: A Vision for Innovation in STEM* frames a section, "Educational experiences that include interdisciplinary approaches to solving 'grand challenges'" (p. 7). This report suggests that:

> Tasking students with tackling a grand challenge provides them with the opportunity to understand the relevance of STEM to their lives and to see the value of STEM in addressing issues that are important to their communities. Undertaking a grand challenge also gives students an accessible entry point as well as the freedom to tinker with ideas

> because there is no one right answer to solving these issues. Therefore, actually solving the challenge is not the learning goal. Rather, the process of developing the solution through interdisciplinary teamwork and persistence is the objective. (AIR, 2016, p. 22)

Interdisciplinary work is attached to solving grand problems, generating value for STEM as the solution for community or global issues (Yanez et al., 2019). Additionally, solving the issues, as noted here, is not necessarily a primary, critical learning outcome. The stated focus on process leaves out the very real desire many young people have to address and make contributions to their communities, especially in ways that align with their own values (Eglash, Lachney, et al., 2020). What remains in the background is the unproblematized structures in the STEM fields which may be the root cause such specific issues, such as industries which cause deep ecological or political harm (Eglash, Bennett, et al., 2020; Vossoughi & Vakil, 2018).

The arguments put forth in national policy documents frame inter- and transdisciplinarity through the purposes set by national interest and values over those that might evolve in local communities, such as OST spaces. Simultaneously, disciplinary integration is presented as apolitical and in the best interest of all. Schmeichel, Sharma & Pittard (2017) present this concept as *neo-liberalism as governmentality*. Neo-liberalism as governmentality "recasts the social domain as economic, and the market as the key mechanism for change" (Schmeichel et al., 2017, p. 197). As such, motivations for inter- and transdisciplinary efforts bringing the arts and science disciplines together in meaningful ways are yoked to the funding and rationale for a narrow set of values and outcomes. These operate as centripetal forces demanding conformity through power over funding and instrumental outcomes rhetoric.

In the remainder of this article, I consider how the macro processes operating at the level of national policy intersect with local responses at SAIM, illuminating how learning

environments integrating the arts and science can be sites of reproduction as well as potential transformation.

Analysis at the local level

Similar to the ways integrated disciplinary work is framed at the national level, the founders of SAIM came together under the belief that there are shared skills necessary and utilized by professional artists and scientists that drive experimentation and innovation. While this becomes evident in the documents, interviews, and encounters below, there also were moments which demonstrated pathways into alternative purposes for art and science transdisciplinarity. I first address where the language and connected ideology mirrors purposes of workforce preparation, a healthy economy, and academic success. Then I explore the conceptualizations of transdisciplinarity that reimagine such discourse and offer directions that might lead to more expansive ways of thinking about pedagogical activity and purpose.

Reifying national discourse

I want to pause for a moment to return to the idea of a centripetal force. It pulls all things toward its one-meaning, one-purpose, one-value. A small non-profit such as SAIM works to sustain itself while fielding the tug of that dominant message. What this means is that members of the SAIM community often feel beholden to framing their work in ways that will be picked up positively by those with either the social capital or economic capital to fund their work. This language is associated with power and represented by the centripetal force. It is also a material power associated with ways projects, events, and organizations are funded. For some SAIM community members, there is a strong awareness of these forces, whereas for others, it is not problematized. The tension inherent between the two are what I work to describe below.

Skills for a new economy. In a document recently updating SAIM's mission and vision, board members articulated the values of *curiosity*, *empowerment*, *creativity* and *access* as those that they hope to sustain through their programming. The strategic plan committee wrote that SAIM is a place for:

> 8 to14 year-olds, in a fun way, to learn creativity, experimentation, and curiosity through unique exhibits that intentionally leave instructions out. Thus, developing intuitive learning that will provide the skills to develop self-starters, problem solvers, creative people. (SAIM Strategic Plan notes, 2021)

In this statement are the often-cited list of skills needed for the "knowledge economy". Echoing the language of 21st century skills that we saw in national policy, board members also highlighted SAIM's programming focus on collaboration, team building and problem solving. It was also brought up that programming could be great for corporate staff workshops as well as a way to generate revenue. One board member mentioned:

> SAIM is solving for building the characteristics, the skillsets that are needed to develop problem solving skills which we all look for when we're building a business…it is important for every team player to perform, to have that curiosity and to be able to solve problems and they're going to be the most successful ones on your team. (Chris interview, 11.2.21)

This remark foregrounded a purpose for hands-on art and science learning as building skills directly linked to successful business. Education, thus was a tool for economic advancement and survival, an investment that might be withdrawn by those with hiring power. Skill-building became bound as a resource to be "mined" and integral for a successful business, rather than as a way for people to reach their full potential (Vossoughi & Vakil, 2018).

It was frequently discussed at the board level that SAIM provided opportunities to learn skills for future employment, currently perceived as those *not* being taught in schools. During a winter strategic planning meeting, board members watched a video on creativity together which set the context that education was not moving fast enough to keep up with the needs of industry (field notes, 9.25.21). This frustration expressed toward schools not preparing students is a key marker of neoliberal emphasis a narrative of school failure which the corporate world must fix (Apple, 2006). The subsequent argument then becomes that schools desperately require modernization in ways that form direct links between school and the labor market. This is often reiterated in ways that do not simultaneously process what the goals of school should be.

The language of entrepreneurship surfaced at the micro-level of student interaction as well. This may be due to curricular materials that emphasize artist/inventor relationships associated with product design, or language such as "indulge your inner inventor" on the website. During a workshop I co-taught, 7th grade participants looked at water collecting mechanisms in plants alongside sculptural work inspired by the plants for the BioDesign program. In a final class sharing, a student named Spencer began the presentation of his work stating, "This is the Mist Nest Portable 2.0!" (class video recording, 8.16.21). After talking through the design of his artifact, Spencer titled and began his presentation as a marketer, vending his latest design to a consumer audience. Spencer was not alone when it came time for students to present their work. This activity is not unusual in STEAM programming, particularly with a focus on design that is then tightly linked to the language of entrepreneurship and filters into the discourse that surrounds student artifacts.

Representational diversity. SAIM members, particularly the founder and staff, expressed in multiple meetings a desire to increase the diversity of the educators in ways that

reflected the diversity of populations reached through their programming and museum site. Yet this was often in tension with the lived connections or relationships with the immediate community surrounding the museum. Beyond accessibility of the space, as well as the individual exhibits, the website highlighted the ways in which the flexibility of their programming addressed diverse student needs such as translating kit instructions into Spanish or including artists from non-dominant communities into their artist and scientist exemplars. In staff meetings, outreach efforts to hire more bilingual contract educators for community programming was also repeated topic. Yet ideas about inclusion were most often framed through language of numbers, be it increasing numbers of the board or staff from diverse backgrounds. As discussed earlier, this can lead to essentializing individuals as representatives of their identity background. It also can mask the work of an equity focused agenda that permeates all aspects of the organization's culture and operation. While championing a desire to bring nondominant populations into their work, the needs of populations they serve were often determined from an outsider perspective. Implicitly embedded in such a rationale is that underrepresented communities' needs can be identified and defined by the organization without the addition of voices and perspectives from the population being discussed. It aligns with national policy whereby engaging underrepresented populations through transdisciplinary learning experiences serves an interest for STEM outside of one identified within the community itself.

Disciplinary learning. Some board members also conceptualized art and science disciplines in ways that reflected the limited perceptions at the national and state level. For example, there was a persistent voicing of science as apolitical and neutral. One board member stated:

> I'm going to go through the model of here's the basics physics behind a catapult, and here's the tools you can do...I think science is about as pure of the places you can go to take away all those items. I think it's entirely neutral. (Todd interview, 11.1.21)

As expressed in this portion of an interview, there was a prevailing sense in the organization that science learning was neutral and value-free, particularly at the board level, reflecting the dominant view of school science. This reinforces what has come to be known as the disciplinary the practices, skills, and tools that constitute a singular narrative of science as the only producer of universal truths. Such visions for science education leave unexamined the possible ways of being and thinking from non-dominant epistemologies and narrows all science learning to that of Eurocentric epistemologies (Bang et al., 2018; Vakil & Ayers, 2019). This narrowing in turn limits what art and science can do together. For example, a board member and current science teacher, who has also taught SAIM programs in the past, offered that:

> Sciences try to keep your feelings out of it whereas with art you try and put your feelings into it. Really art is... It's your own personal sense of the world where I think science is more global. Science is what the majority may perceive of the world. (Julie interview, 9.29.21)

At the staff level, there were strong beliefs regarding the potential of interdisciplinarity to create openings for non-normative ways of learning and thinking. Disciplinary notions limited approaches to consider the many places and people who do science or art, thereby inadvertently reproducing hegemonic understandings of what counts and is valued.

Resisting and reimagining national discourse at the programming level

While offering details that suggest the ways language at the local micro level mirrored that at state and national level, I want to linger on the ways that members at SAIM thoughtfully

expressed alternative purposes for the integration of art and science. I hope to portray that members of the organization work under constraints that often have the effect of pulling their desire for transformative learning toward the language of policy discourse. Recognizing the heteroglossia within the organization works to expand an understanding of the underlying purposes that do not end up in strategic plans, or grant proposals. Rather they are carried in the ways that the members talk about what they see as the purposes and potential of transdisciplinary learning. I turn now to the ways SAIM also reimagined what might be possible through bringing art and science together. These insights came from those most involved with SAIM programming: the founder, the administrative staff and the educators.

Intergenerational learning and relational activity. The museum operations manager emphasized the intergenerational aspects of visiting SAIM, attuning to moments in which he noticed "the reinforcing of family bonds" when parents and grandparents engaged with their kids around an exhibit. He reflected on one story at a knot tying exhibit:

> The grandfather had been in the Navy, and was a sailor, and was way into doing knots. And he sat there and he showed his grandkid how to make all these little knots. Now that's something they could have easily done at home, right? But they didn't, right? But it sets up the opportunity for those kinds of things to happen. (Gordon interview, 6.16.21)

Not only does this moment highlight the doing together of the encounter, but it also suggests that the environment, the exhibit, can *set up the opportunity* for learning and storytelling. A similar moment occurred during a remote learning program when the mother of a participant joined in the creation of a Rube Goldberg marble rollercoaster and began sharing her experiences as a roller coaster engineering inspector (field notes, 12.12.20). Gordon later added that a unique quality of SAIM was its intention to "provide limitless opportunities for people to share what

they do know, share what they're interested in, share what they know about themselves, share what they know about other people" (Gordon interview, 6.16.21). This framing sets in motion the idea that learning and sharing of knowledge happen through stories and relationships, such as between a grandfather and his grandson, stimulated for learning in a given environment. Importantly, the creation of exhibits with attention to ideas of science and art was not just seen as something to engage students. Rather, interacting with others around the exhibit, the social aspect of that experience, was an essential part of the interdisciplinary learning.

Gordon also pointed to the consequences of overly structured learning objectives and activities.

> I think that there's a lot of social problems in school and I think a lot of it relates to power dynamics. I think a lot of what kids end up taking away from their school experience is a false sense of who they are and where they belong. And, the tragedy of it is you get a lot of young kids who would otherwise be very interested in the world, who would otherwise soak everything up like a sponge. But, because you kind of twist their arm, they resist. (Gordon interview, 6.16.21)

Not all educators and staff explicitly connected their motivations for valuing the learning at SAIM through the negative consequences of oppressive pedagogy in schooling environments. For Gordon though, who had worked at a transitional housing center for high school youth, this was an essential aspect of offering experiences to learn outside of formal school. Relationships, for Gordon, were not just about challenging students' thinking and understanding about the world, but were essential to recognizing the dignity of each learner and the importance of students feeling that their inclinations, thoughts, and ideas were valued in the space.

Refusing standardization. Educators and staff often struggled to articulate the learning that happened in SAIM in ways that aligned with how schools communicated about curriculum. Program proposals, grant applications, and outreach often required naming specific sets of outcomes through language that resonated with science standards and traditional forms of curriculum and instruction. The founder offered an example of how she envisioned the curriculum meandering toward the integrative program objectives:

> I'm thinking about air tube as an example, that you can to go up to it and experience the aesthetic joy of watching a single ribbon wind its way through it. I really like that. Or you can desire to figure out how to make something just hover in the middle. …And then potentially to make it more transdisciplinary, whatever angle somebody is naturally trending towards, you could potentially give them a prompt to think of it in a different way. … And even potentially just lead with, "I wonder why it does that". (Beth interview, 6.21.21).

In this example, Beth offered multiple ways into disciplinary conversations based on activity at a wind tunnel exhibit. While not outright naming the science or art learning goals built into the activity, she suggested a number of question prompts as ways to connect to different aspects of the phenomenon being experienced. Her approach to teaching and learning does not begin from a place of disciplinary objectives. Rather, she has worked with the artists and scientists on staff to identify activities and experiences that might spark an initial interest. The role of the teacher is altered to prioritize weaving students' demonstrated interests with traditional ideas of science or art where it emerges and aligns. In her story, Beth also centered the affective dimension of the encounter, the response a student might have when watching the aesthetic floating of a ribbon in the wind versus a version of the arts that is product driven. Delia, the Education Director,

discussed the importance of supporting new teachers with a script, or rough plan of the programs, but making sure that they felt comfortable tweaking it to match their own pedagogical style (field note, 3.10.21). Delia's prioritization of flexibility for educators acknowledged teaching as a creative act, and demonstrated a shared staff desire that teachers felt supported in developing their craft.

The organization's willingness to suspend a linear project curriculum or guarantee a finished product outcome at times complicated their outreach. In highlighting the difficulty of explaining their mission, Operations Manager Gordon stated**:**

> It's not objectives, but that doesn't mean that there's no outcome. That's the tricky part that people get stuck up on. Because, it's like, well, if you don't go into this experience expecting to learn something about math, then you don't necessarily understand that you still could do the experience and come out learning something about math. It's in the cards. It could happen. You don't have to set out with the explicit purpose of learning math in order to potentially learn math. You might still, if it presents itself, in the situation (Gordon interview, 6.16.21)

SAIM staff often discussed what they hope students take away from experiences. They also placed a high value on there being multiple ways of engaging with materials and activities to ensure room was made for multiple possible outcomes.

Making science and art accessible. The bringing together of art and science also opened up ways to contest settled forms of knowledge in each discipline. While they did not explicitly detail or reckon with the political aspects of Eurocentric framings of art, and science, one of the expressed goals at SAIM was to agitate the siloed disciplinary structure of traditional learning environments. As Beth, expressed:

> I think that interdisciplinarity and transdisciplinarity require a breaking down of traditional silos and traditional definitions of what belongs in the silo. And once you start the habit of breaking down traditions and walls and definitions, it leaves you more open to other possibilities, and particularly other ways of knowing and other results that are very valuable. And I do think that traditionally these definitions have been sort of the average white man, six-foot definition. And so by breaking down some of those and opening up, you do allow sort of the natural inclinations of kids who come from very different backgrounds and understandings, to be equally valuable. (Beth interview, 6.21.21)

Beth expressed her perception of the limitations of disciplinarity itself, yet also alluded to the powered ways dominant forms of knowledge are constructed by the six-foot "average white man". In this moment, she suggested by engaging in transdisciplinary experiences, students are able to bring in their understandings of phenomenon in ways that are personally meaningful. What is critical to this as an opening is the last part of her framing which is "to be equally valuable". The end goal, seemingly advocated by Beth, was not for learning to then be reworked toward traditional STEM standards, but that the students' "natural inclinations" have a value of their own.

Troubling technologies and competing with STEAM. As an organization founded in the nascence of the STEAM movement, the now wide public uptake of STEAM programming has also increased expectations for what art and science learning is, and the purpose of such learning. This presents a challenge for the learning environments designed with different aims in mind, such as through the family and community relationships as they emerged. Educators and staff expressed tensions felt between how they were expected to frame art and science learning

and how learning actually happened through the programs at SAIM. The Education and Outreach director, who fields calls from schools and organizations requesting SAIM programming, was often asked about the makerspace part of the museum. The current makerspace at SAIM consists of resources such as paper, cardboard and recycled plastic pieces as well as adhesives and scissors. What she found in the queries about SAIM programming was:

> They want that technological piece that we don't provide. For different reasons, it doesn't mean it's right or wrong. It's just, they want that. They feel like that's important skills for the kids to learn so they're more... They want that robot! I don't think they're impressed when we say, "Oh no, we don't do that. We don't *teach* anything. We don't use robotics. We don't use anything technological." They're like, "Oh, that's too bad." (Delia interview, 9.6.21)

The hands-on programming at SAIM had an intentional supply list. Materials were to be easily accessible from what might be around the house, in the recycle, or purchased at a hardware or corner store. What Delia highlighted is that the language of makerspaces has been so intricately woven with technology that it fuels expectations around objectives, tools, and processes. Rather than conversations focused on the learning goals of such activity, much of her work was to delineate and offer rationale for the equipment used.

A board member who worked closely with staff on events also highlighted an element of creative learning that was widely valued by SAIM staff and educators, and contrasted with the motivations set by 21st century learning: that creativity is always happening in many contexts outside the school. She stated:

> I sort of grew up with other people asking, is there another way to do it? Using the tools that you already have to do a job that you would get someone else to do. In a way,

> looking at things differently…I guess in a creative in a way. Even as I was little and just working with my grandfather around the yard, we get that spool of thread and we're going to take this twig and rock, and we're going to create this, and that will do the job, instead of going to the hardware store and buying a brand new gate type of thing. (Allison interview, 9.21.21)

In recalling a story from her own youth, Allison articulated a what she believed was the value and purpose of inter and transdisciplinary learning at SAMI. She re-centered the home, one's family and community, as a place where rich learning happens, where problems are generated and resolved from within personally relevant and contextualized needs. Decentering the institution as the authority on whose and what knowledge, creativity and innovation is valued remains integral to considerations and locations of expansive disciplinary learning (Bang et al., 2012; Warren, Vossoughi, Rosebery, et al., 2020). It also creates openings to examine who is considered a teacher and holder of knowledge across multiple contexts of learners' lives.

Alternative ethical trajectories. Finally, at the program level, there were many moments where students offer an ethical orientation through the work they create. As they share their thinking around their artifact creations, they effectively reorient to the axiological focus of their explorations. For example, the student who had introduced his Mist Nest 2.0 in the earlier passage went on to say, "Then I added this because I imagined, 'Okay, what if this was real life? Would it be good?'. I was thinking, 'Well, what if the water wasn't pure?'. So I imagined the net as sort of a purifier machine" (class video recording, 8.16.21). Here, Spencer layered complexity into the tinkering we were doing as he considered not just how to collect water but also the issue of the water contamination. This was not something we discussed in the lead up to the activity. Rather, Spencer brought this idea in from experience outside of the session, specifically news he

had heard about access to fresh drinking water. With this ever-present in his mind, he identified a problem and through the activity, offered the class a sociopolitical opening for continued exploration. In the short conversation that followed, we discussed where he imagined his mist net collecting water and what might cause the water to not be pure before moving on (field note, 8.16.21).

In a different design session, students looked at animal habitats created in areas of extreme temperature, increased water levels, or in areas with unstable ground. Connecting these adaptations to extreme living conditions, students designed housing structures based on what they had noticed in nature. After relaying a story of her uncle who had been deeply impacted by Hurricane Katrina, a student named Shona presented a structure that could float under the conditions of rapid sea level rise and flooding (field note, 8.20.21). Centralizing care for her family as a starting point, Shona attended to her own stated purpose and motivation for the design work. Her curiosity and experiences provided an opening for us to talk and learn more about who was impacted by Hurricane Katrina, as well as discuss the complications of federal response. Spencer's comments provided an opening to consider where people were being impacted by water that wasn't pure, and why. In their own way, each student's art and science explorations became a starting point for an axiological orientation different than that found in national policy. When engaging art, design and science work with youth, we must resist the idea that individuals can simply fix complex issues by making new objects bound by an old set of relationships. Stories such as that put forward by Spencer and Shona attended to relationships as central to purposes of a transformative transdisciplinary project.

In summary, national policy frames inter- and transdisciplinary learning in ways that are singularly focused on workforce development, innovation in service of national economic gains,

increased access to STEM learning, and promoting academic success as it is currently defined. These are markers of a neoliberal agenda, though they cannot be causally linked to framings at the local level. Yet such discourse does have the potential to produce particular rules and structures (Schmeichel et al., 2017). The community members at SAIM were committed to breaking down the silos between science and art toward new ways of thinking about disciplinary learning. Tensions arose in the centripetal pull of how this was conceptualized, particularly around board members and staff who felt the need to communicate in ways aligned with funding initiatives. Tension was also present for the staff and educators who saw great potential for prioritizing relationships in their designing for learning not based on use-value. As SAIM continues to develop a sense of the possibility, there is much to be learned from the young people who make connections between the technical knowledge embedded in the activities and human well-being.

Implications for Framing Transdisciplinarity

In undertaking this study, I was interested in exploring how educators, staff and board members at SAIM reflected and reimagined broad policy discourse regarding the purposes and potentials of transdisciplinarity. Transdisciplinarity has been put forward as a differentiation from the normative practices of traditional disciplinary schooling. To fulfill this, more than the name has to change. As Gordon pointed out in the reflection at the beginning of this paper, we have to worry when words change but the ideas are not new. At the macro, national level, the purposes of transdisciplinarity maintain the same forms of oppression at work in our educational system. They recreate forms of schooling that are particularly harmful for those from non-dominant communities, despite rhetoric of change through inclusion of art and design practices. Fairclough (1995) states, “Texts in their ideational functioning constitute systems of knowledge

and belief…and in their interpersonal functioning they constitute social subjects (or in different terminologies, identities, forms of self) and social relations between (categories of) subjects" (Fairclough, 1995, p. 6). Valuing tied to a nationalist lens positions learning as pathway to the creation of human capital, chained to the forces of economic growth and global competitiveness (Apple, 2006; Madkins & McKinney de Royston, 2019; M. A. Takeuchi, Sengupta, Shanahan, Adams, & Hachem, 2020). As such, human beings' lives are made to matter only in their potential for production, despite a call for equity and inclusion. Takeuchi et al. (2020) point out that we must "reorient human capital discourse to human capability that could bring about social change beyond economic growth" (p. 234). In our conceptualizations we must stretch toward a vision for STEM and arts education, that challenges ideas of technocentrism, limited views of innovation, and the discourse of efficacy and employability (Sengupta, Shanahan, & Kim, 2019).

In this paper, I focus on the forces present between actors in the SAIM community and the often-implicit conversation with national rhetoric regarding the purpose of transdisciplinarity. By looking vertically from macrolevel national policy, to the microlevel interactions and reflections from educators, we can see both reification and reimagining, the tension that lives through the heteroglossia of language. I argue that those most involved in the creation of the curriculum and designing for learning at SAIM hold key ideas of a critical and creative transdisciplinarity. Their conceptualizations of the value and purpose of transdisciplinarity is rooted in intergenerational learning, joint activity between educators and students, political discourse sparked by ethical orientations, alternative ethical trajectories, and a commitment to multiple values, beliefs and purposes for human learning. Bakhtin (1981) writes, "Alongside the centripetal forces, the centrifugal forces of language carry on their uninterrupted work; alongside verbal-ideological centralization and unification, the uninterrupted processes of decentralization

and disunification go forward" (p. 272). In some of the ways purposes and aims of transdisciplinarity are framed in local contexts, we can find the starting point for a transdisciplinarity that moves toward transformative learning possibilities. Following Bakhtin (1981), I argue that turning toward the decentralized utterances in local contexts can help us to consider the sociopolitical and ideological activity always in motion.

Integrating STEM learning, and its branching STEAM transdisciplinarity, has been the latest in a long line of efforts framed progressive reform. While language might appear calcified, there exist moments where it can be cracked to reveal the heteroglossia that points toward other value suppositions. Recent uptake of transdisciplinarity needs to be subjected to analytic and political scrutiny, as has been done with STEM and STEAM elsewhere (Barajas-López & Bang, 2018; Eglash, Lachney, et al., 2020; Morales-Doyle & Gutstein, 2019; Tzou et al., 2019; Vakil & Ayers, 2019; Vossoughi & Vakil, 2018). Sengupta, Kim & Shanahan (2019) write that "hegemony always results in the silencing of voices that can disrupt the disciplinary core" (p. 17). As a result, I argue that transdisciplinarity need to be reimagined from the ground up in such a way that liberatory politics and expansive disciplinary learning co-exist and co-develop. There is reason to pause before acting too enthusiastically to adopt and design new ecologies and approaches for learning that echo the authoritative rhetoric of STEAM epistemologies. Rather than propose a framework, a roadmap assuming universal design solutions, we might look to how art and science have been explored through cultural practices in symbolically meaningful ways over time. Attending to a such a set of values and ethics might serve as a compass for enacting transformative transdisciplinary work.

Chapter 4 – Disciplinary Disruptions in Time and Place[2]: An Autoethnography of Art-Science Learning

Figure 4. Author and siblings sitting by lake

I remember the energetic sounds as evening fell, the chorus of insects that came alive to usher in the veil of night. It always took a while to go to sleep, lying out on a tarp, open and exposed without a tent unless it was raining. I slowly turned my head from side to side taking in the expanse of the sky. The moment when a shooting star trailed across my focal view was always hoped for magic. Eventually, I would roll in towards one of my siblings for warmth and let the long day of hiking take over my body.

Figure 5. Author and siblings camping in Yosemite

[2] Throughout this chapter, changes in font and spacing are purposeful, intended to show breaks time and move across spaces of learning. Given the constraints of Word program, this particular arrangement is for the dissertation and should allow for feedback and review as you might another document.

Trips to Yosemite were a summer ritual. They began as soon as a quorum of the seven of us were old enough to carry a small backpack with a rolled sleeping bag roped to the bottom. Hopping on a bus, or in a car if we had one, we would take off to backpack together for week. These trips became my outside breath, orienting me to a world of living beings. More than that, they sparked my curiosity about connections and relationships: the lichen on the tree and the direction of the sun's movement; the wet, rich soil under fallen logs and the burrowing beetles; seeing the bolt of lightening and counting the seconds before the thunder to estimate how long we had before a storm turned our trail into flowing mud; how to tell poison oak in the dryness of summer; how the bears could smell the loaves of bread tucked away in our packs hung high in the tree and further how they heaved their massive bodies up the tall trunk. These were also affective moments charged with beauty – the glowing embers dusted with ash, the curling purple and grey of manzanita bark, the glowing blue of sunset as our eyes adjusted to nightfall.

fall 1994

I stood in front of a blossoming tree on my university campus. The heat of the sun fell on my face, warming me as I turned it toward the sun. I was ~~happy~~ thrilled to leave the dim auditorium lit by the lecture slides, the mouthy seats to flap shut in our absence. My biology peers huddled close with notebooks in hand as my professor talked about gymnosperms and angiosperms, punctuating the flow of words by pointing to the pink flower in front of him. I was transported to the living, to learning in context.

Fixated on my professor's face, I realized I had never seen him close up. Given our lecture hall class size of 150 students, it was still easy to hide two years into my program. I had relegated myself to the back of the classroom, afraid of being called out in class and not knowing. Also, because the dark room and monotone lectures routinely put me to sleep.

This moment outside was rare. Generally, I was disconnected from science – I didn't feel that pull of beauty or animation that I thought I would find in deep study. Relations were severed, cut from what was in the world to chapters in a book. Deep lines bound what I could experience from what I had to memorize. I had lost my sense of wonder in the delivery of science articulated by the professor, or his TA, at the bottom of the dark auditorium.

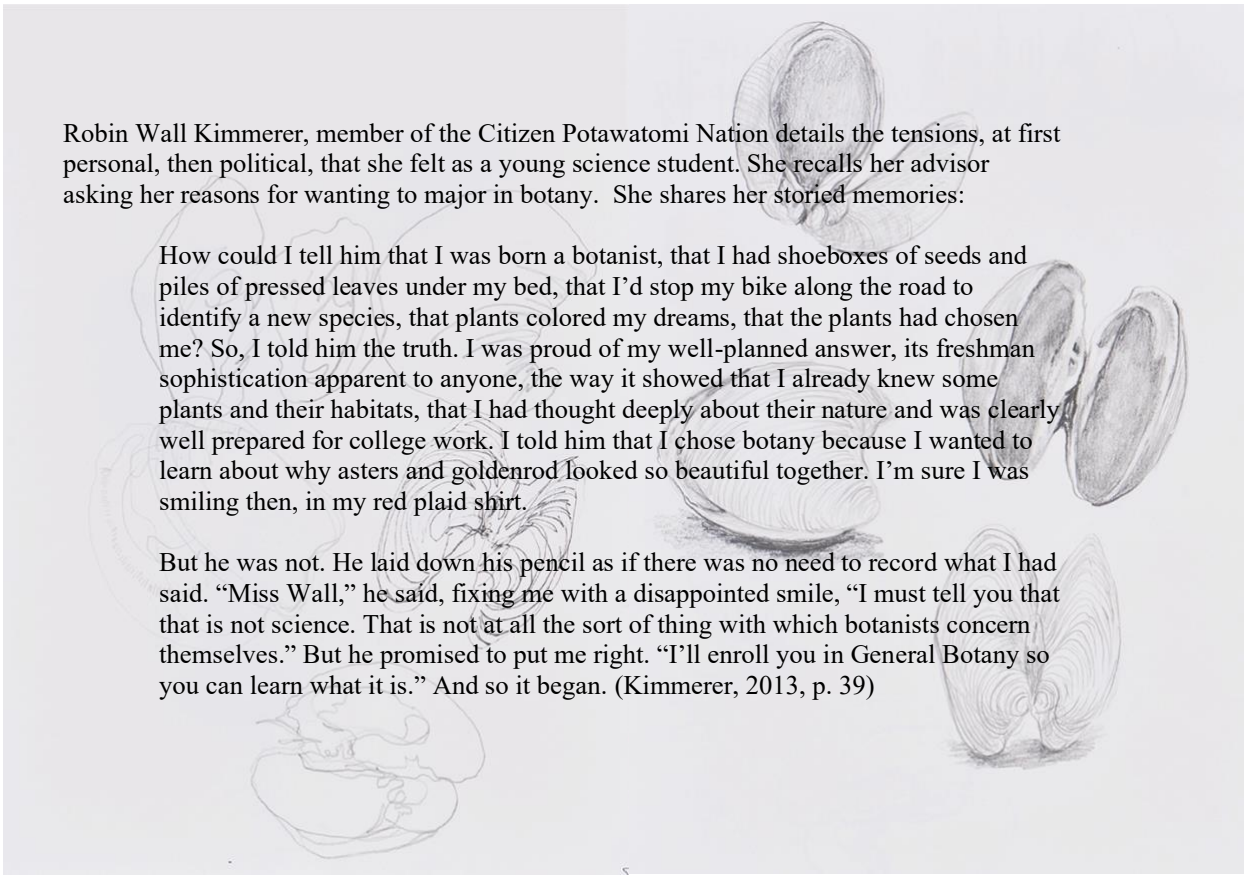


Figure 6. Background is page from the author's sketchbook, drawn while exploring a local beach

I remember similar subtle messaging I received in those first years studying science. There was no place for beauty in science learning. No adjectives in a lab report. No play with the o-chem model. No exploratory palettes in bar charts. Learning science was to serve a different purpose. And I was clearly not fit to be a scientist.

ART & SCIENCE ECOLOGIES: LOCAL ENVIRONMENTS

During the summer of 2021 I taught an 8-session online course through a pre-college program at an art & design school on the East Coast. The program is marketed as an intensive 4-week online program for students entering their senior year in high school who are serious about building portfolio work. The description for the course I taught, read as follows:

Welcome! I am thrilled to get started and learn more about you. In this class, we will be focusing on our relationships with the natural world, specifically the world just outside your door!

One of the reasons for the creating this course is that addressing some of the world's biggest issues is often posed as happening through macro-scale technological or material innovation. Instead, we will consider together that change begins with a focus on our relationship to the environment around us, individually and collectively. Together we will explore not only the science of your local neighborhood, but also the life relationships found in natural systems.

Life science and art inquiry processes are bridged in this course to build skills and techniques that showcase our capacity as researchers, observers and creators. We will explore the work of artists who collaborate with nature, both conceptually and physically, and ask questions that grapple with and imagine possible futures. Assignments will focus on observation at the micro and macro scale along with formal elements of art making. You will be invited to experiment with materials through drawing, and painting and finally a 3D book form. Sketchbook exercises are used to practice techniques and build up your research questions, which then become the material for the final project. Time spent outside your workspace is going to be critical to engaging in the course, whether you live near a forest canopy, suburban neighborhood or cool in the shade of a high-rise.

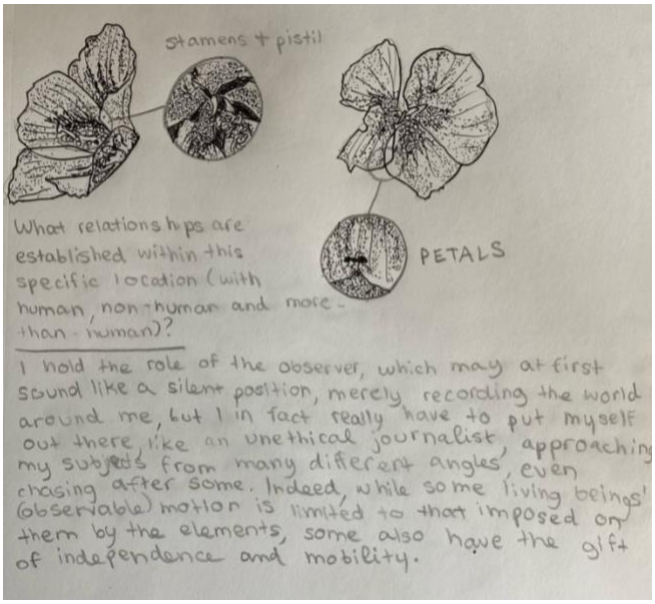


Figure 6. A page from Laurie's sketchbook responding to Assignment 1 prompts

Alongside readings and viewing in class, students were asked to pick a place they would revisit repeatedly over the four weeks of the course. The first assignment, *reciprocity and relationships*, asked students to develop a work which listened to the interconnected partnerships and relationships of a chosen being within the space they were revisiting. The second assignment, *geographies of the middle,* asked students to work from patterns found in images, maps and stories of their chosen space to explore a binary (i.e. life/death, human/animal, persistent/ephemeral, etc.). Their final piece,

storied place, was to create an artist book that that represented a conversation they had/were having with a chosen, local place. This could be an expression of relationship with the space broadly or of a specific moment such as a single walk through the space. Recalling the ideas of the prior assignments, the final piece was intended as an opportunity to express their thoughts about their relationship with/as nature. Each week, students were asked to gather information to respond to given prompts, such as looking up histories of populations that had moved in and on the land. They also were asked to consistently note questions that came up they wanted to pursue as they made observations in their space.

This course had shifted quite a bit from the few years prior. After over a decade of integrating the arts with the sciences under the acronym STEAM (Science, Technology, Engineering, Art and Math), something still did not *feel* right about the entanglement. In reflecting on the ways I was teaching the summer course, I realized I was reproducing many of the disciplinary and political cuts that I had wanted to mend. Student notebooks were filled with beautiful drawings but I had not created the conditions that might shift students' relationship to nature and place. Some of this was externally imposed: the push to create finished portfolio pieces in exchange for the high cost of tuition, the predetermined tools and material lists, the fixed

Figure 7. Teacher example of sketchbook exercise looking for color palettes in nature

curriculum. The world outside the studio, even as an inspiration, was brought in, extracted, as little more than a resource for our making. Yet, in parallel, I was beginning to center anti-colonial and Indigenous scholars in my own research. These scholars offered portals into epistemic disobedience (Mignolo, 2009) and a move away from binaries through epistemologies that existed before and alongside rigid disciplinarity. I wanted to address this during the 2021 summer implementation of the art and science course.

AUTOETHNOGRAPHIC EXPERIMENTAL COLLAGE

This paper is designed as an autoethnographic experimental collage (Wargo, 2018; 2020). In it, I merge anti-colonial theory, feminist theory, and new materialisms with a reflexive exploratory process. Autoethnography calls upon one's own experience in emphasizing the direct ties between individual lives and larger social formations (Chávez, 2012) or as Boylorn & Orbe (2020) state "using personal experience to describe and critique cultural experience" (p.10). I see this method as a type of *illumination* that we might "give name to those ideas which are – until the poem – nameless and formless, about to be birthed, but already felt" (Lourde, 1984, p. 37). Research, becomes a form of searching in and through one's life, outside the bounds of the institution (Sukarieh, 2019). I present this particular collage of stories to demonstrate how I came into the study and understanding of science and art. What called me forward – what pushed me away. These are certainly memories compressed over time in my retelling. In the traces of rememberings they offer a personal entry point into an often-assumed dualism, one at the heart of my interest in the current uptake of transdisciplinarity in the field of education.

In a logical empiricism/logical positivism paradigm, there is a tangible reality that exists outside of intersubjective interpretations. Following the scientific method our representations of

that reality become truth. Key factors that legitimate an objective form of knowledge generation and discovery include reliability, predictability, objectivity and falsifiability (Dixon-Román & McKinney De Royston, 2020). Given my focus on disrupting dualisms through anti and decolonial scholarship, I turn to Gordon (2011) who writes:

> [T]hat modes of producing knowledge can be enlisted in the service of colonization is evident. … Put differently, couldn't there also be colonization at the methodological level? If so, then, any presumed method, especially from a subject living within a colonized framework, could generate continued colonization. To evaluate method, the best "method" is the suspension of method. (p. 97)

Autoethnography, alternatively, extends knowledge specifically through mingling identity with practice, refuting that good theory keeps personal and social values from affecting research. I have purposefully chosen it as a way to work against normative social science methodology that equates rigor with alignment to science practices.

A critical autoethnographic approach looks specifically at canonized knowledge and challenges its modes of construction, including what is traditionally seen as academic knowledge (Brissett, 2020). Mackinlay (2019) writes that autoethnography "belongs out of the past and in with the posts" (p.191), suggesting that it is a research design made possible only through an interruption of modernist dogma. Re-centering the research question that prompts this study, the culture I seek to understand as a reflexive participant and observer in this paper is that of a transdisciplinary space of art and science with high school youth. I ask the question: *How do I and others experience transdisciplinary nature-culture encounters associated with art and science inquiry?*

LAURIE, AND THE ANT

As part of the collage essay, I braid excerpts of the discourse surrounding the unfolding of the final project of one focal student from the summer course, Laurie. While she was not able to be near her home for the duration of the course, she was able to repeatedly visit a park near her home away from home. Laurie was a high school senior who was staying for the summer with her father in Paris, where his work was located. She enrolled in the course because of her interest in ecology and climate change. At her school she was elected *The Minister of Ecological Affairs* and saw herself as someone deeply concerned about the destruction of the planet. During the second week's assignment, Laurie posted a number of photos of her explorations of her chosen place, a park nearby her house. They were not incorporated into her final piece, but I include them as points along the road for her final assignment. If you look at one of her drawings in Figure 1, you can also see the ant's first appearance in a close up call out of the flower's petals.

Figure 8. Laurie's photographs taken in response to Assignment 2.

Jackson (2013) writes that "Inanimate matter and nonhuman animals have affective power, shape human subjectivity, and alter human perception. In fact, nonhuman matter animates biopolitical

realizations and affectivity" (p. 680). What called to Laurie as she wandered through the highly manicured garden near her house? In the midst of summer blooms showing off their palettes, how did the tiniest of creatures beckon her? These images were just a few among many. Manning and Massumi (2014) suggest that "The intercessor is a complex singularity that activates a process, a force that acts as a differential within an ongoing movement of thought. The intercessor: the felt force that activates the threshold between thinking and feeling" (p. 65).

the early 80s

I could have watched him draw for hours, the way he held his blue colored pencil so that the tip softly touched the surface of the ridged paper, leaving a light pigment that filled in the mantle of the Virgin Mary. Other times it was the way he used his hobby blade to carefully cut paper for a homemade book, or our own home-made version of a monopoly game, or figures from a magazine for the flashcards he made me to help learn my multiplication tables. His desk was always an array of tools, project scraps, and pencils sharpened and at the ready. Watching him work was my earliest experience of art.

Figure 9. A family monopoly game, created mostly by the author's father (with some kid design involved)

But I was often also a participant. Sitting around a table, telephone books propped up my little body. My chubby hand clutched a pen to scribble on the old blueprint paper tacked

to the middle of the table. Every so often, my father would spin it, and we would begin to add to the work of the sibling sitting next to us. There was a letting go in this – our art was collective. There was no getting attached because someone else was going to add to it. The surprise gift was what came into your focal view from the sibling next to you. Or two years into my new school, making the birthday gifts that we couldn't buy, practicing what my mother had taught me. I became known for making big denim bags with iron on initials on the pocket, probably the main reason for party invitations. Or there were the gifts we made for our teachers at the end of the school year, our mother helping us carefully create the woven lattice dough that would harden to become a basket.

These were moments of relational making, concrete, playful and purposeful, set in motion by our interests and needs

Figure 10. (l) the four oldest siblings with one of the spin drawings in the background; (r) the author making a bag having learned how to sew from her mom

fall 1995

While taking science classes in college, I was also enrolled in painting classes. In contrast to the dark lecture hall, the studio hummed. We laughed, we moved around the room, we moved toward each other, we talked about our work, our emotions, our ideas – trying to understand, imitate, create meaning-filled signs and symbols that connected and spoke to our relationship to the world and to each other. As we worked on our easels or painted against the wall, we shared stories – of our days, our families, our fears, our hopes for the future. At the end of my second year, the art department recognized me with an award as an emerging artist and it seemed I belonged. So I stayed.

AUTOETHNOGRAPHIC ANALYSIS

For the analytic phase of this paper, I first let the data sit, reflecting outside the data on moments that rang with importance before returning to my field notes, reflections, recordings, images and program artifacts. Next, I attended to an "emergence of sense" or initial *glows* in the data (MacLure, 2013). Returning to the data allowed for the work to move beyond a story to add a layer of analysis by looking at the experience mediated through the cultural artifacts. Ellis et al., (2011) highlight that autoethnographers use their methodological and theoretical tools and research literature, to move back from the data to theory to consider the experiences of others, as well as the characteristics that might render a culture familiar for insiders and outsiders. The movement back and forth works to build layered accounts in which existing data prompts further questions and comparisons versus signaling a supreme truth, or as (Ronai, 1995) details, forcing "a particular understanding of the world masquerading as *the* understanding of the world (p. 396). Ultimately, I worked toward condensing and synthesizing the stories of the data into vignettes that are layered through the voices of multiple subjects in interaction, one that reflects the heteroglossia (Bakhtin, 1981) through multiple points of view always present in social space.

A critical aspect of autoethnography is that it engages with affect[3], either through the emotion embedded in an interaction or event, or connecting to the reader such that the story portrayed is not simply a distant analysis of a text (Brissett, 2020; Chávez, 2012). Through vignettes, the researcher is meant to *show* and not simply *tell* what is going on in the specific

[3] By affect, I mean that vignettes in autoethnography stress the social relationality and engagement between the writer and the environment, two emotive entities that meet in the middle and activate a new 'field of relation' (Manning, 2016). Conradson & Latham (2007) define the affective entanglement as the "energetic outcome of encounters between bodies in particular places'' (p. 232). I will attend to affect as it emerges through resonance and intensities between myself and the environment (including students, materials, events). Vignettes expand the possibility of affect through what is produced between the researcher and reader.

context under study (Mackinlay, 2019). Vignettes are meant to be both aesthetic and evocative, using conventions of storytelling to engage readers and create arcs of interest and action (Ellis et al., 2011). While autoethnography is easily criticized for not meeting the rigor of social scientific standards, Ellis et al. (2011) write:

> These criticisms erroneously position art and science at odds with each other, a condition that autoethnography seeks to correct. Autoethnography, as method, attempts to disrupt the binary of science and art. Autoethnographers believe research can be rigorous, theoretical, and analytical and emotional, therapeutic, and inclusive of personal and social phenomena. (p. 345)

Autoethnography does not follow the linear conventions of traditional or even interpretive social science research. Rather, it is similar to thinking with theory (Jackson & Mazzei, 2012), a practice in which the process of "plugging in," (a term borrowed from Deleuze and Guattari [1980]), is activated to create assemblages that emerge, not from what is, but from what is *becoming or might become.* While this does not offer a clear picture of what will unfold, it is precisely the purpose. What is critical is that the autoethnography is grounded in what is, and what is missing from current explorations of transdisciplinarity.

LOVE HATES BINARIES

I return now to where we left off, as I reoriented my college study toward the arts from the study of science. What I am working to link in this paper is an understanding of the interrelationships between powered binaries (specifically science/art as indicative similar dualisms between civilized/primitive and human/non-human), disciplinarity, and learning. At its core, science and art represent just one of many dualisms that have come to define the epistemology and ontology of a Westernized world. We could leave it at the disciplinary level

and suggest that they each simply offer different ways of coming to know the world. This is where we find much of the discussion regarding art and science integrated curriculum in education research. But I argue we have to dig deeper. Conceptualizations of science and art – and hence anything that emerges from these disciplines – that are predicated on this separation as *inherent to the discipline*, reflects the logic of binaries. It suggests something can be either A or B, but not both, or an A-B or a A-C-B, or any other version for that matter. We are deeply familiar with many of these pairs: science/art, male/female, mental/manual, mind/body, human/nature (non-human), reason/matter, public/private and importantly as almost a summation of the previous, civilized/primitive (Dixon-Román et al., 2020; Plumwood, 2016). And we cannot just gloss past these as a linguistic architecture for understanding all things on a spectrum because the logic of dualisms is connected with ongoing violence and oppression. In the period of epistemic and territorial conquest that followed Enlightenment Era colonialism, dualisms were exported as a foundational aspect of modernity (Grosfoguel, 2013; Santos, 2014). By epistemic conquest I mean the reduction of all ways of coming to know (epistemologies) being flattened into one, universal way to know that had very specific geopolitical roots in Western Europe, and later, the United States (Mignolo, 2009). Mignolo (2009) clarifies that colonialism refers to the historical moments of global expansion of Western imperialism, whereas coloniality (shorthand for colonial matrix of power) refers to the ongoing powered hierarchy of Euro-Western centricity

Dualisms operate through values and power in the broader society, and are associated with specific geographic locations and logics. Mignolo (2009) writes, "As we know: the first world has knowledge, the third world has culture; Native Americans have wisdom, Anglo Americans have science" (p.169). Dualisms are linked through their value and power constructions. One side is framed as superior while the underside is inferior and forever the

"other" side. Regarding these binary associations of modernity, Plumwood (2016) extends that through the logic of dualisms:

> …the postulate that all and only humans possess culture maps the culture/nature pair on to the human/nature pair; the postulate that the sphere of reason is masculine maps the reason/body pair on to the male/female pair; and the assumption that the sphere of the human coincides with that of intellect or mentality maps the mind/body pair on to the human/nature pair…. (p. 45)

Following this thread, the qualities of freedom, universality and rationality are mapped to a public and masculine sphere, and the qualities of everyday, necessity, particularity and emotionality constitute femininity and the private sphere. Importantly, these are not simple hierarchies of difference. One becomes a subject and one becomes an object. The civilized can say things about and do things to the primitive, with authority. The human can do things to and take things from nature. The structure of the ontological relationship, binaries as reality, allows it to be so.

Such narratives structure anthropological understandings of culture, learning and development that create hierarchically ranked racial and geographic distinctions in people, languages and knowledge connected to certain parts of the world, labeling some as primitive and others as civilized. Jackson (2013) speaks to how "at the moment when the conception of "the human" was reorganized such that humanity was understood as coincident with "the animal," humane discourse relying on this new understanding simultaneously reformulated blackness as inferior to both the human and the animal" (p.678). Speaking specifically to the construction of blackness, Jackson (2013) gets at the heart of the oppressive nature of the scientific, A or B rationality. Dualisms are an ongoing tool of coloniality. They are mobilized, "for this purpose of

inferiorising the sphere of nature and those human-beings who may be counted as part of nature, providing a powerful and all-pervasive model of rational meritocracy" (Plumwood, 2016, p.47). Hence, one's humanness, one's ability to think and know emerges from a geopolitical space, a racialized space, and becomes salient in when or how one is valued in society (Mignolo, 2009).

Reverberations of this way of thinking is seen at the scale of theories of learning and development in school as well. For example, Vygotsky's (1981) sociocultural theory allows us to conceptualize learning as human-environment interaction, mediated by people and multiple available sign and tool systems (i.e. linguistic, material). Yet for Vygotsky, development moves from concepts students learn through "informal" experiences to concepts students learn "formally" in school. This movement is one from an interphysiological plane to interpsychological plane, reinforcing a mind/body dualism (Dixon-Róman et al., 2020). The implied dichotomy between *the two* privileges schools. Tasks considered to involve higher order thinking are linked to the institution of school, and privileged over learning in routinized activity (Lee, 2002; Philip, Jurow, Vossoughi, Bang, & Zavala, 2017; Warren, Vossoughi, Rosebery, Bang, & Taylor, 2020, Politics of Learning Writing Collective, 2017).

A critical approach to sociocultural theory actively challenges an anthropological framing of learning and culture as linear, moving from home to school, mirroring a false trajectory of everyday, childlike and primitive, to sophisticated and academic. Such a critique also disrupts a doctrine of disciplinarity. Barajas-Lopez and Bang (2018) reinforce this by saying that "relations between human worlds and natural worlds are culturally constructed, impacting not only forms of practice and engagement but also forms of knowledge, knowledge organization, and reasoning and sense-making about phenomena" (p. 8). The bounding of knowledge practices, as coloniality's extension to modernity, is exercised through a history of domination and control

that honors the values at the center. The qualities we now associate with science, such as objectivity, truth, pure reason, and quantitative method are pitted against those associated with art–the subjective, interpretive, qualitative. I repeat here Plumwood's words: rational meritocracy. The more we exhibit what is considered rational thinking, the more we have a right to be. In the binary of science and art, engaging in science is an intellectual practice, while the arts are the underside, *the other*, non-sanctioned, rendered barbarian in their emotive cage. Sousa Santos (2014) refers to this as "cognitive injustice committed against the wisdom of the world on behalf of the monopoly of science and the technologies sanctioned by science" (p. 34). Science, as it has become universally understood, not only defines the only method of inquiry for truth, but also sets into the motion hierarchical subject-object relationships at its core.

APRIL 2018 (and many times before that)

My professor reached out to meet and shake my husband's hand, looking back and forth between the two of us, *"Oh, so that is where you get your name,"* he said as if a long troubling question had finally been answered. His eyes took in my Mexican-Polish husband's darker skin and deep brown eyes. *"Morales is my maiden name,"* I responded knowing exactly what he was getting at.

This professor was not the first to make assumptions. Racialization has come at me from multiple sides – people working to make sense of my name, my geographic and/or a biopolitical positioning. In my first job out of college, I worked with two different non-profits in California. Koam Art Academy in Daly City, CA was run by two women from South Korea, and Culture on the Corner in the Fillmore District, San Francisco, was run by an African American man. Within days of my being hired, the women from Koam Art Academy admitted, *"We are hoping you can bring some kids of your white friends to our school for classes."* Not long after, the director of Culture on the Corner said, *"We have got to get some of your Latina sisters in here to work with us on projects."* This positioning has happened continually over time and in almost every space of which I am a part. Recently, a colleague and I – with whom I have never talked about my ethnicity – were on the phone when I overheard her say to her interrupting husband, *"Can't you see two brown women are over here talking about important things?!"*

These comments are not unusual, and they render transparent society's desire to categorize, to essentialize, name, label, split apart, and flatten in order to make simple sense of the world. At a young age I become hyper aware of the minute details that constructed race and class, as I became aware of others' need to categorize me and my family. And it didn't help that my answer to where are you from? was vague at best. In the first decade of my life, we moved twice that many times along the coast of California as my father tried to find his voice in society and chased the American Dream along Highway 1 with defiance. A point always fading on the horizon. Our roots did not grow down – they grew horizontally, tangling my nuclear family in our co-production of home, of from.

I have a history with the in-between. Thus, the dynamic middle – a space of cultural and epistemological tension – is central to my personal and professional identity. As a woman with Costa Rican-Catholic and White-Jewish heritage, I am enfolded in entanglements of classification, ultimately increasing my attunement to othering, and society's desiring for a singular narrative (of culture, of history, of gender...). This tension also came from being a very low-income family of nine in an area of great wealth, tracked as scholarship kids in private, Catholic schools. Decoding unspoken visual and verbal cues became a survival tactic, seeing what made someone a this or a that. "Pain makes us acutely anxious to avoid more of it, so we hone that radar. It's a kind of survival tactic that people caught between the worlds, unknowingly cultivate. It is latent in all of us" (Anzaldúa, 1987, p. 61). I incessantly read my environment for the performance code and subtext, and understood positioning was connected to power. But we were not raised to be political. We were raised to be grateful of our privilege. I primarily took on this tension as something wrong within me, not as a manifestation of larger systems of racism, inequity and oppression.

MOVEMENTS TOWARD EPISTEMIC FREEDOMS

Thus far, I have introduced my focus on learning in art and science, binaries and the in-between. I turn now toward the elsewhere, as I did during the science lecture held outside, orienting to feel the sun warm my face. Escobar (2016) writes that the need for new ways of thinking/moving forward on the planet, is a "trajectory for thinking otherwise" (p. 13). This, he suggests, can't be simply grounded in western thought. He speaks in unison with Jackson (2013) who asks, "Is it possible that the very subjects central to posthumanist inquiry-the binarisms of human/animal, nature/culture, animate/inanimate, organic/inorganic-find their relief outside of the epistemological locus of the West? Perhaps the "post" human is not a temporal location but a

geographic one" (p. 673).[4] For me, as for many others, this future looking begins in spaces which don't work from preformed binaries. This is not a new concept for many non-Western communities with cosmologies and philosophies different from the West, whose very onto-epistemology begins with relational ways of being in the world (Ahtone, 2019; Bang, 2020; Paraskeva, 2016; Todd, 2016).

It is my responsibility, thus, to pause here. Todd (2016) speaks to the tension of Indigenous stories and scholarship being employed, particularly in the Western academy, without Indigenous people present. She contrasts this with the risk of not acknowledging Indigenous intellectual thought and theory. Given my own background growing up a U.S. citizen from an English-language-first Catholic household, I move with care, to listen and follow, to amplify but not appropriate. For example, as I remembered my trips to Yosemite, I wrote of my connections to land. Yet I was a settler, a visitor. Yosemite National Park remains unceded territory, known and cared for since time-immemorial by the Ahwahnechee, the Native

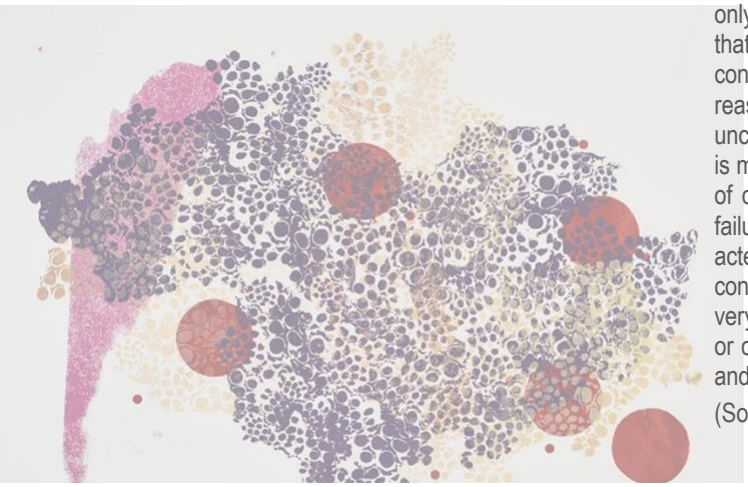


Figure 11. Three color silkscreen on paper by author using microscopy of lichen

> These new possibilities show that irrationality is not the only alternative to what is currently considered rational, that chaos is not the only alternative to order, and that concern about what is less than true (the messy reasons and affections underlying the struggles for uncertain results) must be balanced by concern about what is more than true (the habitus of disproved grand theories of claiming truthfulness in their explanations of previous failures). The new possibilities emerge from new actions acted out by new players with new discourses and conceptions. They are actually not new; some of them are very old indeed; they are ancestral. Our times are not flat or concentric; they are passages between the No Longer and the Not Yet.
>
> (Sousa Santos, 2014, p. 6)

[4] In her essay, "Animal: New Direction in the Theorization of Race and Posthumanism" Jackson (2013) critiques Eurocentric posthumanist theories that seek to deconstruct human/animal, mind/body, mental/physical binaries. She argues that the literature does not engage with Black, Indigenous and queer geneologies of theory, such as that by Silvia Wynter and Franz Fanon, that have long contested the construction of the Western (hu)Man, specifically through their experiences of exclusion from such a category.

American people belonging to the tribes of Miwuk, Northern Paiute, and Kucadikadi Mono Lake people. The Ahwahnechee were forced out of their homes in Yosemite Valley in phases from the late 1800s through the 1900's as settlers pushed into what is now California and the established National Park. Currently, the Miwuk are still working to gain federal recognition and land sovereignty. Looking to elsewheres not rooted in Western epistemic hegemony, requires a discursive acknowledgement of this history. More importantly I believe it requires participation in ongoing political and allied anti-colonial work, while supporting Indigenous led efforts at sovereignty.

My work toward epistemic freedom begins through breaking down binaries which confront me in my efforts toward art and science transdisciplinarity. It is a form of "epistemic disobedience" which is an opportunity to delinks from the illusion of "zero-point epistemology" (Mignolo, 2016, p. 160). One commitment is to learn through the research and scholarship of those whose theory, stories, and philosophies emerge from spaces outside the university alone. Through this scholarship and storytelling I am invited into rethinking relationships with the human and more-than-human world in ways that were not valued in my schooling experiences. For Escobar, "Reflection on relationality re-situates the human within the ceaseless flow of life in which everything is inevitably immersed; it enables us to see ourselves again as part of the stream of life" (p. 29). This reflection sets up an ontological differential, illuminating systems of beliefs and values. In particular it offers a move away axiological assumptions that prioritize the individual over collective, and divide nature from human beings through hierarchical use-value relationships.

This does not imply going back to a pre-colonial time, as if a before and after. Bang (2020) says "We must learn to remember, dream and story anew nature-culture relations" while

emphasizing, “how those relations are always on the move and always layered and shaping the present” (p. 7). It is an invitation to a learning on the move that includes movement between pasts and futures that exist in the right now. Thinking that one existing paradigm (i.e. science or art) will provide answers for all current questions offers a limited horizon of possibility, what Sousa Santos (2016) calls *weak answers* to strong questions. Considering the complexity of possibility will involve a different mobility, “moving beyond the well-worn travel according to historically tested maps” (Sousa Santos, 2016, p. 40). Massey (2005) adds that “You can't hold places still. What you can do is meet up with others, catch up with where another's history has got to 'now', but where that 'now' (more rigorously, that 'here and now', that *hie et nunc*) is itself constituted by nothing more than - precisely - that meeting-up (again)” (p. 124). The here and now is a movement, a moment in reflection and dreaming outside of binaries to attend to relationships. As a moment it is also experienced temporally. De la Bellacasa (2015) writes, “care time suspends the future and distends the present, thickening it with a myriad of demanding attachments” (p. 707). What if the place of elsewhere (other-than binary) is a spatio-temporal, a moment held in the tension, in the push and pull of pasts and possibilities.

TRANSDISCIPLINARITY AS MOVEMENT

What might then be a creative and critical art and science transdisciplinarity as movement, as spatio-temporal opportunity for relational attachment. Might it be felt in the breathing in and breathing out of tensions, of the push and pull.

> As the storm winds and unwinds, leaving a trail – of destruction, if it is severe – across the surface of the earth, so the snail alternately pushes forth and pulls up, leaving its slime trails on the ground. This rhythmic, push-pull cycle seems to me to be fundamental to the

> life of most if not all animate creatures, our human selves included. Like the snail, in walking as in breathing we too must draw in if we are to issue forth (Ingold, 2015, p. 58).

Bang (2020) also speaks to learning that happens in bodily movement:

> Non-movement is an historically accumulating bias that serves the long trajectory of powered struggles in western knowledge systems and societies ontological assertions of human exceptionalism and supremacy (Grosfoguel, 2013). Mobilities and how we see them, how we make them, how we dream them and how we story them are consequential (p. 8)

Ingold (2015) continues:

> In movement every snail, having unwound itself from the interiority of its whorl-shell, has become a line, and in leaving its slime-trace on the ground, it has tangled with the lines of each and every other of its kind so as to form a visible meshwork. Perhaps the outstanding characteristic of these lines is that even when extended in what looks like a consistent direction, they are never perfectly straight. To make a straight line, it is necessary to connect two points, for example by means of a ruler, prior to advancing from one to the other, using the edge as a jig to guide one's movements. But a living line, which must perforce find its way as it goes along, has continually to attend to its path, adjusting or 'fine-tuning' the direction of its advancing tip as the journey unfolds. Only after having reached a certain spot can it feign to have found the way there. (p. 59)

How might we shift from the sedentary disciplinarity of western schools towards invitations to be in relationships with the outside? Bang (2020) asks, *What new ways of seeing, doing, being do we need?* (p. 8). Perhaps the wandering lines are the transdisciplinary tensions that keep us working on those answers, and reframing the questions until we can arrive there together.

THE PROTOTYPE | August 5, 2021

I return to Laurie's ongoing work with the garden across the street from her house. During the third week she brought the class her prototypes for the final *storied place* assignment. She was hesitant to present them in their rough format. In trying to get her ideas out, she felt she had not devoted enough time to craftsmanship. With that disclaimer, she shared images of her work during our works-in-progress critique. I include the transcript below.

Laurie: So the way I interpreted the assignment - my relationship with nature and the approach I decided to take for this was as much as I really, really love nature and admire it and just, I really appreciate its aesthetic beauty and care about the planet, I am sometimes really afraid of things like bugs and stuff and a little grossed out by it, a little unreasonably so. And I'm just trying to come to terms with that and also try to pinpoint what it is I'm so afraid of about those creepy crawlies because they do so much to help the earth. And I know this, but at the same time they do scare me and the best I've come to, being able to describe the feeling is that I'm scared that they are small enough that they can go inside of me and perhaps can go through my pores or penetrate my skin or something or go through any of my orifices like my ears or my nostrils or something. So I definitely wanted to tackle this feeling and try to put it in visuals and in a book.

Figure 12. Laurie's Book Prototype #1

Laurie: I also want to do more research on this and make this even more scientific, but this is a brief outline of the different, this is the green is everything digestive. This is the brain in orange and the red is... I'm actually not sure what that is, but not my research obviously I'd have to credit the person who discovered all these organs, but yeah. And so I tried to reverse the roles kind of, and have the small humans penetrate inside the organs of the ant. And then it is able to pierce through the skin, the membrane almost exoskeleton, then it is standing around and finally it is messing with the organs and holding them and trying to yeah, just manipulating them basically.

Figure 13. Laurie's Book Prototype #2

Laurie: And then the second one, I just, was more of another way to express this. It's pretty simple. It was just the accordion book. And it covers at first a hand laying on top of the grass and then little by little, then the hand is in the grass and the grass intertwines with it, because I'm also not very a fan of grass and try to avoid touching grass most of the time ever since I was a baby. And then the ants... oops, come onto the hand and they open up the skin. So that was just to put into visuals what my irrational fear of insects would be in this one.

[Partial transcript of feedback Laurie received.]

Blake (peer): I think one of the first things that I said in this class was that I tend to enjoy the creepy crawlies that everybody else hates. But it's not like I've always been, like, "Oh yeah, I want to be a beekeeper." I have not always been that. And so I think taking the irrational fears and using that in the role reversal that you've done and trying to tackle and pinpoint what freaks you out is really impressive.

I think that if you lean a little bit more into the second prototype that you'll be able to... I don't know. I feel it resonates with people, the idea of being scared that something's going to crawl under you, the feeling of creepy crawlies is when something is under your skin or all over you or something.

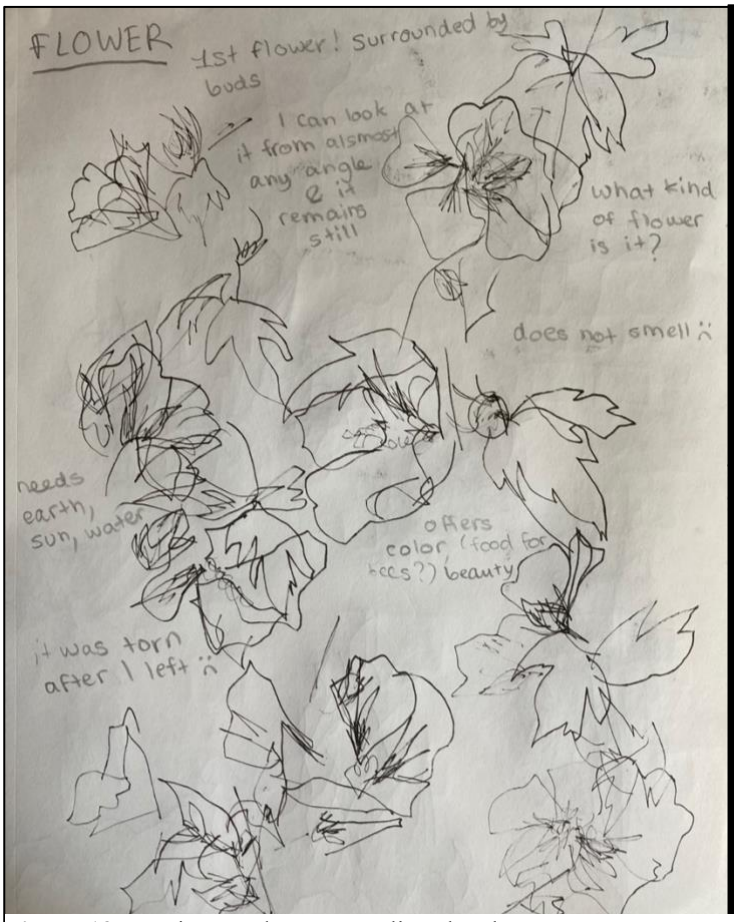
Halle (peer): I agree with Blake about that last part as well, but I do think I really like the way you cut out the first prototype with the legs and making [the book] an actual ant. I think, you could definitely fuse those two ideas together. What I really love about the second one is the way you're fusing together the human and the nature.

I think the first one is, I don't know how to describe it. It's a little bit more... it does feel like a scientific book I'm reading a for science class, I'm reading one of those little colorful maps showing the organs and the actual names of stuff. I think, you might have to choose between a more...I think if you can take that part of the first one and then use that relationship in the second one, I think you will have a really good composition and project.

Rachel (art history teacher): I'm really interested in the way you started with the conceptual. And I think that the concept that you've identified is such a powerful one and stemming from your very honest identification of a fear. This tension between where our boundaries are and where the natural world's boundaries are, I think is an age old very subliminal fear and you're putting your finger on it.

I've often thought about this because I love the creepy crawlies actually. But there's certain ones I don't like, they're all different, right? And I realize that I have a fear of creatures whose behaviors I'm not familiar with. So if I understand a bee and a yellowjacket and an ant and snake from my context and my ecosystem, my environment - I like them. And I know them and I know what to expect from them. I know their behaviors.

In this excerpt Laurie admits to her fear of the ant that she has been dancing with over the few weeks of the course. She begins her story with language that demonstrates a care for nature, nature's beauty, and the future of the planet. Yet she also objectifies nature (nature is an "it"). Aligned with Bang, Marin & Medin's (2018) findings, her explanation demonstrates a feeling that she is *apart* from nature versus *a part* of nature. *It*, nature, was something scary, unknown



Kimmerer (2013) comes to realize it wasn't that her movements were misguided:

I circled right back to where I had begun, to the question of beauty. Back to the questions that science does not ask, not because they aren't important, but because science as a way of knowing is too narrow for the task...I should have been told that my questions were bigger than science could touch (p. 45)

What kinds of questions might emerge if allowed to be bigger than the structures of what we know of as science? In what movements or directions might such inquiry take us?

Figure 13. Laurie's garden contour line sketches

and needing to be tamed, reflecting a "model of the biological world and the position of human beings in respect to it" (Bang et al., 2018, p. 152). Her dissonance is felt. In one prototype of her book, a human character acts out an invasion of the ant, ending in a "messing with the organs". In the second prototype, her hand presses into the uncomfortable scratchy grass. In pressing into the earth, she allows the ants to become a part of her body. Rachel, an art historian joining for critique, extends this concept as an "age-old" fear, a comment both ahistorical and reflective of erasure of non-Western thought. Before the class left we discussed together where she first observed the ant, and what this ant might be looking for in his crawling search.

LEARNING FROM THE OUTSIDE

Lucia Monge (2022) joined us as a guest artist one morning midway through the course. Her interdisciplinary practice spans sculptural and 2- dimensional work that centers on the movement of plants. She specifically calls attention to how humans position themselves within the natural world and relate to other living beings

Monge: I would hope that we're all here in this virtual room potentially because we're interested in this mixing in between art and science. And I think art and also science, they have different ways of viewing the world, right? And we're here to kind of see how we can mix them together. But I would hope that you also feel the freedom and the power to not only take them and mix them, but also reimagine them because they both come with ways of seeing the world that some are fantastic

Figure 14. Monge with sculptural mask – a tool made to to adjust for parallax when observing plant growth

and helpful and some are not. So they're just in your toolbox, right? And science will say, “Oh well, that technically, that thing is not science”. And some things will be like, "Oh, technically that's not art." But those separations are the ones that we also need to be wary about or skeptical about because yeah, maybe it's not art, but I'm going to do it anyway, or maybe that's not science, but I need to try it. So I think in the combination of art and science, I hope there's space also for the combination of your own observations…There's something in between that the science or art might be escaping that you might be capturing and perceiving. And I think that's a rich place to make work because there's a freedom there. You can do anything, right? And it can look like whatever you want it to look, I think.

WALK WITH ME

You are next to me and we are walking along a promenade, along a beach. Imagine your eyes are scanning the horizon, scanning the ground, adjusting to the cracks in the cement, adjusting your gait to my gait, adjusting to the puddles. You are figuring out where to put your foot next. Not because you have mapped it, but because you are constantly learning the landscape. You are learning, in motion. Ingold says *walkers*, a term he uses alongside artists, “thread their lines through the world, rather than across its outer surface. And their knowledge is not built up but grows along the paths they tread” (Ingold, 2015, p. 47). Ingold (2015) goes on to say:

> [M]ovement is not ancillary to knowing – not merely a means of getting from point to point in order to collect the raw data of sensation for subsequent modelling in the mind. Rather moving is knowing. The walker grows as he knows…What distinguishes the expert from the novice, then, is not that the mind of the former is more richly furnished with content – as though with every increment of learning yet more representations were packed inside the head – but a greater sensitivity to cues in the environment and a greater capacity to respond to these cues with judgement and precision. (p. 48)

What conceptualizations of transdisciplinary learning might get us moving? What conceptualizations of transdisciplinarity might lead to elsewheres, along trajectories of thinking otherwise? Among the borders of here and there, then and now, centered and marginal, human and nature, is an invitation for a different epistemological focus that involves more time for care time. "Border epistemology emerges from the senses, from the body sensing the power differential of the border (any border, geo-political and body-political)" offers Mignolo, interviewed by Gaztambide-Fernandez (2014, p. 199). But by returning to the senses, I do not suggest a return to forms of art and making as these too have been constructed with centers and peripheries (Gaztambide-Fernandez, Kraehe, & Carpenter II, 2018). Thinking, making, art and science coming together in movement between.

Transdisciplinarity then could be seen as a way of re-sensitizing, or newly sensitizing, in the movement of a moment. Questioning disciplinary binaries is not just recentering one over the other. Camnitzer (2020) imagines, "The most important work of art in the history of humanity is the one that generated the word "art"…Since there wasn't an art market, that first work of art did not respond to a need to make an art object, but was the application of a method for cognition…The work was the consequence of an attitude" (p. 13). Camnitzer describes art as an attitude, as a method of returning to the senses, as cognition. Following Manning and Massumi's (2014) exploration between sensation and thought, I return the making of movement to the immediacy of its feeling. "In that feeling, a different, more intense, utterly singular thinking will occur" (p. 39). Before the making of the artifact of art is the sensing of a pull to movement. Attending to a feeling, or thinking-feeling, pulls toward another point, a trajectory of thinking, otherwise. Like Ingold's snails, the line is not straight, but tugged this and that way in the here and now. Manning and Massumi (2014) continue, "Movement only comes from movement. But

movement does not come from movement only sequentially, in a rolling continuity of thinking-feeling motionally bodying. Movement is always triggered relationally. That is the answer: movement only comes from movement relationally" (p. 42). This is potentially the heart of transdisciplinarity; in the doing, relationships lead, you are not led to a particular relationship. In the thinking-feeling, there is a moment of resonance that prompts another sensation.

This is a different idea than what tends to be discussed as the arts in an arts integration, STEAM, ArtScience model, when the arts are relegated to a disciplined set of skills, techniques and material interactions. Much of the art in these projects has lost its response to sensation, it's *attitude*. Art was "not only imprisoned in the word 'art,' but also at the mercy of the social class that controls the word" (Camnitzer, 1994, p. 17). Creativity, the action of sensation, collective and individual, has become clouded by what was sanctioned, civilized, sophisticated, and properly defined. *The arts* have been mapped and immobilized. Fielding the affective power of the sensations is the movement that reopens to the world. "The outside is suspended within the work in an appearing-disappearing that beckons to attention. Attending and art-making are aspects of the same process." (Manning & Massumi, 2014, p. 72). Sousa Santos (2014) connects thinking-feeling with life, what Manning and Massumi might call *the outside*, what Ingold might term moving *through* the world versus on it. He distinguishes thinking-feeling as non-Western epistemologies of the South:

> Our knowledge is intuitive; it goes straight to what is urgent and necessary. It is made of words and silences-with-actions, reasons-with-emotions. Our life does not allow us to distinguish life from thought. All our everydayness is thought of every day in detail…Our knowledge flies at low altitude because it is stuck to the body. We feelthink and feelact. To think without passion is to make coffins for ideas; to act without passion

> is to fill the coffins…Our kind of knowledge is existential and experiential; it is therefore both resilient and flexible, disturbed by all that happens to us. (Sousa Santos, 2016, p. 30)

Transdisciplinary learning, thus, is *the movement* held in the middle of science and art, between pasts and futures, between the here and now and the there and then. The sensations to which we attend to are not 'art' sensations or 'science' sensations. Rather, they are moments of thinking-feeling in relation to the world. And this world is always in motion. "Thought gathers in the work. It is the event of the work's unfolding…that seeks to activate a new way of seeing, a new effort at participation" (Manning & Massumi, 2014, p. 65). In the unfolding of student work, our small class was invited into different relational considerations.

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On the last day of class, Laurie presented her *almost finished* (her words) final piece. Discussion began with her holding her work up to the computer camera, moving it around, zooming in, and letting us examine her book as we peered toward the screen. We then moved on to discuss observations, pointing out what we noticed or what stood out. Interpretations followed observations and we added thoughts on the meaning we were making from the piece, identifying how the work made us feel and what it sparked in our own relational encounters in the world.

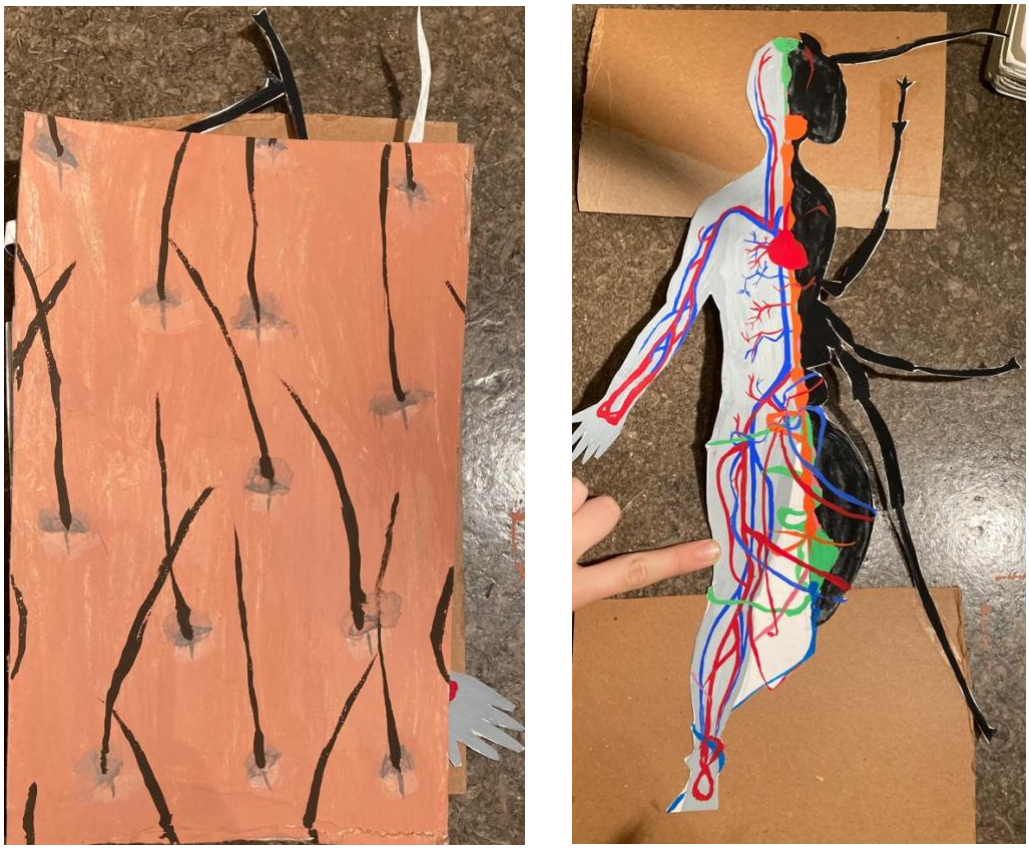

Figure 15. Front and middle of Laurie's book-in-progress

Julieta (course TA): I think it might be about equals between species. And I'm getting that vibe from like they're the same scale. So she's trying to present them as equal, not organisms, but like an importance I guess.

Halle (peer): I was going to say that it does a good job of showing how similar we are, even though yes, we are humans and they are ants. There are a lot of differences, but we all have organs and nervous systems and all of that, which is what makes an organism. Actually, organisms exist without those things, but you know what I'm getting at. And yeah, I think that is conveyed by all of the intertwining and how it starts a little bit more separated. And then as you go, I'm guessing the end of the book is going to be the bottom of the page. So yeah, it's a good evolutionary story.

Blake (peer): I think the scaled-up size of the ant kind of emphasizes sort of how the two are in a way equal, even though the human population and ant population are obviously quite different. I think that because all of the lines, which I interpret to be like veins and arteries, it helps kind of take away from the fact that ants are invertebrates and the humans are vertebrates. I think that the way that the lines are wrapping around each of the organisms kind of helps like tie them together.

Figure 16. Middle and back of Laurie's book-in-progress

INTER-RELATIONAL MOVEMENTS

Considering ideas of the art and science as embedded in the questions and curiosities of students, the movement of thinking-feeling, requires we look at more than just student artifacts. In this paper I have shifted across personal experience, critical theory, excerpts from class discourse around one focal student. I have also fostered, through form, a shifted across what this inter-relational movement and wayfinding is. In Laurie's explorations are the traces of a student whose inquiry was led by affect to ants moving through the garden. In the second week of the project, she sensed and was pulled. A few sessions later Laurie offered the class a science-art thinking-feeling, a movement of ant and human becoming each other, merging, using scale to point us toward an elsewhere beyond a binary. As the conversations unfolded with her peers, this movement also moved others with words like veins, organism, vertebrate embedded in an exploration of fear. Manning and Massumi (2014) write, "What happens in the middle is that the

either–or is held fast together in passing contrast. It is the holding together that is felt, in excess of one or the other…The either–or is taken as such into the passing." (p. 33). The holding fast together creates a space for Laurie to examine her relationship with what she and her peers call "the creepy crawlies" in the first critique session, but refer to as just *the ant* throughout the final critique.

What matters in this trajectory to an elsewhere, beyond *the arts*, beyond *science* is what kinds of relationships evolve within the context of symbolic exchanges involving creative work (Gaztambide-Fernández, 2013). Laurie invited our class to sit with her fear as she wrestled with the disjuncture and dissonance of the idea of human-nature separation. After her peers discussed what they saw in her work, she shared her thinking saying,

> I tried to go as more with the going down on the body. They more and more start linking and sharing with just arteries and organs and just mixing. I wanted this to be a little unsettling and just show that both were penetrating into the sides that they weren't supposed to be in.

For Laurie, her work-in-progress (*again movement)* and her thinking-feeling was a push and pull between a living separate from nature and at once wholly entangled with nature, sharing one heart. Her exploration of this relationship is not a straight line, but a snail trail, whose destination is only known upon arriving at a point and looking back at what glints in the sun-rich trail.

Transdisciplinarity, found in the integration of science and art, has the potential to remind us to feel-think different possible relationships other than those constructed through narrow disciplinary visions. For much of the world, this will not be new. This thinking-feeling with the earth, or *sentipiensan* as Escobar (2016) called it following the Zapatistas, is a foundational part of relational epistemologies (Bang et al., 2018). Fahseh, interviewed by Sukarieh (2019) extends this idea saying, "A main difference between living in harmony with wisdom and living in

accordance with the dominant ideology today is manifested in how we perceive science. Whereas civilizations prior to the European one perceived it as protecting and living in harmony with nature, Francis Bacon conceived it as subduing and conquering nature" (p. 187). What might it be like to live in harmony with wisdom? What are the rich cultural practices we can collectively bring together that create space for connecting with wisdom versus achievement alone. In such activity we can contest universalized methods seen as foundational to how we generate knowledge, making room for something new to emerge about learning.

Kimmerer, speaks to the wisdom of her own community's knowledge:

> [speaking about goldenrods and asters] Their striking contrast when they grow together makes them the most attractive target in the whole meadow, a beacon for bees. Growing together, both receive more pollinator visits than they would if they were growing alone...Why are they beautiful together? It is a phenomenon simultaneously material and spiritual, for which we need all wavelengths, for which we need depth perception. When I stare too long at the world with science eyes, I see an afterimage of traditional knowledge. Might science and traditional knowledge be purple and yellow to one another, might they be goldenrod and asters? We see the world more fully when we use both. (p. 46)

As many who have undertaken transdisciplinary projects know, it is often a messy, unpredictable and hard-to-define. Massey (2005) suggests that the event of a place is special precisely because of its "throwntogetherness". This throwntogetherness may at times be the encounter of onto-epistemologies with different geopolitical centers, that leads to questions of within discipline boundaries (i.e. whose values and whose knowledge is legitimized). At other times, the event-

place may spark encounter which requires unavoidable negotiation of the here-and-now, within and between humans and nonhumans. And at other times still, the former may spark the latter in a moment of dissonance. The combining of art and science offers greater potential than topical disciplinary integration. “Acknowledging other kinds of knowledge and other partners in conversation for other kinds of conversation opens the field for infinite discursive and non-discursive exchanges with unfathomable codifications and horizontalities” (Sousa Santos, 2014, p. 35). Other kinds of conversations can spark other visions for learning, for valuing, for being human. Conversations can be the movement which leads to movement.

Chapter 5 - Conclusion

My goal with this dissertation was to forward conversations concerning how we – as educators, as researchers, as individuals – might reimagine rigid structures of disciplinarity. Further, I am interested in how we engage in pedagogical dreaming but avoid enlisting new terms (i.e. STEAM) to maintain narrow understandings of educational environments and experiences. Approaching transdisciplinarity through the sensibilities of critical interanimation, contact zones of onto-epistemic heterogeneity and culturally symbolic production challenges rhetoric of innovation that outwardly speaks to new ways to solve problems while leaving the internal source of the problem undisturbed. While investigating racial privileges and biases in Science, McKittrick (2021) centers the lives of black creatives, writing:

> Telling, sharing, listening to, and hearing stories are relational and interdisciplinary acts that are animated by all sorts of people, places, narrative devices, theoretical queries, plots. The process is sustained by invention and wonder. The story has no answers. The stories offer an aesthetic relationality that relies on the dynamics of creating-narrating-listening-hearing-reading-and-sometimes-unhearing. (p. 6)

The complex and trans-sectorial problems being faced at a global level require ways of thinking and being that challenge the dominant political and ethical orientations of our society, including our position in the natural world. And there is a story educators and researchers are trying to tell or attend to when taking up the word transdisciplinarity. Yet with little empirical work to guide and understand the enactment of transdisciplinarity – as concept as well as a practice or series of practices – in the classroom, it is at risk of becoming yet another passing trend.

Educational spaces, as I advance in and through each of the papers, can be one place to recognize and amplify stories that challenge the norm. We need research that can guide our understanding

of the characteristics, tools and pedagogical requirements of supporting critical and creative transdisciplinary work.

Summary of exploratory thoughts

In the first paper of this dissertation, I offered considerations for developing a critical and creative transdisciplinary pedagogy. This included recognizing that all projects stemming from disciplinary standards created in an institutional context alone are limited through ongoing forms of epistemicide and erasure. Secondly, I suggested we must recognize the many ways students come to know the world, animated through the rich contacts zones of integrated art and science learning. Third, in the interanimation between school art and science practices, I emphasized the importance of bringing to light the powered relationships that exist both within and between disciplines. And finally, I posed transdisciplinarity as a form of culturally symbolic activity that happens across the many places students move throughout their lives. My efforts to develop these considerations is an attempt to push the development of theory on transdisciplinarity.

In the second paper, I analyzed the ways bringing together art and science learning is framed through policy initiatives, and how that was reflected or reimagined at the local level of one art and science museum. Those working closely on curriculum development and teaching at SAMI, offered conceptualizations of transdisciplinarity that go beyond nationalistic, capitalistic and workforce driven purposes. Transdisciplinarity was reframed as a process of intergenerational learning, joint activity between educators and students, political discourse sparked by ethical orientations, affective calls to inquiry, and a commitment to multiple values, beliefs and purposes for human learning. and the tensions between centrifugal and centripetal forces at the local level.

In the third paper, I purposefully attempted to desettle normative research practices by activating autoethnography, weaving together story and theory that centers art-science dualisms. In so doing, I suggested ways that expansive disciplinary engagements map open up possibilities to engage with some of the separations presented by Western Eurocentric nature-culture relationships. In tracing one student's work, I demonstrated not how she grappled with her fears but also how she imagined a new connection, alignment or similarity with the creature that beckons her. This was a momentary portal to an elsewhere – to potentials that exist outside of where we are today. I suggest that we are attentive to the thinking-feeling of transdisciplinary spaces, to listening for the other worlds. This is not to say transdisciplinarity will hold all the answers. Rather, they lead us to feel the tensions of the push and pull of the line, opening to learning as sense-making that is connected to relationships, values, goals and identities of learners and their communities.

Study Limitations

As the research for this dissertation began, COVID sent formal and informal programming into chaos. This extended for the year in which data generation took place. The impacts to the work were felt in last minute changes to research permissions, such as filming online programming, or communicating with to families. As such, many of my hopes for these projects were narrowed, and required shifting focus. For example, a six week/12 day, 8-hour session happening in-person was shortened to a 4-week online program with eight total 3-hour sessions. It also turned out that the group of students enrolled in the course were taking it remotely from multiple places in the country. Students' families had taken the opportunity of online participation to 1) live abroad for the summer, 2) begin college tours, and 3) travel between family households. This shifted the place-based work of the third study. Critical to

participating in all of the research spaces was the development of relationships and trust I had already built as a member of the community. This in and of itself is not a limitation. Rather, the projects became models or prototypes that can point me in directions for future research.

Implications for Future Research, Teaching and Learning

Reflecting on relationality – made possible through a critical and creative transdisciplinarity – has the potential to resituate human learning in a broader search for meaning and values. This will require restructuring how learning is organized in schools (Warren, Vossoughi, Rosebery, et al., 2020), as well as rethinking how we engage with teacher education to support such teaching and learning. All changes in schools require support that extends to shared understandings at the funding and policy levels. The complexity of the issues we grapple with globally are not going away, nor are we finding that our ways of resolving them are sustainable for all. Through the interanimation of knowledges previously bound geographically and politically, we can begin to challenge the stories that have been told in singular forms. Manning and Massuimi (2014) write, "Movement is always triggered relationally" (p. 42). One way to think about this idea is to consider the ongoing histories of searches for knowledge, epistemologies, as movements. They are different ways of being with the world and coming to understand the world through a set of relationships which hold values. An essential piece of this understanding is that only in the meeting-up of these ongoing movements, be it in a classroom or a professional development session or a policy room, can we find insight for next directions.

Creating spaces for onto-epistemic heterogeneity does not simply mean that many varied knowledge systems exist and should be valued. While I believe this to be true, such an oversimplification suggests a form of epistemological relativism. On the contrary, spaces where pluralism can thrive compels new methods for facilitating dialogue between differences that is

simultaneously grounded in the rooting out of oppression or a denial of the humanity of others. In this dissertation, I have explored both within and across disciplinary differences as a way to consider what is made possible through dialogue and translation of ideas.

I do not suggest that one knowledge system should be replaced by another – such as replacing science with art, Western epistemologies with one of varied Indigenous epistemologies or those of the global South – so that all disciplinarity is done away with. That would effectively swing the pendulum once again toward epistemicide and contradict counterhegemonic aims. Nor is this critique of dominant knowledge systems a plea to go back to a time frozen in history, a pre-modernity. As Massey states "You can't hold places still" (p. 124) as the eventspace of pre-modernity is not a fixed point. Rather, I suggest we attune to the movement created in spaces of epistemological coming togethers, such that their interanimation surfaces the ways each is not a complete picture of the world.

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