

## “Globalization,” Coloniality, and Decolonial Love in STEM Education

Miwa A. Takeuchi, University of Calgary

Ananda Marin, University of California Los Angeles

### Land Acknowledgements

As a member of the University of Calgary, Miwa A. Takeuchi acknowledges land stewardship by the people on the traditional territories of the Treaty 7 region in Southern Alberta, which includes the Blackfoot Confederacy (comprising the Siksika, Piikani, and Kainai First Nations), as well as the Tsuut’ina First Nation, the Stoney Nakoda (including the Chiniki, Bearspaw, and Wesley First Nations) and Métis Nation. As an educational researcher, I commit to reflect on the colonial histories in schooling and take actions toward reconciliation with and the resurgence of Indigenous communities.

As a member of the University of California Los Angeles, Ananda Marin acknowledges the Gabrielino/Tongva peoples as the traditional land caretakers of Tovaangar (Los Angeles Basin, South Channel Islands). As a land grant institution, we pay our respects to the honuukvetam (ancestors), 'ahiihirom (elders), and 'eyoohiinkem (our relatives/relations) past, present, and emerging, and are grateful to have the opportunity to work for and with the taraaxotam (Indigenous peoples) in this place.

#### Citation:

Takeuchi, M.A. & Marin, A. (2022). “Globalization,” coloniality, and decolonial love in STEM education. *Oxford Research Encyclopedia of Education*. <https://doi.org/10.1093/acrefore/9780190264093.013.1655>

## **Summary**

From the era of European empire to the global trades escalated after the World Wars, technological advancement, one of the key underlying conditions of globalization, has been closely linked with the production and reproduction of the colonizer/colonized. The rhetoric of modernity characterized by “salvation,” “rationality,” “development,” and nature-society or nature-culture divides underlies dominant perspectives on Science, Technology, Engineering, and Mathematics (STEM) education that have historically positioned economic development and national security as its core values. Such rhetoric inevitably and implicitly generates the logic of oppression and exploitation. Against the backdrop of nationalist and militaristic discourse representing modernity or coloniality, counter-voices have also arisen to envision a future of STEM education that is more humane and socioecologically just. Such bodies of critiques have interrogated interlocking colonial domains that shape the realm of STEM education: (a) settler colonialism, (b) paternalism, genderism, and coloniality, and (c) militarism and aggression and violence against the geopolitical Other. Our ways of knowing and being with STEM disciplines have been inexorably changed in the midst of the COVID-19 pandemic, which powerfully showed us how we live in the global chain of contagion. What kinds of portrayal can we depict if we dismantle colonial imaginaries of STEM education and instead center decolonial love—love that resists the nature-culture or nature-society divide, love to know our responsibilities and enact them in ways that give back, and love that does not neglect historical oppression and violence yet carries us through? STEM education that posits decolonial love at its core will be inevitably and critically transdisciplinary, expanding the epistemological and ontological boundaries to embrace those who had been colonized and disciplined through racialized, gendered, and classist disciplinary practices of STEM.

## **Keywords**

STEM education and coloniality, settler colonialism, paternalism, genderism, militarism, neoliberalism, globalization

## **Chronotope: The COVID-19 Pandemic**

We open this article by specifying the time and space where we are located. Bakhtin (1981) exemplified analyses of “chronotope” (p. 84) in novels, the intersection of the spatial marker and the temporal marker that provides the concrete wholeness and richness of characters and events. Analyses of chronotope can provide historicity (Gutiérrez, 2016) as we inquire into our collective epistemology of Science, Technology, Engineering, and Mathematics (STEM) disciplines and coloniality. We wrote this article in the years 2020 and 2021, in the midst of the COVID-19 pandemic. The COVID-19 pandemic powerfully showed us how we live in the global chain of contagion (Kucharski, 2020). Our experiences with time-space and the daily round are more hyperlocal (Marin et al., 2020) and human bodies are constrained in their mobility, longing families and friends who live close and afar—some who live in different continents. Through these embodied experiences of changed mobility, we feel the global networks that shape who we are—intensified feelings of globalized social relations. As Giddens (1990) defined, globalization is “the intensification of worldwide social relations which link distant localities in such a way that local happenings are shaped by events occurring many miles away and vice versa” (p. 64). Every day, we are gazing at graphs marking the overwhelming number of deaths locally and across the globe. Every day, we are also questioning the number of deaths caused by settler colonialism and racial and economic inequity, which are often masked in the mainstream media internationally. We frequently compare and contrast different mathematical models that predict the future in light of local, national, and international policies. We sympathize with the fatigue of front-line medical professionals. We are also grateful to the essential workers who continue to harvest crops and make it possible to receive nourishment. We keenly read articles about the mechanism of the COVID-19 virus and different paths for vaccine development as they are gradually uncovered, while being concerned about the global race for the COVID-19 vaccine that could leave economically vulnerable peoples and countries behind. Our ways of knowing and being with STEM disciplines have been inevitably changed in the midst of the pandemic.

The year of 2020 also marked a rise of global anti-racism social movements, in memory of George Floyd’s life, Breonna Taylor’s life, and uncountable Black lives taken in injustice and by police brutality. In the Black Lives Matter movement, assumptions and practices that have historically shaped STEM disciplines have been questioned, as seen in social movements on #ShutDownSTEM (Chen, 2020). Questions around racial bias in artificial intelligence algorithms and cryptography in mass surveillance are examples of racism and racial surveillance that have been in question relative to macroethics (Vakil & Higgs, 2019). More and more, voices are rising to question the intended and unintended use of STEM disciplines to perpetuate racism including surveillance and police brutality, as

seen in social movements by mathematicians urging to end the application of mathematics for policing (Burke, 2020). More than ever, in this era of pandemic and protest, people are questioning the colonial history within STEM disciplines and naming how these disciplines have been built through and for the exploitation of racialized bodies (Morales-Doyle et al., 2020; Philip & Sengupta, 2020) and the abuse of the natural worlds (Bang, 2020; Marin, 2020). Scholars and activists are also storying the ways in which socioecological injustices, carried out in the name of science, land within Indigenous territories and complex colonial histories (Kimmerer, 2013; LaDuke, 2016). These stories or theories remind us that racialized forms of supremacy are rooted in nature-culture divides that also position our more-than-human relatives as being without agency and created for resource extraction (Junker, 2020). Hopefully these conversations will facilitate a remaking of STEM education “as not merely a technical and economic pursuit, but a moral and ethical one” (Morales-Doyle et al., 2020).

The COVID-19 pandemic is thus making us fundamentally rethink taken-for-granted colonial world views. Statues of colonial symbols have been taken down to reclaim history and to seek a resurgence of ethical lifeways. Discourses are also monuments, as Foucault (1991) stated: discourse is “a monument to be described in its intrinsic configurations” (p. 60). The power of discourse extends beyond the symbolic to the material and physical. In the realm of STEM disciplines, Eurocentric and Imperialist monumental discourses have inscribed coloniality, global-scale forced migration, and slavery of bodies. Such monumental discourses in STEM education were interrogated and taken down in radical senses in 2020, marked as a year of the pandemic and protests (Morales-Doyle et al., 2020; Philip & Sengupta, 2020).

This article is a critique of colonial discourses that have shaped the field of STEM education globally. At the same time, this article is also about decolonial imaginations of STEM education that this era we live in is fundamentally calling for. The recent literatures in STEM education are collectively inviting us to shift our foci away from global competitiveness, militarization, genderism, and human capital discourse that have long shaped the hegemonic discourse. In dialogue with critical literatures, we envision future directions of the STEM education field that center decoloniality and decolonial love.

### **Framing Globalization and Coloniality**

From the era of European empire to the global trades escalated after the World Wars, technological advancement, one of the key underlying conditions of globalization, has been closely linked with the production and reproduction of the colonizer/colonized. Given the influences of the disciplines of STEM on the technological advancement underpinning globalization, this article delves deeper into this colonial relationship that the STEM disciplines have been (covertly) perpetuating.

In order to discuss coloniality and decoloniality in the realm of STEM education, we draw from what Mignolo (2007) and Quijano (2007) poignantly pointed out: coloniality is constitutive of modernity. In other words, the rhetoric of salvation, rationality, and development that characterizes modernity inevitably and implicitly generates the logic of oppression and exploitation (Mignolo, 2007; Quijano, 2007). The logic of oppressions is also epistemic and grounded in the simultaneous disqualification and appropriation of Indigenous knowledges (Mignolo, 2007). The coloniality of power came to be intertwined with the social categorization of race and the imposition of racial classification on the colonized under Eurocentricity (Quijano, 2007). Mignolo (2007) argues that this inextricable relationship between modernity and coloniality has been amplified by the geopolitical colonial matrix of power that is often hidden under the rhetoric of modernity. The colonial matrix of power stretches across the world by shaping and reshaping the global order to sustain the dispensability of lives. Such a colonial matrix of power is characterized by interlocking domains of control: “economy (exploitation of labour and appropriation of land/natural resources), authority (government, military forces), gender/sexuality and knowledge/subjectivity” (Mignolo, 2009, p. 19). Unlike colonization, which has been conceptualized through historically and geographically bounded politics and violence, Mignolo’s (2009) notion of geopolitical colonial matrix of power extends beyond the nation-state politics and refers to the colonial world order that is both geographically and temporally stretched. As Quijano (2007) states, even in the post-empire and post-colonial era, coloniality “is still the most general form of domination in the world today, once colonialism as an explicit political order was destroyed” (p. 170). What is central to this conceptualization of coloniality is its control over our epistemology through the linkages between geohistorical locations and bodily politics of knowledge production (Mignolo, 2009).

Linda Tuhiwai Smith (2021) describes modernity as a project of nation-building that is constituted by the discovery of “new” worlds and “liberal political and economic theories” which focus on individual reason and autonomy, the rule of law, and the pursuit of economic self-interest (p. 68). As Smith points out, “Once it was accepted that humans had that capacity to reason and to attain this potential through education, through a systematic form of organizing knowledge, then it became possible to debate these ideas in rational and ‘scientific’ ways” (p. 68). Thus, modernism is characterized by the development of scientific thought and discovery of other worlds by Europeans. Importantly, colonialism as tied to modernity involved the “re-arrangement, re-presentation, and re-distribution” of human and more-than-human relationships (Smith, 2021, p. 71). The formation of new states depended upon separating humanity from nature (Aldeia & Alves, 2019). This hierarchical organization of society or culture over nature is constitutive of the logics of coloniality and modernity and provides the basis for human exceptionalism and mastery over nature. Modernity, as linked to the New World, depended upon positioning more-than-human beings, including lands or waters, as existing for the benefit of man.

Through this linking, “large portions of humanity were relegated to categories of Nature-outside-humanity” (Aldeia & Alves, 2019, p. 7). These settled expectations of nature-culture relations constrain how core phenomena in STEM are conceptualized and shape STEM education including what is considered valid subject matter as well as how science knowledge is deliberated in moment-to-moment instruction (Bang & Marin, 2015; Bang et al., 2012).

Moreover, the rhetoric of modernity, characterized by the rhetoric of “salvation,” “rationality,” and “development” (Mignolo, 2007; Quijano, 2007), underlies dominant perspectives in STEM education that have historically positioned economic development and national security as its core values (Philip & Sengupta, 2020; Takeuchi et al., 2020; Vossoughi & Vakil, 2018). Such a rhetoric of modernity has tactfully reproduced the logic of coloniality, which is often masked and tacit in the field of STEM education. Unveiling the imperialism that has historically been silenced in the discipline of (and in the global mass industry of) computing, Philip and Sengupta (2020) argue that theories of learning need to account for the exploitation of labor made by endarkened bodies in the discipline: “learning in the disciplines is to be in solidarity with people who do disciplinary work, and more importantly, with people whose labor is hidden through the mechanisms of imperialism while making disciplinary work possible” (p. 12).

Paradoxically, globalization could intensify nationalist sentiments while diminishing some aspects of relationships bound to nation-states (Giddens, 1990). Modern coloniality is escalated through such nationalist sentiments (Dirlik, 2011). In light of this, in their critical review of STEM education research published in leading international journals during the early formation of the field of STEM education (2007–2018), Takeuchi et al. (2020) identified Americentrism. This Americentrism can be visualized by Figure 1, which is based on Takeuchi et al.’s (2020) analysis on contexts of study, wherein STEM education studies were conducted in selected international journals. In their review of 143 empirical studies, the United States was not only the most frequently studied context but also influential in shaping nationalistic agenda through STEM education research. One of the major foci of STEM education research has been around career preparation to strengthen school-to-workplace pipelines for global competitiveness in STEM domains. This Americentrism could be related to the fact that the notion of STEM education originated in the United States historically and was rooted in concerns for national security and militarization in the post-Sputnik era (Shanahan et al., 2016; Vossoughi & Vakil, 2018).



Figure 1. Americentrism in STEM education research.

In the governmental vision, STEM education discourses in the United States are strongly characterized by the dual foci on national security and economic competition. In *Charting a Course for Success: America’s Strategy for STEM Education*, a government-issued publication in 2018, such foci are evident:

Since the founding of the Nation, science, technology, engineering, and mathematics (STEM) have been a source of inspirational discoveries and transformative technological advances, helping the United States develop the world’s most competitive economy and preserving peace through strength. The pace of innovation is accelerating globally, and with it the competition for scientific and technical talent. Now more than ever the innovation capacity of the United States—and its prosperity and security—depends on an effective and inclusive STEM education ecosystem (Committee on STEM Education of the National Science and Technology Council, 2018, p. v).

This vision for STEM education has been critiqued for the underlying neoliberalist agenda that promotes market-driven choices of curriculum and pedagogical resources as well as privatization of public education (Hoeg & Bencze, 2017; Strong et al., 2016; Zeidler, 2016; Zouda, 2018). Based on critical discourse analysis of the Next Generation Science Standards (NGSS) that has been highly influential in shaping STEM education in the United States and beyond, Hoeg and Bencze (2017) interrogated how the NGSS prioritized measurable and reproducible performances that are “associated with the economic values and principles of neo(new)-liberalism” (p. 291). Similarly, Zeidler (2016) raised concerns around what is omitted and mistreated as STEM education governed by the NGSS and called attention to the

exploration of STEM through “human-based morality” (p. 17) that includes critical reflections on knowledge production and sociopolitical understanding of how scientific knowledges are socially constructed. Strong et al. (2016) similarly interrogated the neutrality in the NGSS that ignored unequal access to symbolic, material, and social capital under the meritocratic rhetoric emphasized in neoliberalism.

The current hegemonic position of the U.S. government in shaping STEM education discourse is stark: epistemology that shapes disciplinary practice has historically been linked with the geopolitical colonial matrix of power and the world order molded through coloniality (Mignolo, 2009). In the guise of diversity and inclusion initiatives within the nationalistic discourse, “the children of historically colonized and oppressed communities are positioned as potential contributors to STEM fields in so far as they identify with a narrow view of American national interests” (Vossoughi & Vakil, 2018, p. 136). Moreover, the nationalistic discourse of coloniality also shapes who the learners are and who they become. The rigid institutionalized categorization in the politically-laden disciplinary space of STEM co-constructs the geopolitical Other (Said, 1978) as potential threat and as a target of hostility and aggression (Philip et al., 2018; Takeuchi, 2021; Vossoughi & Vakil, 2018).

### **Countering Coloniality Through STEM Education Research**

Against the backdrop of the official and nation-state driven discourses, there has also been critical scholarship that has collectively countered the hegemonic coloniality in STEM education practices and research. Such bodies of critiques can be clustered into the following three interlocking colonial domains that shape the realm of STEM education: (a) settler colonialism, (b) paternalism, genderism, and coloniality, and (c) militarism and aggression and violence against the geopolitical Other. These three areas of coloniality are conceived under the geographically and temporally stretched colonial matrix of power (Mignolo, 2007) and Eurocentric racial classification of the colonizer/colonized (Quijano, 2007).

#### **Countering Settler Colonialism**

Settler colonialism that is based on the settler’s acquisition of land as private property simultaneously establishes a set of settler norms that include: “(a) erasure of Indigenous presence, (b) staged inheritance of indigeneity by Whites (Reardon & Tallbear, 2012), and (c) erasure of African descendants’ humanity through the structuration of slavery and resultant reduction to and control of Black bodies (Wolfe, 2006)” (Bang & Marin, 2015, p. 532). Settler colonialism restructures time-space relations and positions humans as apart from the natural world. Specifically, settlers have been positioned as superior and human entitlement to the natural world as normative. These positionings have also been inscribed in the dominant theories of learning (Bang, 2017). Bang (2017) eloquently alarmed us: “the temporal



positioning of Indigenous people as primitive or as less developed constructs a cultural-historical temporality in the service of settler-colonialism that enables the erasure of Indigenous peoples in the present” (p. 128). Importantly, the erasure of Indigenous peoples occurs simultaneously with the appropriation of Indigenous scientific knowledge.

Seminal works countered settler colonialism, challenged epistemological and ontological erasures of Indigenous people, and unsettled sets of assumptions behind theories of learning that have shaped practices and research of STEM education (Bang, 2017; Bang & Marin, 2015; Cajete, 1994; LaDuke & Cowen, 2020; Little Bear, 2000). As Cajete (2004) points out, before Western sciences have come to understand quantum physics, Indigenous epistemology has long positioned nature as “a dynamic, ever-flowing river of creation inseparable from our own perceptions, the creative centre from which we and everything else have come and to which we always return” (p. 48). Yet, Indigenous relationships with nature, which is perceived as being in constant flux and agentive, have long been undermined in the discipline of Western sciences.

The following body of work is together reimagining STEM education that counters settler colonialism. In Bang and Marin’s (2015) community-based design research centralizing everyday parent-child interactions, they documented emergent forms of science pedagogy that can desettle settler colonialism: for instance, constructing non-humans as agents or place makers and remediating colonial time-space constructions through naming places with Indigenous languages. Pedagogies of walking, reading, and storying land discussed in Marin and Bang (2018) center bodily moves and orientation to land as intergenerational epistemology of or within ecology. Marin (2020) posits that lands or waters and mobility are “fundamental parts of human life” and encourages those who research STEM education to develop systems of analysis that “re-member (Grande & McCarty, 2018; Wa Thiong’o, 2009) relationships between land, humans and more-than-human relatives” (p. 31). Similar to Marin and Bang (2018), Czuy and Eagle Speaker (2019) situate decolonial epistemology in humans’ intergenerational relationships to land, well-being of communities, and bodies that sense in their movement. Czuy and Eagle Speaker (2019) criticize how Indigenous stories have been stolen, misappropriated, or dismissed by settlers and how such colonial relationships resulted in the ascendancy of the static Eurocentric mathematics discipline, which is often detached from humanity. In this light, Czuy and Eagle Speaker (2019) centralize the gift of Indigenous stories to humanize mathematics, under the pedagogy weaved together through a decolonial relationship with Indigenous communities.

The gift of the Indigenous practice of storytelling was also at the core of Lam-Herrera, Ixkoj Ajkem Council, and Sengupta’s (2019) project to design a new symbolic tool to advocate for complex environmental issues from the perspective of the Guatemalan Indigenous community. Their project

sought for a meaningful dialogue between Indigenous epistemology and Western scholarship on computational modeling and complexity. Rahm et al. (in press) have collectively woven a story of learning and becoming through Inuit relational epistemology (Inuit Qaujimajatuqangit). Grounded in the contexts of youth hunter programs in Inuit Nunangat, Rahm, Tagalik and Baker depict heterogeneous learning where intergenerational knowledge exchange, community relations and well-being, and youth's well-being and ways of knowledge are meaningfully intertwined.

Partially due to the colonial history of official schooling in Indigenous communities, many of the projects introduced here were conducted outside the official school space. Msimanga and Shizha (2014) poignantly cautioned against the epistemic erasure that was imposed through institutionalized schooling and curriculum during and post the colonial era in South Africa. Such erasure “denigrates and silences the phenomenological lived experiences and worldviews” (Msimanga & Shizha, 2014, p. 140) in the spaces of schools.

With this complexity in mind, Meaney et al. (2013) engaged in redesigning the context of school. They depict how learning of mathematics is situated in the whole ethos of school and therefore curriculum, teacher-student relationships, and school-community relationships need to be decolonized altogether. From this perspective, Meaney, Trinick, and Fairhall's project redesigned kura (school) centralizing relations, language, and identity that the Māori community values.

Altogether, this body of work has been countering symbolic and corporeal erasures of Indigenous people under settler colonialism, by redesigning curriculum, schools, pedagogy, and language in the realm of STEM education. Through their works, they are refreshing the notion of “research” that was problematized as “one of the dirtiest words in the indigenous world's vocabulary” (Smith, 2021, p. 1). As seen in the variety of Indigenous territories across continents that these researchers are voicing from, settler colonialism has been, and should continue to be, challenged globally.

### **Countering Paternalism, Genderism, and Coloniality**

The epistemology of STEM cannot be isolated from gender politics and colonial histories (Harding, 2008). The colonial matrix of power penetrates into the domain of gender and sexuality in the disciplines of STEM, especially if we examine through the contrapuntal lenses that Philip and Sengupta (2020) advocated for. The invisible labor of marginalized and colonized people to make up the discipline is simultaneously racialized, classed, and gendered. Drawing from Banerjee and Rincón's (2019) sociological study on immigrant tech industry workers of color, Philip and Sengupta (2020) challenged the apolitical representation of computing perpetuated through dominant educational practices and policies. In contrast to such a politically neutral picture of computing, what Banerjee and Rincón (2019)

depicted were the intersectional systems of oppressions that immigrant coders of color could face, including the patriarchal gender hierarchy the immigration regime they were in produced and reproduced at their households. Further, Banerjee and Connell (2018) maintain that decolonizing gender means embracing solidarity-based epistemology while re-centralizing knowledge from gender theories deeply rooted in the Global South. Banerjee and Connell's (2018) vision for Southern Theory of gender responds to Spivak's (1988) critique to the Western formation of a discipline that has tacitly excluded and erased voices of the gendered and classed subaltern who has historically been spoken for and been represented for. In this intersectional gender-based exclusion rooted in global geopolitical power, apolitical and ahistorical views have begun to be challenged beyond examining gender gaps on achievement and participation in STEM disciplines. Krishnamoorthy (2021) examined how through human-material relations heterosexual ways of being get positioned as normative in school science spaces. Raveendran (2021) depicted how classed and gendered discourses are perpetuated and challenged in secondary students' engagement with a socioscientific issue of commercial surrogacy, which deeply affects women from the Global South. Takeuchi and Aquino Ishihara (2021) highlighted the power of migrant woman of color leadership in social movements and mobilization of mathematical literacy to counter violence on the bodies of migrant women who were forced to migrate from the Global South (often in the form of human trafficking) and work in the transnational enterprise of the entertainment industry. These studies suggest the need to complicate the nature of gender and advocate for the inclusion of voices, bodies, and experiences of women, queer, and trans/genderqueer people from the Global South toward making the discipline of STEM more socially just and anti-colonial.

Such anti-colonial and solidarity-based epistemology of gender is in contrast with the ways in which STEM education practices and research have been conceptualizing gender, which often perpetuate genderism. Esmonde (2011) and Leyva (2017) pointed out how mathematics education research has repeatedly reproduced the gender binary, which resulted in genderism that privileges people who can conform to local gender norms. Leyva (2017) also argued that such comparative gender studies perpetuated not only genderism but also the masculinization of the domain of mathematics by unfairly holding men's higher levels of achievement as a measure of success. Such genderism and the masculinization of the STEM discipline were similarly observed in the recent body of scholarship in STEM education research (Takeuchi et al., 2020). As Takeuchi et al. (2020) pointed out, "the risk of reducing our intersectional histories and experiences to deterministic categories is the further subjugation of learners and erasure of the heterogeneity of their histories, desires and experiences by disciplinary apparatus" (p. 25).

On gender-based and race-based representational politics ubiquitous in STEM education policies and practices, Sengupta-Irving and Vossoughi (2019) interrogated the paternalism underlying in the discourse that assumes racialized girls and women's pursuit of STEM careers as valuable and desirable. Paternalism in representational politics in STEM education negates "the possibility that not choosing STEM careers reflects sound reasoning" (Sengupta-Irving & Vossoughi, 2019, p. 481). Such implicit paternalism reproduces social control and non-reciprocal relationships between experts and novices of the STEM domains. Instead, Sengupta-Irving and Vossoughi (2019) advocate for understanding learners' relationships to STEM disciplines on their own terms to contest representational politics. Subjective experiences of learning STEM for two girls of color depicted in Sengupta-Irving and Vossoughi (2019) challenge the normative picture of what STEM disciplines are and who are included there, from anti-racist and feminist lenses. Studies depicting learner experiences through intersectionality lenses (Avraamidou, 2020; Joseph et al., 2019; Leyva, 2016, 2017; McGee & Bentley, 2017; McGee & Martin, 2011) collectively illustrate visions for STEM learning with dignity that Sengupta-Irving and Vossoughi (2019) called for. For instance, Joseph et al. (2019) painted the picture of mathematics learning spaces that can challenge the dehumanization of Black girls, wherein they are intellectually challenged, encouraged to learn collaboratively with others while being treated as a respected and valued contributor and being playful if they choose to be. McGee and Bentley (2017) highlight the resilience of Black women in STEM while also cautioning against an individualized model of resiliency that abuses their inner strengths without changing institutional environments.

Challenging hegemonic STEM disciplinary practices that perpetuate sexism and genderism requires changing the portrayals of the doers of STEM. As Leyva et al. (2016) argued, recentering voices of LGBTQ+ engineers can queer the historically masculine engineering discipline. By centralizing queer experiences in moment-to-moment interactions, mathematics can be renewed as a discipline filled with emotions, desires, and a sense of belonging (Radke, 2021). Shining a light on stories of queer experiences can simultaneously queer the discipline of computing, which is now constituted as a masculine domain that over-relies on colonized labors (Paré et al., 2019; Philip & Sengupta, 2020). Bringing a queer sensibility can also bring forth distinct educational intimacy that can serve as a catalyst for the transformation of the collective (Uttamchandani, 2021). As the history of social movements and scholarships led by queer women of color demonstrated (Combahee River Collective, 1974; Moraga & Anzaldúa, 1981), the collective characterized by a non-hierarchical and decolonial distribution of power is essential to create a history anew.

From the lenses of decolonial queerness, the following body of scholarship can be repositioned as efforts to foster the collective and gathering toward queering the discipline of STEM. Through their

research on family science workshops with Latina mothers and daughters, Kayumova et al. (2015) depicted how such spaces of gathering contributed to countering deficit-oriented normative institutional perspectives toward Latina/o families and languages. Through Civil's (2007, 2016) longitudinal community-based research, working-class Latina/o parents came together to find voices to position themselves as competent doers of mathematics, even when the mathematics they knew differed from the ones their children were learning at school. As Civil described in her studies, the collective space allowed Spanish-speaking Latina/o parents to engage in dialogues with schools on their children's mathematics learning. Booker and Goldman (2016) emphasized what they termed as epistemic authority by depicting how families in their participatory design research came to own the agency and power to know what they want to know about mathematics. Takeuchi (2018) shined a light on non-dominant embodied algorithm for multiplication that was hidden at the school by Filipina migrant mothers and children. The hidden embodied algorithm was legitimized in the designed workshops where migrant parents and children came together to re-engage with the discipline of mathematics. Altogether, these emergent spaces of gathering showed a possibility for decolonial queerness — “querying the workings of neo-colonial epistemic categories, systems of classification and taxonomies that classify people” (Bakshi et al., 2016, p. 1). In other words, through such spaces of gathering, researchers and participants together countered colonial categories and classification that had masked STEM competences that labeled people exhibit.

### **Countering Militarism**

The amassed critical voices are changing the portraits of STEM education, by collectively challenging its historically dominant militaristic picture. Philip et al. (2018) interrogated covert militaristic ideologies that have driven normative curricula and pedagogies in the discipline of engineering. In the context of American post-secondary engineering education, Philip et al. (2018) conducted micro-interaction analysis on in-class discussion and demonstrated how the development of technology such as weaponized drones were contextualized by co-constructed racialized categories such as “terrorists” and “civilians.” In the interactional process they focused on, racialized, nationalist, and militaristic ideologies were reinforced and co-constructed despite the interactional opportunities for ideological expansion. Gupta et al. (2019) also demonstrated how the social-technical divide is interactionally co-constructed in the disciplinary space of engineering. Everyday micro-interactions can be a site for what Philip et al. (2018) termed as ideological expansion, “analogous broadening of the ideological field” (p. 185) and ideological convergence, “the narrowing of the field of ideological stances that are salient and seen as useful as individuals participate in a joint activity” (p. 185). The socio-technical divide and early ideological convergence identified by Gupta et al. (2019) in the context of engineering call for more spaces toward ideological expansion.

On militarization and STEM education in the United States, Vossoughi and Vakil (2018) similarly problematized how wartime goals and agenda have altered research foci and priorities in STEM disciplines especially after the World War II and during the pivotal historical moments of the Cold War and the War on Terror, the global war on terrorism. Knowledge production under the military-industrial-academic complex cannot happen in a political vacuum. While acknowledging the scientists' efforts to repurpose military agenda toward humane technoscientific advancements, Vossoughi and Vakil (2018) raise concerns about the role of STEM education in promoting the war, destruction, and death.

Militarism stabs into widely circulated STEM education programs that are marketed as apolitical. Taking the Maker movement, Vossoughi et al. (2016) critiqued its close connection with military interests such as the Defense Advanced Research Projects, behind its seemingly progressive agenda to move away from consumerism. The Maker movements under the hidden agenda of militarism can implicitly coerce students' engagement of warfare technologies (Singer, 2010) such as robotics and drones. As Philip and Azevedo (2017) pointed out, depoliticized representations of STEM education programs such as Makerspaces can mask contested ideologies and "limit conceptions of equity that genuinely include and allow for more ideological and epistemological diversity and are thus more democratic" (p. 527). Vossoughi et al. (2016) critiqued how corporate-driven and military-driven STEM education programs can result in promoting individual success within the hegemonic system rather than the collective reimagining and transformation of the system itself. Without critical consciousness about the hidden militarism, learners may be tacitly socialized into militaristic agenda through STEM education.

The macro-narrative of the War on Terror that Vossoughi and Vakil (2018) pointed has been shaping the context of learning and development for Muslim youth where they negotiate and navigate the surveillance regime (Ali, 2018). Countering to the power that polices their bodies, Muslim youth's learning depicted in Ali (2018) shows how learning is inherently the process of developing "political voice and critique" and can be expressed through "anger and dissent" (p. 255).

Macro-narratives of militarism and the War on Terror can sneak into everyday micro-interactions and can shape the institutionalized categorization of the geopolitically colonized Other in the spaces of disciplinary learning even beyond the contexts of the post-9/11 United States (Takeuchi, 2021). In the classroom interactions depicted in Takeuchi (2021), the media representation of pro-war against terrorists provided symbolic resources for inheritance and reproduction of Othered identities for an Afghan refugee learner in Canada through in-school learning of mathematics whose curriculum inscribed categorical and binary frameworks. Avraamidou (2020) similarly pointed out that the post-9/11 media portrayal of Muslims was one of the interlocking oppressions a Muslim woman physicist had to navigate in her

becoming a scientist in Western Europe. These studies point out that co-construction of identities that is seemingly devoid of militarism is in fact affected by it.

Overall, this growing body of scholarship is collectively countering militarism tacitly underlying in the vision and practices of STEM education. This set of literature is also taking into account the global impact of militarism on learners and learning, beyond nationalistic discourses.

### **Conclusion: Toward Decolonial Love in STEM Education**

*I know love I know* — lessons we've carried throughout time. Should I go missing: don't stop searching; drag every river until it turns red and the waters of our names

stretch a flood so wide it catches everything. And we find each other whole and sacred, alive and breathing and breathing and breathing.

— From *Love lessons in a time of settler colonialism*, by Tanaya Winder, June 2018

Decolonial love resists the nature-culture or nature-society divide; it involves knowing our responsibilities and enacting them in ways that give back so that we have “the privilege of breath” (Kimmerer, 2013, p. 384). For example, water protectors knowingly put their lives on the line to (re)claim right relationships with our (the Peoples’) more-than-human relatives. Through their movements they seek to build infrastructures beyond current-day settler colonial infrastructures (LaDuke & Cowen, 2020). This work is forged through acts of decolonial love. As Recollet (2015) explains, decolonial love is “spatial and generative” and “critiques the conditions of coloniality” (p. 130). In this way, decolonial love is seen taking shape when, for instance, people put their bodies on the line to resist the construction of oil pipelines—the infrastructure of settler colonial nations. Love in this context is dangerous and has real consequences. For example, hundreds of water protectors in Minnesota have been arrested during protests in Minnesota against the construction of the Enbridge Line 3 tar sands pipeline at the Shell River (Democracy Now!, 2021). How do we embrace these tensions—the need for healing through decolonial love while at the same time knowing that love can be subjugated and that enacting love can put lives in danger? But what is more dangerous? Remaining silent or reaching for elsewhere? Betasamosake Simpson (2015) invites us to imagine and remember how love resides in our bodies despite histories of colonial violence. Similarly, Kimmerer (2013) reminds us that decolonial love is naming and grieving for what has been lost, broken, harmed, forgotten and then choosing joy over despair in order to enact respect, relationality, and reciprocity.

Understandings of decolonial love stand in contrast to settled expectations in STEM education. For example, in the period of early formulation of STEM education, its driving force was human capital discourse that reduced learners of STEM disciplines as the future workforce rather than shining a light on what Sen (1999) termed as human capabilities (Takeuchi et al., 2020). Implicit in such capitalist agenda of education are the globalized racist ideologies that have exploited the labor of endarkened people in the STEM disciplines (Philip & Sengupta, 2020), under the guise of “innovation” (as seen in critiques by Irani, 2019) and “development” (as seen in critiques by Harding, 2008; Ames, 2019). Countering nationalist and militaristic discourse representing modernity or coloniality that has led STEM education, critical voices have also arisen to envision the future of STEM education that is more humane and socially just (Kayumova et al., 2018; Marin & Bang, 2018; McKinney de Royston & Sengupta-Irving, 2019; Nasir & Vakil, 2017; Philip et al., 2018; Sengupta et al., 2019, 2021; Takeuchi et al., 2020; Vakil & Ayers, 2019; Vossoughi & Vakil, 2018). As Vossoughi and Vakil (2018) provoked, such a future should be accompanied with imaginations where “young people learn about natural, physical and technological phenomena as deeply imbued with social and political values, where the production of new scientific and technical knowledge is coupled with the development of a more just world” (p. 119). Such a future should be guided by historical epistemology (Gutiérrez, 2016) that positions learners who see themselves as a “historical actor who develops a sense of their own identity in relation to broader social and historical forces” (Gutiérrez et al., 2019, p. 292).

In lieu of paternalistic, militaristic, and colonial imaginaries of STEM education, such a future should be centered around voices of the subaltern (Spivak, 1988) whose labor, bodies, and representation have historically been exploited, consumed, and masked in the geopolitical matrix of coloniality. What kinds of portrayal can we depict if we dismantle Eurocentric and Imperialist imaginaries of STEM education (Philip & Sengupta, 2020) and instead center decolonial love?

STEM education that posits decolonial love at its core will be inevitably and critically transdisciplinary and expand epistemological and ontological boundaries to embrace those who had been colonized and disciplined through racialized, gendered, and classist disciplinary practices of STEM (Takeuchi et al., 2020). For instance, the COVID-19 pandemic has manifested an unsustainable and unjust system in globalized food production and distribution that heavily relies on the exploitation of migrant labor. Such a system has not only exploited and harmed racialized migrant bodies that are one of the most vulnerable in the order of global economy, but also damaged the land and ecology for the sake of cost-effectiveness and capital accumulation for the haves. How could STEM education be accountable for the injustice in food production and exploitation? How could STEM education be accountable for the repercussions of an oppressive past that violently stole lands and food sources from Indigenous people



(Settee & Shukla, 2020) and forced the labor of Black bodies on slave plantations (Penniman, 2018)? How could STEM education be accountable for environmental damages humans have caused under the guise of efficiency and industrialization (Date et al., 2019)? Transdisciplinary STEM education stemming from decolonial love will deepen such questions toward a liberating future—one that will move us toward interconnectedness, one shaped by “mutual flourishing” (Kimmerer, 2013, p. 371) and flourishing of all species—that we should strive to bring about together, in the post-COVID-19 pandemic world.

## References

- Aldeia, J., & Alves, F. (2019). Against the environment. Problems in society/nature relations. *Frontiers in Sociology*, 4(29), 1–12. <https://doi.org/10.3389/fsoc.2019.00029>
- Ali, A. (2018). Learning in the shadow of the war on terror: Toward a pedagogy of Muslim indignation. In S. Daulatzai & J. Rana (Eds.), *With stones in our hands: Reflections of race, Muslims, and U.S. Empire* (pp.244–257). University of Minnesota Press.
- Ames, M. (2019). *The charisma machine: the life, death, and legacy of One Laptop per Child*. The MIT Press.
- Avraamidou, L. (2020). “I am a young immigrant woman doing physics and on top of that I am Muslim”: Identities, intersections, and negotiations. *Journal of Research in Science Teaching*, 57(3), 311–341. <https://doi.org/10.1002/tea.21593>
- Bakhtin, M. (1981). *The dialogic imagination: Four essays*. University of Texas Press.
- Bakshi, S., Jivraj, S., & Posocco, S. (2016). *Decolonizing sexualities*. Counterpress.
- Banerjee, P., & Connell, R. (2018). Gender theory as Southern Theory. In B. Risman, C. Froyum, & W. Scarborough (Eds.), *Handbook of the sociology of gender* (pp. 57–68). Cham, Switzerland: Springer. [https://doi.org/10.1007/978-3-319-76333-0\\_4](https://doi.org/10.1007/978-3-319-76333-0_4)
- Banerjee, P., & Rincón, L. (2019). Trouble in tech paradise. *Contexts*, 18(2), 24–29. <https://doi.org/10.1177/1536504219854714>

- Bang, M., Warren, B., Rosebery, A. S., & Medin, D. (2012). Desettling expectations in science education. *Human Development*, 55(5-6), 302–318. <https://doi.org/10.1159/000345322>
- Bang, M., & Marin, A. (2015). Nature-culture constructs in science learning: Human/non-human agency and intentionality. *Journal of Research in Science Teaching*, 52(4), 530–544. <https://doi.org/10.1002/tea.21204>
- Bang, M. (2017). Towards an ethics of decolonial trans-ontologies in sociocultural theories of learning and development. In I. Esmonde & A. Booker (Eds.), *Power and privilege in the learning sciences: Critical and sociocultural theories of learning* (pp. 115–138). Routledge.
- Bang, M. (2020). Learning on the move toward just, sustainable, and culturally thriving futures. *Cognition and Instruction*, 38(3), 434–444. <https://doi.org/10.1080/07370008.2020.1777999>
- Betasamosake Simpson, L. (2015). *Islands of decolonial love*. ARP Books.
- Booker, A., & Goldman, S. (2016). Participatory design research as a practice for systemic repair: Doing hand-in-hand math research with families. *Cognition and Instruction*, 34(3), 222–235. <https://doi.org/10.1080/07370008.2016.1179535>
- Burke, L. (2020). Mathematicians urge ending work with police. *Inside Higher Ed*. Retrieved from <https://www.insidehighered.com/news/2020/06/24/mathematicians-urge-cutting-ties-police>
- Cajete, G. (1994). *Look to the mountain: An ecology of Indigenous education*. Tonasket, WA: Jcharlton Publishing.
- Cajete, G. (2004). Philosophy of native science. A. Waters (Ed.). *American indian thought: Philosophical essays* (pp. 45–57). Oxford, OX: Blackwell.
- Chen, S. (2020). Researchers around the world prepare to #ShutDownSTEM and ‘Strike For Black Lives.’ *Science*. <https://doi.org/doi:10.1126/science.abd2504>

- Civil, M. (2007). Building on community knowledge: An avenue to equity in mathematics education. In N. Nasir & P. Cobb (Eds.), *Improving access to mathematics: Diversity and equity in the classroom* (pp. 105–117). Teachers College Press.
- Civil, M. (2016). STEM learning research through a funds of knowledge lens. *Cultural Studies of Science Education*, 11(1), 41–59. <https://doi.org/10.1007/s11422-014-9648-2>
- Combahee River Collective. (1974). The combahee river collective statement. *Freedom Organizing Series*, 1, 1–7. Retrieved from [https://americanstudies.yale.edu/sites/default/files/files/Keyword\\_Coalition\\_Readings.pdf](https://americanstudies.yale.edu/sites/default/files/files/Keyword_Coalition_Readings.pdf)
- Committee on STEM Education of the National Science and Technology Council (2018). Charting a course for success: America’s strategy for STEM education. Retrieved from <https://www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf>
- Czuy, K., & Eagle Speaker, C. (2019). Critical braiding approach to ethno[mathematics]. In *Encyclopedia of Educational Philosophy and Theory*. Springer. [http://doi-org-443.webvpn.fjmu.edu.cn/10.1007/978-981-287-532-7\\_648-2](http://doi-org-443.webvpn.fjmu.edu.cn/10.1007/978-981-287-532-7_648-2)
- Date, G., Dutta, D., & Chandrasekharan, S. (2019). Solving for pattern: An ecological approach to reshape the human building instinct. *Environmental Values*, 30(1), 64-92. <https://doi.org/10.3197/096327119X15579936382653>
- Democracy Now! (2021, July). Just out of jail, Winona LaDuke decries militarized crackdown on Enbridge line 3 pipeline protests. [https://www.democracynow.org/2021/7/23/protests\\_line\\_3\\_pipeline\\_minnesota](https://www.democracynow.org/2021/7/23/protests_line_3_pipeline_minnesota)
- Dirlik, A. (2011). Rethinking colonialism: Globalization, postcolonialism, and the nation. *Interventions: International Journal of Postcolonial Studies*, 4(3), 428–448.

<https://doi.org/10.1080/136980102200001383>

- Esmonde, I. (2011). Snips and snails and puppy dogs' tails: Genderism and mathematics education. *For the Learning of Mathematics*, 31(2), 27–31.
- Foucault, M. (1991). Politics and the study of discourse. In G. Burchell, C. Gordon, & P. Miller (Eds.), *The Foucault effect: Studies in governmentality* (pp. 53–72). The University of Chicago Press.
- Giddens, A. (1990). *The consequences of Modernity*. Stanford University Press.
- Gupta, A., Turpen, C., Philip, T., & Elby, A. (2019). Narrative co-construction of stances towards engineers' work in socio-technical contexts. In P. Sengupta, M-C. Shanahan, & B. Kim (Eds.). *Critical, transdisciplinary and embodied approaches in STEM education* (pp. 251–272). Springer.
- Gutiérrez, K. (2016). Designing resilient ecologies: Social design experiments and a new social imagination. *Educational Researcher*, (April), 187–196.  
<https://doi.org/10.3102/0013189X16645430>
- Gutiérrez, K. D., Becker, B. L. C., Espinoza, M. L., Cortes, K. L., Cortez, A., Lizárraga, J. R., Rivero, E., Villegas, K., & Yin, P. (2019). Youth as historical actors in the production of possible futures. *Mind, Culture, and Activity*, 26(4), 291–308. <https://doi.org/10.1080/10749039.2019.1652327>
- Grande, S., & McCarty, T. L. (2018). Indigenous elsewheres: Refusal and re-membering in education research, policy, and praxis. *International Journal of Qualitative Studies in Education*, 31(3), 165–167. doi:10.1080/09518398.2017.1401144
- Harding, S. (2008). *Sciences from below: Feminisms, postcolonialities, and modernities*. Duke University Press.
- Hoeg, D. G., & Bencze, J. L. (2017). Values underpinning STEM education in the USA: An analysis of the Next Generation Science Standards. *Science Education*, 101(2), 278–301.  
<https://doi.org/10.1002/sce.21260>

- Irani, L. (2019). *Chasing innovation: Making entrepreneurial citizens in modern India*. Princeton University Press.
- Joseph, N. M., Hailu, M. F., & Matthews, J. S. (2019). Normalizing Black girls' humanity in mathematics classrooms. *Harvard Educational Review*, 89(1), 132–156. <https://doi.org/10.1007/978-94-6209-281-5>
- Junker, Y. A. (2020). On Covid-19, US Uprisings, and Black Lives: A mandate to regenerate all our relations. *Journal of Feminist Studies in Religion*, 36(2), 11–129. <https://doi.org/10.2979/jfemistudreli.36.2.09>
- Kayumova, S., Karsli, E., Alleksaht-Snider, M., & Buxton, C. (2015). Latina mothers and daughters: Ways of knowing, being, and becoming in the context of bilingual family science workshops. *Anthropology and Education Quarterly*, 46(3), 260–276. <https://doi.org/10.1111/aeq.12106>
- Kayumova, S., McGuire, C. J., & Cardello, S. (2018). From empowerment to response-ability: rethinking socio-spatial, environmental justice, and nature-culture binaries in the context of STEM education. *Cultural Studies of Science Education*, 1–25. <https://doi.org/10.1007/s11422-018-9861-5>
- Kimmerer, R. (2013). *Braiding sweetgrass: Indigenous wisdom, scientific knowledge, and the teaching of plants*. Minneapolis, Minn.: Milkweed Editions.
- Krishnamoorthy, R. (2021). *Science education, knowledge creation and Hindu nationalism: Examining how human-material relations shape science teaching in a South Indian School*. [Doctoral dissertation, New York University]. ProQuest Dissertations Publishing.
- Kucharski, A. (2020). *The rules of contagion: Why things spread - and why they stop*. New Basic Books.
- LaDuke, W. (2016). *All our relations: Native struggles for land and life*. Haymarket Books.
- LaDuke, W., & Cowen, D. (2020). Beyond wiindigo infrastructure. *South Atlantic Quarterly*, 119(2), 243–268. doi 10.1215/00382876-8177747

- Lam-Herrera, M., Ixkoj Ajkem Council., & Sengupta, P. (2019). Decolonizing complexity education: A Mayan perspective. In P. Sengupta, M-C. Shanahan, & B. Kim (Eds.). *Critical, Transdisciplinary and Embodied Approaches in STEM Education* (pp. 329–348). Cham, Switzerland: Springer.
- Leyva, L. A. (2016). An intersectional analysis of Latin@ college women’s counter-stories in mathematics. *Journal of Urban Mathematics Education*, 9(2), 81–121.
- Leyva, L. A., Massa, J., & Battey, D. (2016). Queering engineering: A critical analysis of the gendered technical/social dualism in engineering and engineering education. In *Proceedings of the American Society for Engineering Education’s 123<sup>rd</sup> Annual Conference and Exposition*, New Orleans, LA. doi:10.18260/p.26026. Retrieved from <https://peer.asee.org/26026>
- Leyva, L. A. (2017). Unpacking the male superiority myth and masculinization of mathematics at the intersections: A review of research on gender in mathematics education. *Journal for Research in Mathematics Education*, 48(4), 397–433.
- Little Bear, L. (2000). Jagged worldviews colliding. In M. Battiste (Ed.), *Reclaiming indigenous voice and vision*. Univeristy of British Columbia Press.
- Marin, A., & Bang, M. (2018). “Look it, this is how you know:” Family forest walks as a context for knowledge-building about the natural world. *Cognition and Instruction*, 36(2), 89–118. <https://doi.org/10.1080/07370008.2018.1429443>
- Marin, A. M. (2020). Ambulatory sequences: Ecologies of learning by attending and observing on the move. *Cognition and Instruction*, 38(3), 281–317. <https://doi.org/10.1080/07370008.2020.1767104>
- Marin, A., Taylor, K. H., Shapiro, B. R., & Hall, R. (2020). Why learning on the move: intersecting research pathways for mobility, learning and teaching. *Cognition and Instruction*, 38(3), 265–280. <https://doi.org/10.1080/07370008.2020.1769100>
- McGee, E. O., & Bentley, L. (2017). The troubled success of Black women in STEM. *Cognition and*

*Instruction*, 35(4), 265–289. <https://doi.org/10.1080/07370008.2017.1355211>

McGee, E. O., & Martin, D. B. (2011). “You would not believe what I have to go through to prove my intellectual value!”: Stereotype management among academically successful black mathematics and engineering students. *American Educational Research Journal*, 48(6), 1347–1389.

<https://doi.org/10.3102/0002831211423972>

McKinney de Royston, M., & Sengupta-Irving, T. (2019). Another step forward: Engaging the political in learning. *Cognition and Instruction*, 37(3), 277–284.

<https://doi.org/10.1080/07370008.2019.1624552>

Meaney, T., Trinick, T., & Fairhall, U. (2013). One size does NOT fit all: Achieving equity in māori mathematics classrooms. *Journal for Research in Mathematics Education*, 44(1), 255–263.

<https://doi.org/10.5951/jresematheduc.44.1.0235>

Mignolo, W. D. (2007). Delinking: The rhetoric of modernity, the logic of coloniality and the grammar of de-coloniality. *Cultural Studies*, 21(2–3), 449–514. <https://doi.org/10.1080/09502380601162647>

Mignolo, W. D. (2009). Epistemic disobedience, independent thought and decolonial freedom. *Theory, Culture & Society*, 26(8), 159–181. <https://doi.org/10.1177/0263276409349275>

Moraga, C., & Anzaldúa, G. (1981). *This bridge called my back: Writings by radical women of color*. Kitchen Table.

Morales-Doyle, D., Vossoughi, S., Vakil, S., & Bang, M. (2020). In an era of pandemic and protest, STEM education can't pretend to be apolitical. *Truthout*. Retrieved from <https://truthout.org/articles/in-an-era-of-pandemic-and-protest-stem-education-cant-pretend-to-be-apolitical/>

Msimanga, A., & Shizha, E. (2014). Indigenous knowledge and science education in South Africa: What messages from the curriculum? In E. Shizha (Ed.). *Remapping Africa in the global space* (pp. 135–

150). Brill.

Nasir, N. S., & Vakil, S. (2017). STEM-focused academies in urban schools: Tensions and possibilities. *Journal of the Learning Sciences*, 26(3), 376–406. <https://doi.org/10.1080/10508406.2017.1314215>

Paré, D., Sengupta, P., Windsor, S., Craig, J., & Thompson, M. (2019). Queering virtual reality: A prolegomenon. In *Critical, transdisciplinary and embodied approaches in STEM education* (pp. 307–328). Springer.

Penniman, L. (2018). *Farming while black: Soul fire farm's practical guide to liberation on the land*. Chelsea Green Publishing.

Philip, T. M., & Sengupta, P. (2021). Theories of learning as theories of society: A contrapuntal approach to expanding disciplinary authenticity in computing. *Journal of the Learning Sciences*, 30(2), 330–349. <https://doi.org/10.1080/10508406.2020.1828089>

Philip, T. M., Gupta, A., Elby, A., & Turpen, C. (2018). Why ideology matters for learning : A case of ideological convergence in an engineering ethics classroom discussion on drone warfare. *Journal of the Learning Sciences*, 27(2), 183–223. <https://doi.org/10.1080/10508406.2017.1381964>

Philip, T. M., & Azevedo, F. S. (2017). Everyday science learning and equity: Mapping the contested terrain. *Science Education*, 101(4), 526–532. <https://doi.org/10.1002/sc.21286>

Quijano, A. (2007). Coloniality and modernity/rationality. *Cultural Studies*, 21(2–3), 168–178. <https://doi.org/10.1080/09502380601164353>

Radke, S. (2021). *Emergent and unfolding: A multi-sited, person centered approach to understanding the learning and doing of mathematics and identity development*, [Doctoral dissertation, New York University]. ProQuest Dissertations Publishing.

Rahm, J., Tagalik, S., & Baker, K. (in press). Youth's relationships with the land, each other, and their community: A critical lens and engagement with the transdisciplinary and heterogeneous. To be



- appeared in M-C. Shanahan, B. Kim, M.A. Takeuchi, K. Koh, P. Preciado-Babb, & P. Sengupta (Eds.). *The learning sciences in conversation: Theories, methodologies, and boundary spaces*. New York, NY: Routledge.
- Raveendran, A. (2021). Invoking the political in socioscientific issues: A study of Indian students' discussions on commercial surrogacy. *Science Education*, *105*(1), 6298.  
<https://doi.org/10.1002/sce.21601>
- Reardon, J., & TallBear, K. (2012). “Your DNA is our history” genomics, anthropology, and the construction of whiteness as property. *Current Anthropology*, *53*(S5), S233–S245.  
<https://doi.org/10.1086/662629>
- Said, E. W. (1978). *Orientalism*. New York, NY: Pantheon Books.
- Sen, A. (1999). *Development as freedom*. New York, NY : Anchor Books .
- Sengupta, P., Shanahan, M.-C., & Kim, B. (2019). *Critical, transdisciplinary and embodied approaches in STEM education*. Springer.
- Sengupta, P., Dickes, A., & Farris, A. (2021). *Voicing code in STEM: A dialogical imagination*. The MIT Press.
- Sengupta-Irving, T., & Vossoughi, S. (2019). Not in their name: re-interpreting discourses of STEM learning through the subjective experiences of minoritized girls. *Race Ethnicity and Education*, *22*(4), 479–501. <https://doi.org/10.1080/13613324.2019.1592835>
- Settee, P., & Shukla, S. (2020). *Indigenous food systems: Concepts, cases, and conversations*. Canadian Scholar Press.
- Shanahan, M.-C., Burke, L. E., & Francis, K. (2016). Using a boundary object perspective to reconsider the meaning of STEM in a Canadian context. *Canadian Journal of Science, Mathematics and Technology Education*, *16*(2), 129–139.

- Singer, P. W. (2010). War of the machines. *Scientific American*, 303(1), 56–63.
- Smith, L. T. (2021). *Decolonizing methodologies: Research and indigenous peoples* (3<sup>rd</sup> Ed). Zed Books .
- Spivak, G. C. (1988). Can the subaltern speak? In C. Nelson & L. Grossberg (Eds.), *Marxism and the Interpretation of Culture* (pp. 271–313). Macmillan.
- Strong, L., Adams, J. D., Bellino, M. E., Pieroni, P., Stoops, J., & Das, A. (2016). Against neoliberal enclosure: Using a critical transdisciplinary approach in science teaching and learning. *Mind, Culture, and Activity*, 23(3), 225–236. <https://doi.org/10.1080/10749039.2016.1202982>
- Takeuchi, M. A. (2018). Power and identity in immigrant parents’ involvement in early years mathematics learning. *Educational Studies in Mathematics*, 97(1), 39–53. <https://doi.org/10.1007/s10649-017-9781-4>
- Takeuchi, M. A., Sengupta, P., Shanahan, M. C., Adams, J. D., & Hachem, M. (2020). Transdisciplinarity in STEM education: a critical review. *Studies in Science Education*, 56(2), 213–253. <https://doi.org/10.1080/03057267.2020.1755802>
- Takeuchi, M. A. (2021). Geopolitical configuration of identities and learning: Othering through the institutionalized categorization of “English language learners.” *Cognition and Instruction*, 39(1), 85–112. <https://doi.org/10.1080/07370008.2020.1825438>
- Takeuchi, M. A., & Aquino Ishihara, V. (2021). Learning to assemble the hidden bodies: Embodied and emplaced mathematical literacy in transnational migrant activism. *Journal of the Learning Sciences*, 30(1), 103–124 <https://doi.org/https://doi.org/10.1080/10508406.2020.1820341>
- Uttamchandani, S. (2021). Educational intimacy: Learning, prefiguration, and relationships in an LGBTQ+ youth group’s advocacy efforts. *Journal of the Learning Sciences*, 30(1), 52–75. <https://doi.org/https://doi.org/10.1080/10508406.2020.1821202>
- Vakil, S., & Ayers, R. (2019). The racial politics of STEM education in the USA: interrogations and

- explorations. *Race, Ethnicity, and Education*, 22 (4), 449–458.
- Vakil, S., & Higgs, J. (2019). It's about power: A call to rethink ethics and equity in computing education. *Communications of the ACM*, 62(3), 31–33. <https://doi.org/10.1145/3306617>
- Vossoughi, S., Hooper, P. A. K., & Escudé, M. (2016). Making through the lens of culture visions for educational equity. *Harvard Educational Review*, 86(2), 206–232. <https://doi.org/10.17763/0017-8055.86.2.206>
- Vossoughi, S., & Vakil, S. (2018). Towards what ends? A critical analysis of militarism, equity, and STEM education. In *Education at war: The fight for students of color in America's public schools* (pp. 117–140). New York, NY: Fordham University Press.
- Wa Thiong'o, N. (2009). *Something torn and new: An African renaissance*. New York, NY: Basic Civitas Books.
- Winder, T. (2018, June). *Love lessons in a time of settler colonialism*. Poetry Foundation. <https://www.poetryfoundation.org/poetrymagazine/poems/146709/love-lessons-in-a-time-of-settler-colonialism>
- Wolfe, P. (2006). “Settler-colonialism and the elimination of the Native.” *Journal of Genocide Research*, 8(4), 387–409. <https://doi.org/10.1080/14623520601056240>
- Zeidler, D. L. (2016). STEM education: A deficit framework for the twenty first century? A sociocultural socioscientific response. *Cultural Studies of Science Education*, 11(1), 11–26. <https://doi.org/10.1007/s11422-014-9578-z>
- Zouda, M. (2018). Issues of power and control in STEM education: a reading through the postmodern condition. *Cultural Studies of Science Education*. <https://doi.org/10.1007/s11422-017-9820-6>

## Further Reading

Critical Perspectives to STEM Education: Reviews, Special Issues, Edited Books

Marin, A., Taylor, K.H., Shapiro, B., & Hall, R. (2020). Why learning on the move: Intersecting research pathways for mobility, learning and teaching. *Cognition and Instruction*, 38(3), 265–280.  
<https://doi.org/10.1080/07370008.2020.1769100>

Note: This is an introductory article for the Special Issue, Learning on-the-move: A new genre of learning and teaching with/in communities.

McKinney de Royston, M., & Sengupta-Irving, T. (2019). Another step forward: Engaging the political in learning. *Cognition and Instruction*, 37(3), 277–284. <https://doi.org/10.1080/07370008.2019.1624552>

Note: This is an introductory article for the Special Issue, STEM Learning: For Whom and Toward What Ends? in *Cognition and Instruction*

Sengupta, P., Shanahan, M.-C., & Kim, B. (2019). *Critical, transdisciplinary and embodied approaches in STEM education*. New York, NY: Springer.

Takeuchi, M.A., Sengupta, P., Shanahan, M.-C., Adams, J.D., & Hachem, M. (2020). Transdisciplinarity in STEM education: A critical review. *Studies in Science Education*, 56 (2), 213–253.  
<https://doi.org/10.1080/03057267.2020.1755802>

Leyva, L. A. (2017). Unpacking the male superiority myth and masculinization of mathematics at the intersections: A review of research on gender in mathematics education. *Journal for Research in Mathematics Education*, 48(4), 397–433.

Vakil, S., & Ayers, R. (2019). The racial politics of STEM education in the USA: interrogations and explorations. *Race, Ethnicity, and Education*, 22(4), 449–458.

Note: This is an introductory article for the Special Issue, The Racial Politics of STEM Education in the USA: Interrogations and Explorations in *Race, Ethnicity and Education*

Vossoughi, S., & Vakil, S. (2018). Towards what ends? A critical analysis of militarism, equity, and STEM education. In *Education at war: The fight for students of color in America's public schools* (pp. 117–140). New York, NY: Fordham University Press.

Zeidler, D. L. (2016). STEM education: A deficit framework for the twenty first century? A sociocultural socioscientific response. *Cultural Studies of Science Education*, 11(1), 11–26.  
<https://doi.org/10.1007/s11422-014-9578-z>