



Towards Equitable, Social Justice Criticality: Re-Constructing the “Black” Box and Making it Transparent for the Future of Science and Technology in Science Education

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Abstract

In the wake of the COVID-19 pandemic, which has resulted in the rapid emergence of vaccines, the dual benefits of both science and technology have been lauded, while dominant, deficit-based narratives of vaccine hesitancy and mistrust in science and medicine by the general public, particularly minoritized populations, run rampant. In this paper, we argue for a counternarrative, where instead of erroneously positioning communities of color as the problem, the problem is reframed to consider what the scientific, technological, and science education communities need to do to become more trustworthy and transgress the persistent shortcomings related to racism and injustice. Specifically, in this position paper, we (a) discuss the interactions of science, technology, and society from the perspective of the nature of technology; (b) engage an understanding of how bias, access, and racism operate in and at the intersection of science, technology, and technological systems; (c) discuss implications of these ideas in science education; and finally (d) pose recommendations to counter alienation and racism with an emphasis on a sixth dimension, *equitable, social justice criticality*, for science-technology education. In conclusion, we make recommendations by centering a more equitable, social justice criticality of science and technology.

1 Introduction

A lingering mistrust of the medical system makes some Black Americans more hesitant to sign up for COVID-19 vaccines. It has played out in early data that show a stark disparity in whom is getting shots in this country — more than 60% going to white people, and less than 6% to African Americans. The mistrust is rooted in his-

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tory, including the infamous U.S. study of syphilis that left Black men in Tuskegee, Ala., to suffer from the disease. (In Tuskegee, “Painful History Shadows Efforts To Vaccinate African Americans,” National Public Radio, Elliott, February 16, 2021) To the real question, How does it feel to be a problem? I seldom answer a word...To be a poor man is hard, but to be a poor race in a land of dollars is the very bottom of hardships.

W.E.B. Du Bois, 1897.

The vignette presented above (Elliot, 2021) describes racialized disparities and what appears to be COVID-19 vaccine hesitancy among Black communities in the USA. An overwhelming number of reports have focused on the perceived mistrust and vaccine hesitancy among Black and Brown communities. While many of these reports call attention to the horror of the US Public Health Service’s syphilis research, together they also create a disturbing narrative in which Black and Brown people stand out as the majority groups against the COVID-19 vaccine, ignoring the statistically majority white population, who have shown notable distrust towards science and technology. The above article (Elliot, 2021) is only one such example of reports that isolate communities of color as groups who mistrust vaccines and science. These reports are not only inaccurate and harmful, but they also perpetuate stereotypical and harmful generalizations about communities of color instead of focusing on structural issues at the root of the problem (e.g., racialized issues foundational to the current science and medical technology).

As Dembosky (2021) argued, the US Public Health Service Syphilis Study has been used as a scapegoat to absolve politicians, healthcare professionals, and scientists from understanding the past and current root causes and disparities in research and the healthcare system and in effect admit that structural racism is at the core of the loss of lives and vaccine mistrust related to COVID-19. Consequently, the current COVID-19 pandemic re-exposed complex challenges associated with misinformation and disinformation related to science, public health, and technology; systemic racism and lack of access to quality healthcare; and overall social apathy and mistrust of science and technology on a global level. This current moment brings to sharp focus an important conundrum—how our past and current approaches in science education contributed to the current moment and how we use this knowledge to help the science education community formulate a more informed, critical stance on the interactions of science and technology and their implications for teaching, learning, and research.

In this position paper, we draw on the nature of technology to explore how and what manifests as mistrust in science related to the pandemic is inextricably connected to systemic racism, violence, oppression, and exploitation used towards communities of color in the formation and development of Western medical technologies. In doing so, we show how issues of mistrust are entrenched in the dominant conceptions of science and technology, which require close examination, re-thinking, and re-constructing. As argued by Volti (2017), the “inability to understand [science and] technology and perceive its effects on our society and on ourselves is one of the greatest, if most subtle, problems of an age that has been so heavily influenced by technological change” (p. 3). Hence, we argue that instead of focusing on the general public’s mistrust of science, or minoritized populations specifically, the questions should be reframed to focus on what scientific and science education communities need to do to dismantle existing injustices built in our technologies rooted in histories of colonialism and racism.

In the call for papers, *Why Trust Science and Science Education?*, there is a clear tension between science as practice and knowledge and society. The call outlines these tensions

and points to important contradictions that question, “Why should science be trusted?” and in the same vein assert the vaccine as evidence of the powerful outcomes of science. Thus, this call challenges the science education community to wrestle with these contradictions and engage questions that inform on critical gaps in science education research and practice. For this position paper, the following two questions from the special issue frame the direction and subsequent analysis: If science is inherently oppressive (i.e., sexist, racist, imperial), how can it be salvaged from its exploitative nature and legacy? How can science learning environments be shaped to acknowledge the power and limitations of science? To address these questions, this paper uses understandings of the nature of technology to frame and expose the inequalities that are obscured intentionally and unintentionally via the proverbial “black” box and in response re-construct and make transparent the “black” box through equitable, social justice criticality.

More specifically, this position paper engages a discussion of (a) the interactions of science, technology, and society from the perspective of the nature of technology; (b) understandings of how bias, access, and racism operate in and at the intersection of science, technology, and technological systems; (c) the implications for science education; and (d) pose recommendations to counter alienation and racism with an emphasis on a sixth dimension: equitable, social justice criticality for science-technology education. This discussion is framed by the understandings of the nature of technology (NoT) framework in science education (Waight & Abd-El-Khalick, 2011). These interactions are particularly significant for the COVID-19 pandemic and its impact given that the emergence of the vaccine and related treatments involved the dual benefits of science and technology. While this paper is prompted by the heightened effects of COVID-19, which we are experiencing in real time, it is important to note that the science and technological impact is historical and persistent beyond the current reality of the COVID-19 pandemic. Thus, addressing each domain in silos and limiting the discussion to COVID-19 would further perpetuate misinformation and disinformation about science and technology.

2 The Enduring Problem of Racialized Othering

Science and technology are viewed as domains that improve daily living and solve important problems (Bybee, 2013; McComas & Burgin, 2020; Sengupta-Irving & Vossoughi, 2019; Szostkowski & Upadhyay, 2019). However, the pandemic and its associated response (for good or ill) re-exposed longstanding, underlying skepticism of science that was in part fueled and exacerbated by the political climate (Moura et al., 2021). It is well documented that this skepticism is also propagated by a culture of elitism and exclusivity that has historically functioned to exclude and marginalize Black, Brown, and Indigenous communities (Medin & Bang, 2014; Settlege et al., 2018). Issues of White supremacy, a racialized and colonial history of science, and continued marginalization of Black, Brown, and Indigenous communities in the sciences and healthcare system have been called into question once again (Morales-Doyle, 2019; Mutegi, 2011; Rosa & Mensah, 2016). Following the Black Lives Matter movement, thousands of scientists went on strike worldwide, condemning enduring racism in STEM fields under the banner hashtag, “ShutDownStem” (#ShutDownSTEM). Although reform efforts such as *Science for All* (American Association for the Advancement of Science (AAAS), 1990) and the *Next Generation Science Standards* (Next Generation Science Standards (NGSS) Lead States, 2013) included language that address historical inequities in science, the current sociopolitical climate evidenced that

these reforms have not achieved their intended outcomes. In other words, these efforts have not done enough to call out or disrupt the persistent injustices present in the sciences rooted in histories of colonialism, slavery, and racism. Racialized narratives have been heightened as a result of the COVID-19 pandemic and its subsequent vaccination dilemmas (Quinn & Andrasik, 2021). For instance, the news media has continuously reported the skepticism among Black and Brown communities and their refusal to get vaccinated, furthering racialized discourses that perpetuate false narratives about nondominant communities. Rarely do these discourses address the histories of science and medical technologies by which Black, Brown, and Indigenous communities, their bodies, and health have been exploited, experimented, violated, discriminated, and dehumanized in the name of science and research (Benjamin, 2013; Gee et al., 2009; Medin & Bang, 2014; Washington, 2006).

3 Black and Brown Invisibility in Technology-Based Research in Science Education

In science education, the dominant narrative about technologies and technological phenomena is one that promotes simplified conceptualizations of technologies as instrumental, linear, neutral, and objective (Waight & Abd-El-Khalick, 2011; Nasir & Vakil, 2017; Vossoughi & Vakil, 2020). Similarly, there is a reductive discussion of the interplay of science and technology that obscures the complexity of this relationship—that while science and technology have been inextricably linked, these domains have also developed independently. And while technologies solve problems, they simultaneously create new problems. These new problems can be even more intractable when embedded biases, structural racism, and lack of diverse representation are involved in technological design, development, and implementation. Philosophers of technology have engaged isolated historical case studies that exemplify racism and racialized inequality (e.g., the development of photography and Robert Moses’s infrastructure design) of technological development and implementation (Volti, 2017). For example, in interrogating if artifacts have politics, Winner (2009) addressed the intentional social effects of the deliberate design of low hanging overpasses and highway systems in Long Island, NY. Essentially, Robert Moses designed this infrastructure to discourage the use of buses, thus limiting access for racialized minorities and low-income groups from accessing specific parkways and, in the case of Long Island, access to Jones Beach: “many of his monumental structures of concrete and steel embody a systematic social inequality” (p. 253). What is significant with this case is that it has implications for current social stratification, with communities segregated according to racialized lines. Understandings related to the above cases are significant because it has implications for how we engage technological design, development, implementation, and adoption in science education.

Elsewhere, we describe that as a science education community, we are in a profoundly “axiological moment where we must frame questions concerning technology and Science, Technology, Engineering and Math (STEM) education, especially in the context of public education, also as ethical and political” (Kayumova & Tippins, 2021, p. 3). Research shows that presumptions of technological neutrality or objectivity are no longer matters of novelistic debate; they are evidence-based and consequential, harming people of color and gendered minorities from nondominant communities through various mechanisms of discrimination, implicit bias, surveillance, and incarceration (Costanza-Chock, 2020). Philosophers, sociologists, and historians of technology have grappled with the

above factors from different lenses. In comparison, only a few researchers have engaged a critical examination of these issues in the science education context (e.g., Waight & Abd-El-Khalick, 2011; Blom & Abrie, 2021; Sengupta et al., 2021). The science education discourse has similarly disregarded the impact of technological design, development, implementation, and enactment on racially, ethnically, and linguistically diverse students and users. As Waight & Neumann (2020) documented, most of the studies in this domain have focused on inquiry-based, technology-supported teacher education and disciplinary-focused and design-based learning, understanding, and assessment. An examination of the premiere journal in science education research, the *Journal of Research in Science Teaching*, revealed that until recently “No studies focused on issues of cultural, ethnic, and racial equity, and social justice” (Waight & Neumann, 2020, p. 1313). This lack of attention and representation is concerning and provokes questions about the invisibility of minoritized learners and about the intentions of and inherent bias embedded in the cycle of technology deployment in science education classrooms.

The glaring absence of research with and for minoritized populations in science and technology is merely an extension of the rhetoric of science for all—being a dream shelved and gatekept by science education power brokers (Rivera Maulucci, 2010). This is visible with the persistent racialized disparities and inequitable and historical exclusion of minoritized populations in science education, science teaching and learning, and participation in science and STEM domains broadly (Mutegi, 2011; Rangel et al., 2020). These inequities and lack of representation manifest as schooling that is disconnected from the lived experiences and interests of urban students of color (King & Pringle, 2018) that overlooks and discounts students of color as capable of excellence and high achievement despite dominant practices and narratives falsely positioning them as deficit (Sheth, 2018). Moreover, these inequities are present through the lack of access and meaningful engagement with high-quality science opportunities in science education for students of color (Upadhyay et al., 2020; Walls, 2016).

Of relevance is the parallel nature of science research which, with a few exceptions (Hansson & Yacoubian, 2020; Walls, 2016), has remained silent on issues of equity and social justice in science practice and science teaching and learning. As one example to the exception, Walls (2016) used critical race theory (CRT) and reported that in 40 years of NOS published research, there was a glaring absence of racialized diversity among the participants, and he exposed how a colorblind ideology, White privilege, and structural racism functioned to erase the views and lived experiences of people of color. Hansson and Yacoubian (2020) confirmed how NOS and social justice efforts “have mostly been separate tracks” (p. 1) despite the fact that these research agendas seek to challenge traditional school science and push back on myths of science as static and fact-based. This divergence and notable absence of minoritized people’s views of science beg questions of the NOS research enterprise. This reinforces why time and again the discourses of science, science practices, and science teaching and learning remain sterile and incomplete.

This collective invisibility naturally extends to the broader community. In many ways, what happens in science classrooms mirrors the socialization of science—that is, who belongs and can participate in science. So, the question of trusting science is one that is misplaced. Instead, the focus should be on how we interrogate exclusionary science practices and who benefits from incomplete narratives about scientific and technological practices. Here, the focus on science and technology is significant because the COVID-19 pandemic and vaccination process are informed by the interrelationship between science and technology.

To situate this egregious silence and the corresponding narrative of science mistrust, we follow with a discussion of the interplay of science and technology. We argue that exclusionary science practices are in fact rooted in the superficial treatment of the interplay of science and technology and the omission of minoritized peoples' experiences and contributions with technologies in science education. In her book, *Race After Technology*, Benjamin (2019) explores how technologies, "which often pose as objective, scientific, or progressive, too often reinforce racism and other forms of inequity" (p. 2). Partly, we argue that many of these topics and concepts are presented in isolation, as if they stand apart neutrally and naturally, rather than being embedded and entangled within complex human, natural, sociopolitical, and historical interactions and systems within science and technology studies.

4 Understanding the Science-Technology Intersection

Kuhn (1962) writes that too often history presents science as an enterprise that is about a scientific method, "exemplified by observations, laws and theories" (p. 1). Frequently, this simplified notion of science is replicated in discourses about the interrelationship of science and technology. In discussion of scientific knowledge and technological advancement, Volti (2017) noted that there is a complex science-technology relationship, and it is often in flux. Volti argued that one of the most common ideas about technology is that it is applied science. However, while scientific knowledge was instrumental to the development of technologies such as the transistor, synthetic materials, and medical practice, not all technologies are directly informed by science. Contrary to popular belief, technological advancement has not always been informed by scientific knowledge and vice versa. For example, while the Greeks were prolific in science, their technological innovations were less impressive. In contrast, the Romans offered major contributions in engineering but less so in science. Volti detailed examples of the soaring cathedrals in Europe and the blacksmiths using steel in sophisticated ways in the Middle East; yet, these developments often occurred without the corresponding technological or scientific knowledge. Volti contended that this history keenly distinguished the current time period as one that is unique because of the simultaneous advancement in science and technology.

The discussion about the science-technology relationship exposes the nature of science and technology. Essentially, there are fundamental differences that are often obscured in the discussion of these domains and practices (Volti, 2017). First, science is about knowledge generation for its own sake, while technology develops and applies knowledge to solve a problem. However, this process is rather complex and is not linear but, most importantly, is informed by context, motivations, and subjectivities of the researchers who decide the kinds of questions to ask to guide the processes of scientific and technological practice. As Volti (2010) described, "scientific inquiry is not a disinterested, fact-driven search for truth, but a human creation that has been shaped by cultural patterns, economic and political interests, and gender-based ways of seeing the world" (Volti, 2010, p. 61). Second, the outcomes of both practices are defined by different objectives. In the case of scientific knowledge, the focus is on "is it true," while for technology, the question is "will it work" (p. 62). The variation in science and technological practices has significant implications for how we understand and take up these practices.

The science-technology understandings are further obscured with the ever-evolving “black box” (Eglash, 2004). This notion of the black box—or using technologies without fully understanding how and why they work—is related to our central argument about trusting science. Notably, Volti explained that it is often the case (and also documented through historical cases) that technologies are developed and used without any understanding of its underlying principles. To this end, Pacey (1983) argued that the misconceptions related to technology are based on the definitions of technology—or what gets lost with simplistic attempts to define technology. For example, philosophers defined technology as a mere tool, while others define technology in terms of skill, technique, or activity (Illich, 1973); organization (Ellul, 1964); or a system (Tenner, 1996). Kaplan (2009) asserts that “technology cannot be defined as a mere tool” (p. 2) because this only accounts for efficiency. Drawing on Heidegger’s notion that technology is a human activity, he argues that technology serves as a means to an end. Pacey (1983) describes technology as technical, cultural, and organizational. He emphasizes the practice-oriented nature of technology, thus describing it as technology-practice. While the technical aspect focuses on skills, techniques, tools, and machines, the organizational aspect includes the economic and industrial activity, the users, and professional activity. The cultural aspect focuses on the goals, values, ethical codes, and overall beliefs in progress and creativity. This holistic conceptualization of technology thus counters and exposes the problematic nature of the instrumentalist and neutral-free notions of technology.

In addressing questions about the neutrality of technology, Pacey (1983) provides an example of snowmobiles in different cultures. On the surface, the snowmobile might be regarded as just a tool regardless of how it is used. However, depending on how it is marketed and subsequently used, snowmobiles can be important for sustaining livelihoods and providing for families, for reindeer herding, or for tourist recreation. When we engage the totality of the multiple faces of technologies, one begins to understand that technologies do not exist in isolation. Once we introduce the design and development of technology, how it is used and why it is used, and its subsequent impact on the environment, the notion of neutrality evaporates. In essence, the interactions of technology with people, the society, and the environment introduce other systems that bring values and belief systems into the equation. Pacey argues that these interacting variables render technology as a cultural artefact with values. As Bush argued:

Technology is a form of human cultural activity that applies the principles of science and mechanics to the solution of problems. It includes the resources, tools, processes, personnel, and systems developed to perform tasks and create immediate particular, and personal and/or competitive advantages in a given ecological, economic, and social context. (p. 121)

Hence, understanding technologies and how they originate requires “opening” up these technologies; that is, it involves examining the internal anatomies, understanding how the technologies are wrapped up in technique, how the anatomies are comprised of systems interacting with other systems, and at the macro level, how these technologies interact with political, economic, educational, environmental, and other technological systems (Arthur, 2009).

5 Nature of Technology

Arthur (2009) is among a small cadre of writers (e.g., Dusek, 2006; Kaplan, 2009) who has focused on understanding how technologies are generated in a more systematic manner. He notes that while there has always been a preoccupation with fashionable technologies such as computation and biotechnology, there has been a marked absence of literature related to the nature and the evolution of technology and specifically, a unifying framework that defines and maps the development and progress of technologies. In response, Arthur focused on understanding, “What is technology, what is it in its nature, where does it come from and how does it evolve?” (p.10). These understandings are critical because they have economic and educational implications for how technologies develop and evolve. This quest to identify a common and systematic logic to technology is based on the notion that so much of humanity’s hopes are embedded in the belief that technology is intended to make our lives easier and solve problems. Encumbered in this hope is an unsettling reality that while technologies solve problems, they also create new problems. Thus, as we seek to counter misinformation and disinformation in science and technology, it is imperative that we re-center the foundational principles that guide the how and why of technologies.

According to Arthur (2009) “if we want to know how they [technologies] relate to each other, and how they originate and subsequently evolve, we need to open them up and look at their inside anatomies” (p. 14). There are three interrelated principles that provide a basis for understanding the nature of technologies. The first principle describes how technologies are assembled from component parts or a combination of different parts. Arthur argued that these component parts function collectively or independently as assemblies, subsystems, and sub-technologies. One example is the computer and its many working and interrelated parts. Second, there is recursiveness, or that the building blocks of a technology are individual, standalone technologies that are comprised of their own parts, sub-assemblies, and assemblies. Recursiveness suggests that technologies are malleable, “highly reconfigurable; never static, never finished, never perfect” (p. 42). The ability for technologies to adapt and evolve is in fact a direct effect of the recursive nature of technologies.

Third, technology is based on phenomena and mimics the workings of nature. An important consideration here is that when a technology becomes familiar and thus transparent—it becomes a normal part of everyday personal or work life—the phenomena or effect can also become normalized and thus move to a space of invisibility. In contrast, the effect can be more salient and thus highly visible when technologies are new or when we are learning a new technology. In the case of the former, we do not often stop to ponder what a car is doing as we travel from one location to another. So, technology always utilizes some phenomena, and the visibility or awareness of the phenomena depends on the usability and functionality of the technology.

Understandings of the nature of technology have implications for science education. When we omit understandings of the system nature of technology, its recursiveness and how we transition to technological transparency, we intentionally engage incomplete narratives about the life cycle of technologies. Thus, to create a culture of trust with science-technology interactions, these understandings should be standard in any discussion, practice, or development of educational technologies. In the next section, we explicate how these understandings materialize in the context of science education.

6 Nature of Technology and Science Education

Research on the nature of technology in science education is limited, but we are beginning to see more research conducted in this domain (e.g., Waight & Abd-El-Khalick, 2012, 2018; Blom & Abrie, 2021; Sengupta et al., 2021; Yenilmez Turkoglu et al., 2021; Vakil & Ayers, 2019). For this paper, we focus on Waight & Abd-El-Khalick (2011, 2012) NoT framework because it involves theorization that is empirically supported. This work examined how Biology Student Workbench, a web-based tool that was developed for scientific research and later adopted for high school, was implemented and enacted in five biology classrooms. The findings revealed that classroom enactment lacked elements of inquiry, followed prescriptive activities, and was teacher-centered. That a sophisticated scientific technology redesigned and adopted for high school learning did not live up to the hype begged further analysis to understand how technologies are transformed in context. Understandings of the nature of technology, as articulated by philosophers of technology (e.g., Dusek, 2006; Pacey, 1983; Tenner, 1996), were used to frame analysis of technological design, development, implementation, and enactment in the science education context. Consequently, we identified six core dimensions that are at the core of how technologies are implemented and enacted in the science education context. To ground our discussion of equitable, social justice criticality (which follows in the ensuing sections), we present a brief discussion of each dimension (for a detailed presentation of each dimension, please see Waight & Abd-El-Khalick, 2012, 2011).

The first dimension, culture and values, dispels the idea that technologies are neutral and value-free. Culture and values are represented in the diverse contributions and expertise involved in the process of design and development; the role, knowledge, and contributions of; and the racial, ethnic, and linguistic backgrounds of school agents. According to Volti (2017), diffusion involves the transfer of technologies, knowledge, and expertise across contexts and subdomains. How this transfer occurs is dependent on cultural alignment and the readiness and needs across contexts. The nature of the transfer and the complementary modifications determine the rate of innovation and successful uptake of technologies.

In the second dimension, technological progression is closely linked with culture and values and explicates that technological progress is an inherently human expectation, which is based on the need for more, better, and faster technology. On the surface, this need for efficiency can be misleading since it suggests that we should aspire for continuous advancement. The third dimension, technology as part of systems emphasizes the multi-faceted nature of technology. Additionally, since technologies are both contextual and cultural, technologies impact and are impacted by their designers and users. Technologies thus shape their users, and in turn, users shape technologies based on their cultures and needs. The fourth dimension engages technology as a fix, the notion that technologies function to solve problems; often, these problems are non-technical in nature (Volti, 2010). Most of these problems are social and cognitive.

The fifth dimension addresses expertise, which is vital for design and development, and implementation of technologies. How we define expertise and who is an expert to design and use technologies determine how technologies shape and are shaped in context. Expertise is thus at the core of understanding the nature of technology. Essentially, the expertise of the designers and developers determines the built-in scaffolds, or lack

thereof, of technologies. The expertise and knowledge of users thus determine how technologies are adopted and used in learning spaces.

7 Technologies, Unconscious Bias, Racism, and Access

The above dimensions explicitly alert attention to the importance of culture and context and the need for alignment, with the values of who holds expertise and knowledge in the designer, developer, and user spheres. These dimensions are consistent with conceptualizations of technology that advance holistic understandings that technologies are systems, which interact with other systems and thus are value-laden. Implicit in these dimensions are narratives of what and whom is of value in the discussion of technologies. However, these dimensions fall short of naming how technologies impact marginalized communities of color in the USA and globally. Even more significant, there is a major gap in documenting how technological tools perpetuate inequitable practices and in effect function to promote racism and social injustices. While we acknowledge that philosophers and sociologists of technology have reported on case studies of technological practices that are inherently inequitable and racist and have cautioned against the dangers of technological development, these case studies are often isolated events that overlook the systemic nature of these practices (Basalla, 1988; Clark, 2003; Winner, 2009). In the next section, we highlight relevant technologies that exemplify the insidious nature of technological access, racialized bias, and racism.

Racialized bias in the development of photography and film is among one of the well-known technological cases that intentionally excluded people of color. Volti (2017) writes about the demand for photography by poorer yet affluent (as opposed to the elite or aristocratic) people; however, he fails to mention that this technology was largely inaccessible to people of color and particularly people with darker skin tones. Lewis (2019a, 2019b), a Harvard professor, tells the story of how her experience with lighting when preparing to give a talk—the fact that her jacket was lighter than her face and being told that this was a problem—reminded her of the unconscious bias built into photography. The Shirley Card, the face of a White woman with a light skin tone, functioned as the standard for photography. As Lewis indicates, it was not until the mid-1990s that Kodak finally included multiracial photography cards. However, this inclusion was not because Kodak sought to remedy representation in photographic film but rather the change was a result of complaints from furniture and chocolate companies who desired variations in the shade of brown in order to market their products. This motivation for change here is telling! Beyond this phase of manual photography, perhaps even more concerning is how this very bias was then transferred to digital imaging technology via algorithms: “ Yet, algorithmic bias is the end stage of a longstanding problem” (Lewis, 2019a, p. 14)

Another example of technological design, intended to restrict and divide access to marginalized communities of color, is the work of Robert Moses (Winner, 2009). Moses is an avowed racist who designed and built parkways to divide urban communities along racialized lines. In addition, his low bridges over New York parkways were intended to block public transportation and thus make park systems inaccessible to people of color. Winner argues:

What makes the conclusion that Moses’ bridges are inegalitarian political artifacts a strongly defensible proposition is not difficult to grasp. It can be seen in the role

that the bridges play in the social and political history of a particular community at a particular time, as well as in the personal history of a power broker notorious in his willingness to use all possible means, including public work projects, to shape social patterns to match with his vision of what was desirable. (p. 374)

These examples underscore that as a system, it is not just the technology but also who designs and develops and how decision-making of politicians, policy makers, federal and state agencies, and community members uphold racist technologies and practices. The repercussions of Robert Moses's parkways are still evident in these communities. Racial segregation marked by redlining and high poverty is a direct and enduring outcome of these racist technological systems.

Other technologies holding relevance for the current COVID-19 pandemic are medical and biotechnologies. In fact, bias in biotechnology employed in the field of medicine, is a longstanding problem. Medical research has historically excluded Black and Brown people in testing and data collection. For example, the spirometer and pulse oximeters are medical devices that apply race-based standards and thus disadvantage and misrepresent Black physiology. Essentially these examples illuminate of how medical and health institutions continue to engender discriminatory practices.

The history of the spirometer, a diagnostic device that measures an individual's lung capacity, can be traced back to the Civil War. Research by Braun (2015) demonstrated that at this point in American history, Black bodies were justified as being physiologically unfit for the field along with concurrent findings that suggested Black people had weaker lungs when compared with their White counterparts. These early findings advanced today's innately flawed medical diagnostic processes that dangerously under or over predict Black people's lung capacities when compared with their White counterparts. Significantly, tools such as the spirometer rely on flawed logistics. In actuality, they are "race-corrected," although they are not explicitly so; the data that drives the diagnoses of Black versus White individuals relies on precedent dis/ability estimates, clinical diagnoses, and pre-employment physicals (Braun, 2015). It is important to note that these sources of data are human-driven, and human-driven sources of data are the epicenter of bias and inequality. Conclusively, medical technology was not designed for people of color and did not keep their conditions and histories in mind. This technology is similar to other technologies that were conceived of and designed based on binary assumptions.

Pulse oximeters, which measure oxygen levels, have become increasingly common, especially in light of the COVID-19 pandemic. However, a seemingly simple device such as the oximeter is another example of a racialized tool in medical technology (Sjoding et al., 2020). A pulse oximeter relies on certain features to accurately read blood oxygen levels. In order to "see" it, infrared light must pass through the skin to reach oxygen saturated hemoglobin for its reading. According to research by Sjoding and colleagues (2020) published in the *New England Journal of Medicine*, pulse oximeters are developed and calibrated for lighter skin tones resulting in less accurate, or subtle differences, in readings for people of color. This poses serious implications that continue to be overlooked as harmless due to the normalization of unequal standards. The "subtle" differences that are observed by people of color are exclusive to them, not White people. This is largely due to accuracy testing when developing the devices, as claimed by John N. Severinghaus of UCSF on medical devices in anesthesiology. The critical nature of small errors in displaying oxygen levels is life-threatening, and such readings similarly affect critical care decisions, where subtlety and nuance matter. In context, a Black person with COVID-19, for example, could have a pulse oximeter reading of 77, when in reality, it could be 69 (Sjoding et al., 2020).

Amid this pandemic and unreliable testing, patients of color have reported being dismissed from the ER, where their breathing difficulties have been misattributed to anxiety or other factors, unrelated to the disease. This reality illustrates not just racism and discrimination but also implicit biases held by medical personnel. People of color must exhibit more severe symptoms or health issues to be given the same level of care or medical intervention when compared with White patients (Ledford, 2019).

The examples we provide above are only a small fraction of the technologies that reflect bias, exclusion, segregation, limited access, racialization, and othering of people of color. In naming these technologies, we illustrate how technologies are cultural and how they are shaped to embody and enact the culture and values of their designers and developers and context of deployment. In order to build a critical consciousness about technologies, it is imperative that science education addresses these narratives. Below we map a sixth dimension that outlines the dangers, what Clark (2003) refers to as “bad borgs,” that perpetuate racial bias, exclusion and racism (as seen in the above technologies), and a subsequent discussion of the tenets of what equitable, social justice criticality looks like for science education.

8 Towards a Sixth Dimension of the Nature of Technology: Equitable, Social Justice Criticality

Knowledge of inequitable access, conscious and unconscious bias, and racism in the conception, design, implementation, and use of technologies heightens the urgency in bringing attention to the system-oriented nature, culture- and value-laden impact, and associated dangers of technologies. The urgency for criticality of technological tools is particularly significant for science education because of its proximity to scientific knowledge and practice. What this means is that how we engage scientific practice and its culture and knowledge generation will be largely connected to how we write about, present, and take up technologies. Indeed, Benjamin (2019) notes that “numerous efforts are also underway to develop technologies that ameliorate social cleavages” (p. 140). Benjamin frames this effort as technological benevolence. To ensure that these fixes move beyond mere technical fixes, we first engage well-documented dangers that must be accounted for in order to promote a more equitable, social justice criticality.

While there are numerous possibilities associated with technologies, Clark (2003) highlights “new closures, dangers, invasions, and constraints” (p. 167) of technologies as “bad borgs.” Clark explains that as captive audiences who co-exist with technologies and technological systems, that bad borgs are part and parcel of the “new liberties and capacities” (p. 167) that are attached to our roles as human-technology symbionts. These bad borgs are trade-offs, outcomes, new problems that are inherent, but often silenced and obscured, privileges, and limitations of technologies. Clark identifies these bad borgs as inequality, intrusion, uncontrollability, overload, alienation, narrowing, deceit, degradation, and disembodiment. We engage and counter these bad borgs to frame our recommendations for equitable, social justice criticality. First is inequality, where there are large disparities in access, such as with the Internet, made more publicly apparent during the COVID-19 pandemic with virtual learning and online registration for COVID-19 vaccine appointments. Intrusion is related to the need for privacy, where cookies, globally unique identifiers (GUIDs), and smart technologies evoke “threats of electronic tattling and ubiquitous interference” (p. 169) as they monitor and track online movements with precision. That is, to

reap the benefits of recommendation systems, one's privacy serves as a tradeoff that allows outside agencies to surveil and exploit this collected information. Tracking is also closely related to narrowing, which can lead to a sort of "communal tunnel vision" (p. 182), where people are fed things that they like, which confirms the suggestions by clicking, reading, liking, and/or purchasing, and the cycle repeats itself in a positive feedback loop. Another characteristic of bad borgs is overload, such as the flood of emails, resulting in the need to unplug, and the difficulty with controlling the quality and accuracy of a barrage of information, misinformation, and disinformation.

Alienation is another concern. As new technologies alter human social relations and senses of selves and others, identities are negotiated in the new human-machine symbiosis, and the technologies "mimic aspects of our social interactions...only shallowly and imperfectly" (p. 178). In this way, "the simple presence of these technologies thus contributes to the generation of the very problem (frequent, easy, long-distance communication) they help to 'solve'" (p. 181). The bad borg facet of deceit, related to degradation, recognizes how it has become easier to create different, multiple personas on the Internet, spread misinformation and lies, and use cyberbots, resulting in the need for CAPTCHA, a technical fix.

Indeed, the Internet was the most popular information source that participants in the Archila et al. (2021) study gained information about COVID-19. Clark poses the question that, in a world where "anyone can publish thoughts and insinuate emails into thousands upon thousands of inboxes, how are we to separate the wheat from the chaff?" (p. 187). Time is a precious resource, and "we cannot afford to read everything everyone has to offer us in order to decide—even assuming we could tell—what is most authoritative and important" (p. 187). The last characteristic of bad borgs is disembodiment. Human biological brains are incomplete and are "naturally geared to dovetail themselves, again and again, to a shifting web of surrounding structures, in the body and increasingly in the world" (p. 189–190), and because of this, the brain can be fooled and tricked, such as the feeling of remote presence.

Thus, there must be critical consciousness raising around these characteristics of bad borgs, which inform the design and implementation of technological tools. We must recognize that there are "multiple conscious and nonconscious elements spread across brain, body, and world" (Clark, 2003, p. 192). Human-centered technologies highlight the importance of bodies and perspectives; they allow for more mobility, richer interfaces, and increased interactive support. As Clark contends:

The task is to merge gracefully, to merge in ways that are virtuous, that bring us closer to one another, make us more tolerant, enhance understanding, celebrate embodiment, and encourage mutual respect. If we are to succeed in this important task, we must first understand ourselves and our complex relations with technologies that surround us. We must recognize that, in a very deep sense, we were always hybrid beings, joint products of our biological nature and multilayered linguistic, cultural, and technological webs. Only then can we confront, without fear or prejudice, the specific demons in our cyborg closets. Only then can we actively structure the kinds of world, technology, and culture that will build the kinds of people we choose to be. (p. 195)

In this way, we need biological relationships with technologies, those that enrich and humanize rather than carry the facets of bad borgs, which restrict and alienate. Related to inequality, technologies must be "freeing" for the user, such that they can become more helpful than a hindrance, what Illich (1973) refers to as conviviality and Benjamin (2013)

refers to as technologies of humility. As Clark (2003) notes, “they need to be cheap, robust, and intuitive-to-use—in a word, human-centered” (p. 168). That is, technologies should “become less fragile, cheaper, and easier-to-master” so that “more doors open to more people than ever before” (p. 168). Human-centered technologies would “progressively blur the already fuzzy boundaries between thinking systems and their tools for thought” (Clark, 2003, p. 177). Human-centered technology is for all, not only a select few.

9 Discussion and Recommendations

In her plenary presentation during the NARST, a Global Organization for Improving Science Education through Research, Virtual Conference (April 7–10, 2021), Ruha Benjamin focused on the question: Why trust science? She noted that the focus should not just be about trusting science but how we engender trustworthiness. She explained that trustworthiness involves removing the metaphorical “spikes” that create inequitable and racist conditions that systematically exclude people of color and other marginalized communities. It is well-documented that equity has not been a major concern for domains involved in technological development, progression, and implementation (Benjamin, 2019; Bush, 2009). Nevertheless, technology is in fact an equity issue: “technology has everything to do with who benefits and who suffers, whose opportunities increase and whose decrease, who creates and who accommodates” (Bush, 2009, p. 120). Much of the silence about technology as an equity issue is undergirded by incomplete understandings that frame technologies as neutral and objective, positive and beneficial, and intended to solve problems and make life easier (Takeuchi et al., 2020; Vakil & Ayers, 2019).

In science education, this silence about technology as an equity issue is further exacerbated by the superficial, uncritical approaches employed in technological design and implementation. While most of the guiding questions focus on impact, very few studies have interrogated the cultural, ethnic, and racial equity, linguistic diversity, and social justice impact (Waight & Neumann, 2020). In fact, Waight & Neumann (2020) documented that there were no studies that addressed the latter in the *Journal of Research in Science Teaching*, the premiere science education journal. Similar findings for *Science & Education* were noted. So, to counter these shortcomings, with this paper, our goal is to open a space for a broader dialogue about the exclusionary, oppressive state of science and technology and to imagine liberatory possibilities for the way forward. Our review of the literature and analysis revealed that given the scientific, public health, technological, political, economic, and social effects of the COVID-19 pandemic, it is imperative that the field of science education explicitly engages understandings of the nature of technology and, more specifically, critically interrogates the equitable, social justice tenets of technologies and the relationship between technology and scientific practice. As we seek to expose the inequities and racism embedded in design and development of technologies obscured by the “black box,” we engage recommendations for equitable, social justice criticality of technologies in science education. We present tenets as recommendations for science education-technology research and practice and use the illustrative example (Futureism, 2017) in Fig. 1 to ground the discussion of the tenets of equitable, social justice criticality.

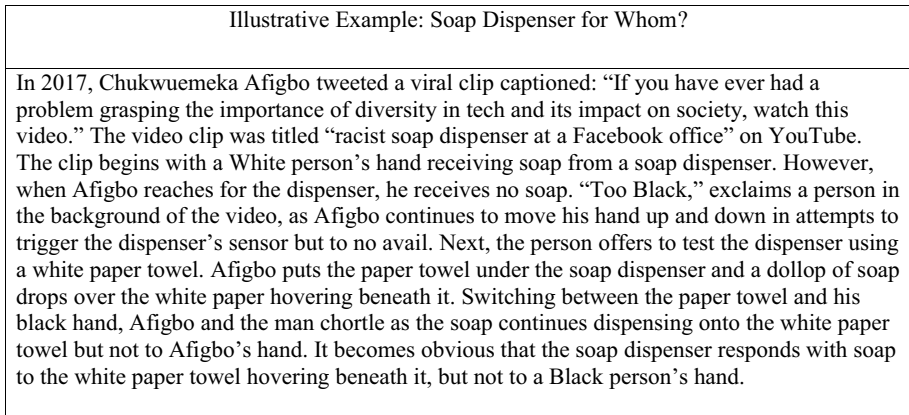


Fig. 1 Illustrative example: soap dispenser

9.1 Equitable, Social Justice Criticality

Equitable, social justice criticality brings to the fore the following tenets: (1) broadening participation, (2) exposing the myth of neutrality, (3) amplifying asset-based counterstories for broadening participation, (4) centering a racial equity/justice and humanity-centered fix, and (5) committing to technological transparency.

9.1.1 Broadening Participation

Broadening participation addresses the inequality bad borg. Broadening participation mitigates exclusion and allows for ethnic, racial, and linguistic representation and voice. How do we ensure that past and enduring harms and dangers caused by technologies such as photography and the Shirley cards and the Robert Moses parkways and bridges are not replicated in science education teaching and learning environments? It is critical that the science education community takes up questions about access and how broadening participation translates across contexts and student populations that are historically excluded and marginalized. Broadening participation also asks questions about implementation and instructional quality and how this is assessed across contexts; it engages how diffusion and expertise are experienced by students in diverse contexts. It challenges the myth that technologies act alone and thus exposes that the system-oriented nature of technologies can be harnessed to challenge inequalities.

In the context of the soap dispenser, seemingly everyday technologies and trivial day-to-day activities, like washing our hands after using the restroom, are racialized. A soap dispenser unable to recognize a black hand illustrates lack of access for people with darker skin tones. That the design and development of this technology have occurred in the last decade and that it mirrors racist practices visible with photography and the Shirley card are significant and telling.

9.1.2 Exposing the Myth of Neutrality

Exposing the myth of neutrality addresses intrusion and narrowing. Centering the value-laden nature of technology removes the veil of technology as objective and neutral. This understanding is critical in centering accurate and complete narratives about how technologies operate in our schools, classrooms, and society. Following Gil-Pérez et al. (2005) argument, a “simplistic view of the science-technology relationship” not only results in the “absence of the technological dimension in science education” but also contributes to a “naïve and distorted view of science” and lack of “necessary scientific and technological literacy of all citizens” (p. 309). Thus, technologies as instruments do not operate in isolation; instead, context and the cultural values of the designer, developer, and user are integral in this interaction. Exposing the myth of neutrality centers questions about how different stakeholders understand and experience this phenomenon and how it materializes in context. When we champion specific technologies in science classrooms, whose voices and presence do we privilege and evoke? What are the markers of cultural relevance with technology implementation and enactment?

With the soap dispenser example, it may be easy to overlook this event as isolated or a “fluke” in the engineering design or technological development process; however, such “flukes” are due mainly to the fact that the creators behind everyday devices are often White and design products with the needs and interests of White people in mind, even if unconsciously. In effect, the soap dispenser merely reflected the values of the designers and developers, whom in this case, excluded highly pigmented skin complexions—people of color. That this design did not involve testing with darker skin complexions exposes technological neutrality as a myth.

9.1.3 Amplifying Asset-Based Counterstories for Broadening Participation

Amplifying asset-based counterstories for broadening participation addresses the alienation bad borg. While it is important to point out structural issues and inequities foundational to the conceptions of Western science and technology, it is equally important that we do not perpetuate further harm and deficit-centered narratives about marginalized communities of color. As Benjamin (2013) argues:

It is vital that the research community depathologize ‘black distrust’ and question the normalcy of ‘white trust.’ These implicitly racialized dispositions, which are institutionalized in contemporary biomedical and public health discourses about ‘patient noncompliance’ and ‘scientific literacy,’ are firmly entrenched in the deficit model for public understanding of science, wherein ‘hard to reach’ populations are routinely depicted as uneducated, uninterested, or even hostile. (p. 152)

As described in the opening vignette of our paper, even when we speak about inequities related to the COVID-19 vaccination, these conversations may turn into stereotypical generalizations in which Black and other communities of color are only mentioned when it comes to mistreatment or being positioned as problems.

A similar trend is central to science and technology education in which conversations about equity and broadening participation begin with deficit narratives about what is lacking about children, youth, and families of color. It is important to resist these harmful narratives and instead engage stories of historically marginalized communities of color not only as objects of mistreatment but as beneficiaries of the expertise of African, Indigenous,

and ancestral communities of color, as inventors of knowledge, practices, and technological tools. These stories can serve as counternarratives to the White savior myth which becomes so prominent—and the stories of those who actively resisted and refuted scientific racism (Rusert, 2017). For example, in Gandolfi's (2020) study, eighth grade students learned about the diversified history of medicinal plants and medical expertise that derive from various places around the world and have been exploited. Through the story of the compass, students learn about the exchange of knowledge from China to the Islamic world, East Africa, and Europe, and that this knowledge exchange enabled technological development, which, in turn, fostered circulation and exploitation of knowledge and resources, such as medicines and minerals.

Moreover, when considering immunology and inoculation, instead of lauding Edward Jenner as the father of immunology, the story of Onesimus and his African ancestors should be foregrounded. Onesimus, an enslaved African, had knowledge that contributed to the inoculation against smallpox. In Africa, before his enslavement, pus from a smallpox victim was scraped into his skin with a thorn, a practice hundreds of years old that built up immunity to disease and was a precursor to modern vaccination that prevented many deaths in West Africa (Kendi, 2016). There is much to learn from these stories, such as human virtues of humanness, communalism, interdependence, and moral responsibility that are central to the African philosophy of Ubuntu (Ogunniyi, 2020).

With the soap dispenser example, one is prompted to ponder, "What if the designers and developers represented more diverse racial backgrounds" and/or "What if the designers were Black?" In other words, this case further validates why diverse representation is important. What is more, exposing teachers and students to these technologies, as well as amplifying asset-based counterstories of equitable and just technologies—that are created by and work for minoritized populations—reinforces the significance of the creation and production of technologies as opposed to only participating in the consumption of technologies. Indeed, Eglash (2004) illustrates how production led by people of color is more cultural and racially aligned with its users.

9.1.4 Centering a Racial Equity/Justice and Humanity-Centered Fix

Centering a racial equity/justice and humanity-centered fix addresses the disembodiment borg. Benjamin (2019) writes that a fix that grapples with racialization must continually burnish its benevolence, which is furthered through the noble-sounding ambitions of technoscience. To counter the tunnel vision of technical fixes, we highlight the need to address context and culture. Addressing context and culture humanizes the social, cognitive, and behavioral. A racial equity/justice and humanity-centered fix needs to start from a "socially conscious approach" (Benjamin, 2019), one that is cognizant of subjective and collective biases. A socially conscious approach that is humanity-centered addresses technologies at the intersection of race, gender, language, dis/ability, class, religion, and so on. This is important because even when we center race, there are other intersecting identities and associated oppressions, which inform how technologies are realized in design and use.

When we seek to solve problems that target marginalized communities, it is important that these approaches reflect deep knowledge of the problems and those whom the approaches purport to serve. Without an in-depth understanding of the problem, context, and people, technologies simply reinforce and replicate existing, unjust systems. Benjamin (2013) explicates that structural inequalities are viewed as too big, and as a result,

the treatment overlooks the symptoms that cause the structural inequalities. Since fixes are often associated with half-way technologies (Volti, 2017), time to accommodate investigation is significant to ensure informed understandings. Finally, even with substantial time to study a problem, Volti (2017) cautions that we never fully solve problems, because new problems always emerge. Criticality thus requires transparency with the reporting of these new problems and a continued critical awareness and anti-oppressive action. The totality of a racial equity/justice and humanity-centered fix is responsive to the mechanisms involved in solutions as well as the emerging new problems.

In the example of a soap dispenser, teachers and students can engage in conversations and discussions about how science, engineering, and technology practices can potentially become racialized given that these practices are carried out by people. Centering racial equity/justice and humanity-centered fix would mean that STEM spaces and practices are equally carried out by people from racially, linguistically, culturally, and socio-economically marginalized communities. In the case of the dispenser, the technology manifested systemic issues in STEM disciplines that are racialized and exclusionary. The design and engineering of the tool revealed a lack of understanding of context and a range of users. A soap dispenser that reflects a racial equity/justice and humanity-centered fix would work well for all users and be designed with the needs and interests of a range of users in mind, such as individuals with dis/abilities and other linguistic backgrounds and cultures, who might otherwise also have difficulty using the soap dispenser in its current form. It would be safe, environmentally conscious and sustainable in ways that promote well-being. Such a fix would embody a full understanding of the problem, context, and needs and interests of all people, from development, use, and discard, and thus encompass an ongoing endeavor. Inequitable barriers to access and participation would be removed and continually monitored. Consequently, providing students and teachers with a pedagogical space in which these criticalities are addressed is fundamental to the efforts of equity and justice.

9.1.5 Committing to Technological Transparency

Committing to technological transparency addresses the deceit and degradation bad borg. While the spread of misinformation is not unique to this current moment, we remain cognizant that the COVID-19 pandemic and corresponding political climate exacerbated the proliferation of misinformation and mistrust in scientific and technological evidence. Maia et al. (2021) acknowledged that the pandemic is a contemporary socioscientific issue which highlighted the need of the general population to understand science and the work of scientists and their research. As explicated above, this need to understand what scientists do has been a pervasive and enduring problem. Equitable, social justice criticality centers the learner and the knowledge they bring to the classroom and what and who informs the development of this knowledge. In the science classroom, the following recommendations can guide this process: focus on the nature of science and technology in context, engage the credibility and critical reading of information (Maia et al., 2021), and include evidence from a diversity of knowledge areas (Justi & Erduran, 2015).

Technological transparency also exposes the ever-expanding, opaque black box which privileges an elite cadre of technologists and scientists. In effect, the black box conveys and obscures expertise and knowledge and simultaneously excludes the majority of users. To counter these exclusionary and deceitful practices, equitable, social justice criticality requires a shift “from technology as an outcome to toolmaking as a practice, so as to

consider the many different types of tools needed to resist coded inequity, to build solidarity, and to engender liberation” (Benjamin, 2019, p. 113).

Technological transparency with the soap dispenser would involve opening the dispenser “box” in order to configure the constitutive elements that define the workings of this technology. That is, at what point in the design does complexion trigger the soap dispenser to release soap? What about a new design tested with multiple skin tones? Another layer of transparency involves exposing how many technologies come with built-in spikes (Benjamin, 2019) and thus function to exclude people—in this case, people with darker skin complexions.

Here we argue that science teachers, students, and associated stakeholders should be exposed to such cases and critically interrogate the bad borgs of technologies since these cases counter commonly held beliefs that technologies function to make life easier and by extension automatically improve science teaching and learning. Equitable, social justice criticality prompts the question, “Soap dispenser for whom?” But the next step should engender conversations of new designs—the creation and production of new soap dispensers that reflect humanity-centered, inclusive racial, cultural, social, and environmental values and are transparent so that its users can trace the scientific and engineering design practices and processes and mechanical and algorithmic functions of how the dispenser works.

9.2 In Closing: The Future of Science and Technology

The point we aim to reinforce here is that the ways in which we have been teaching science and technology as neutral, universal, disembodied, apolitical, and ahistorical not only disservice young people but also science itself. We advocate for the centering of equitable, social justice criticality at the core of our existing nature of technology framework (Authors, 2011, 2018) for science education. Instead of science-related issues and knowledges being presented to students as abstract and ready-made, “natural” facts (Kelly & Chen, 1999), equitable, social justice criticality centers the rights and voices of local communities, which seeks to eliminate the false image of both science and technology as if they are separate and sterile entities independent of each other (Kayumova & Tippins, 2021); this is a view which permeates current science curricula (Hufnagel et al., 2018) and becomes consequential in maintaining binary assumptions about nature-culture relations (Kayumova, McGuire & Cardello, 2019 2020).

Consequently, we advocate for the re-constructing and peering into the black box and a radical re-thinking of and critical reflection on dominant assumptions about science and technology—not merely the reusing and/or repurposing of them. For example, a large corpus of research on technologies in science education stems from a technocentric viewpoint (Turkle & Papert, 1990), focused on the technology qua technology and how it can potentially improve human conditions without acknowledging an underlying problem among the knower, that which is known, and the knowledge-making practices (Kayumova, Zhang & Scantlebury, 2018). Attending to and disrupting issues of power and politics and illuminating how science and technology work and become implicated in the political and social-economic decisions made on behalf of communities of color are other important ways of revealing the centrality of science and technology in people of color’s lives. Thus, in schools we need to develop a more holistic view of science and technology that fosters a shared understanding of how participating in science and technological decision-making has greater implications for the present and future of socially, environmentally, and culturally revitalizing, sustaining, and thriving communities.

Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

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