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Defining the Flow—Using an Intersectional Scientific Methodology to Construct a VanguardSTEM Hyperspace

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Abstract: #VanguardSTEM is an online community and platform that centers the experiences of women, girls, and non-binary people of color in science, technology, engineering, and mathematics (STEM) fields. We publish original and curated content, using cultural production, to include a multiplicity of identities as worthy of recognition and thus redefine STEM identity and belonging. #VanguardSTEM is rooted firmly in Queer, Black feminisms which delineate that the experiences and critiques of Black women matter and that these insights can foster a restorative and regenerative construction of the cultures in which we exist. In describing how #VanguardSTEM descended from countespaces, we draw on speculative fiction to define a #VanguardSTEM hyperspace as a fluid “place-time” that is born digital and enabled by social media, but materializes in the physical world for specific purposes. As Black women in STEM, we consider how our situated knowledges and scientific expertise inform our process. We propose an intersectional scientific methodology to address the influence of embodied observation, embedded context and collective impact on scientific inquiry. Through #VanguardSTEM, we assert, without apology, the right of Black, Indigenous, women of color and non-binary people of color to self-advocate by fully representing ourselves and our STEM identities and interests, without assimilation.

Keywords: culture-centered interventions; community organizing; decolonizing methodologies; education; mental health; healing

1. Introduction

At its simplest, science, technology, engineering and mathematics (STEM) are a set of disciplinary practices and systems of knowledge that explore questions about the physical world¹. How one goes about such exploration varies widely based on training, access to resources, culture and decision-making power. In a western, colonial context, people who follow a rational and falsifiable set of practices (Abbot 1885) to understand the world are called “scientists”, and the process they employ to make these claims is called

¹ Merriam-Webster defines science as, “knowledge or a system of knowledge covering general truths or the operation of general laws especially as obtained and tested through scientific method” <https://www.merriam-webster.com/dictionary/science>.

the “scientific method.” In the United States, “scientific thinking” is tied to notions of meritocracy and objectivity. Namely, that the people who deserve to become scientists will inevitably do so and once they become scientists they will embark on the process of scientific discovery using an entirely neutral and impartial scientific method. However, objectivity and meritocracy are demonstrably not neutral and are instead tied to behavioral norms and practices with sociological and cultural histories (e.g., [Prescod-Weinstein 2015](#); [Harding 1993](#); [TallBear 2014](#)).

The interpretation of objectivity as neutral does not allow for participation or stances. This uninvolved, uninvested approach implies “a conquering gaze from nowhere” ([Haraway 1988](#)). In many ways, claims of objectivity allow one to “represent while escaping representation” ([Haraway 1988](#)) and mimics the construction of Whiteness² in the racialization of marginalized peoples ([Battey and Leyva 2016](#); [Guess 2006](#)). Indeed, there is extensive evidence suggesting that STEM cultural norms are traditionally White, masculine, heteronormative and able-bodied ([Atchison and Libarkin 2016](#); [Chambers 2017](#); [Eisenhart and Finkel 1998](#); [Johnson 2001](#); [Nespor 1994](#); [Seymour and Hewitt 1997](#); [Traweek 1988](#)). Thus, while purporting to be a neutral application of a generic protocol, science—and STEM more broadly—has a distinct set of cultures that governs legitimate membership and acceptable behaviors. The concept of a meritocracy is often used to justify who succeeds in STEM cultures. However, far from “leveling the playing field”, meritocracies exist in cultural systems that prioritize people who have, or to a lesser extent closely emulate, these traits. Success in science, then, tends to privilege cultural traits associated with the above identities and often marginalizes scientists who can not or will not perform these identities. This introduces structural inequities in the pursuit of science that align with social manifestations of racism, colonialism, sexism, homophobia and ableism ([Cech and Pham 2017](#); [Wilder 2014](#)).

If participation in and successful contributions to STEM were equitable, one could expect the demographics of the STEM workforce to match that of the population from which they are drawn. According to the 2010 Census ([US Census Bureau 2015](#)), women and girls of all ethnicities and races represent the majority (50.8%) of the United States (U.S.) population³, of which women of color⁴ make up 19.4%⁵. The National Science Foundation (NSF) reports that 25% of doctoral degrees in STEM are obtained by women of all ethnicities and races. Women of color (as defined by the NSF⁶) earned 4.5% of STEM PhD degrees, of which Black women obtained 2.7% of STEM doctorate degrees between 2004–2014.

The National Girls Collective⁷ found that middle school African American and Latine⁸ girls of color show the same interest in STEM as their White and Asian counterparts, roughly 34%. All girls in that study had similar STEM competence, as measured by subject-specific test scores. By the time girls of color arrive at college, they are more interested in STEM majors than other women in their cohort. College-aged African American women show higher rates of interest in majoring in STEM than White women [O’Brien et al. \(2015\)](#). Given that girls of color have expressed early STEM interest, performed equivalently on skill proficiency assessments and demonstrated higher interest in STEM majors upon entering college, this is clearly not an issue of desire or ability. As such, we resist the assumption that Black, Indigenous, women of color (BIWOC) are not capable or interested in STEM based on their low rates of STEM Ph.D. attainment, as this is simply not born out by the data.

² <https://zora.medium.com/im-a-black-scholar-who-studies-race-here-s-why-i-capitalize-white-f94883aa2dd3>.

³ <https://www.census.gov/quickfacts/fact/table/US/SEX255219>.

⁴ Defined by the U.S. Census as Black or African American (alone), American Indian and Alaska Native (alone), Native Hawaiian and Other Pacific Islander (alone).

⁵ <https://www.census.gov/quickfacts/fact/table/US/SEX255219?>, <https://www.nsf.gov/statistics/2017/nsf17310/static/data/tab1-2.pdf>.

⁶ <https://www.nsf.gov/statistics/2017/nsf17310/static/data/tab7-7.pdf>.

⁷ <https://ngcproject.org/statistics>.

⁸ <https://wearemitu.com/things-that-matter/heres-why-some-latinx-users-are-switching-to-latine-instead/>.

Yet, Black, Indigenous, women of color do not persist in STEM at the same rates as their white male counterparts and more frequently cite social or interpersonal factors⁹ (rather than skill-based ones) as the decisive factor in their departure (Ong et al. 2018). Black, Indigenous, women of color more often report a sense of loneliness, discrimination and rejection as it relates to moving through their STEM trajectories (for example, Winkle-Wagner 2009).

We hypothesize that this significant underrepresentation of women of color in STEM is symptomatic of structural issues in STEM culture. Furthermore, the marginalization and discrimination that STEM culture engenders, creates an alienating environment that pushes girls and women of color out of STEM, despite their demonstrated interests. If, due to the structural oppression they face, they choose not to continue in a STEM discipline, it is a demonstration of their agency and autonomy over their own careers and wellbeing and not a lack of ability. Not only are the structural barriers inequitable, but so too is the denial of students' individual freedom to pursue careers to which they are drawn.

We include here brief note on nomenclature to aid the reader. We refer and relate to our community most often through the axes of gender and racialized/ethnic identity and we use a person-centered approach when addressing identity. We use the terms "woman/girl of color" to include anyone who self-identifies as a Black, Indigenous, woman of color (BIWOC) and/or who otherwise identifies as a woman of the Global Majority¹⁰. These terms are used interchangeably throughout the text. We use the term "non-binary person of color" to refer to someone who identifies as a Black, Indigenous, person of color (BIPOC) and who does not conform to gender binaries. We are a part of the community of women, girls and non-binary people of color for whom we built this programming. So we use the following nomenclature for clarity: when we are talking about the #VanguardSTEM team and/or the authors of this manuscript we use "we", "us", and #VanguardSTEM. We use "women, girls and non-binary people of color" and "our community" or communities to refer to our core audiences and the standpoint from which our interventions derive.

2. Literature Review

This work is rooted firmly in Queer, Black feminisms as theorized by, for example, Smith (2000); Collins and Bilge (2020); Collins (2002); Giddings (2014); Lorde (1984); Taylor (2017). These women and many others articulated the still revolutionary notion that the inner spaces, experiences, insights and critiques of Black women matter. Not only that, but that those insights could form a restorative and regenerative construction of the United States, and the world, that did not rely on oppressive patriarchal, sexist, capitalist structures (Smith 2000). Of particular importance is Black feminist standpoint epistemology (Collins 1997, 1998), which situates Black women, and often Queer Black women, at the center of the political discourse.

These theorists made clear that there is no way to understand the experiences and oppressions that Black women face without a coincident analysis of their gender, race, class and sexual identities (Hancock 2016). This multiplicity of identities and the differential power dynamics they delineated have always been central to Black feminist thought. Kimberlé Crenshaw coined the term "intersectionality" as part of her legal critical race theory work in 1989 (Crenshaw 2018), and it has since become a much more broadly known concept (Hancock 2016).

Perhaps less widely known is the role Black women scientists played in the introduction of these epistemologies in the STEM context. In particular, as noted by Ong et al. (2018), Dr. Shirley Malcom, a Black woman zoologist, alongside Paula Q. Hall and Janet W. Brown, co-wrote a paradigm-shifting report in 1976 called, *"The Double-Bind: The Price of Being a Minority Woman in Science"*, which addressed the structural oppressions faced by BIWOC in STEM (Malcom et al. 1976, p.14). They wrote with clarity and rigor that, "it becomes difficult, if not impossible, to determine which "ism" is in force. In such a case, it does not

⁹ <https://www.aip.org/sites/default/files/aipcorp/files/teamup-full-report.pdf>.

¹⁰ <https://citizensclimatelobby.org/building-bridges-dr-barbara-love/>.

matter whether one is being hit with the club of sexism or racism—they both hurt. And this is the nature and the essence of the double bind.” Dr. Malcom’s visionary leadership on these topics made the way for generations of successful women of color in STEM; #VanguardSTEM is certainly descended from her insights.

In subsequent decades, many Black women in STEM have, in various ways, engaged the intersection of critical race theory and STEM culture. They include, but are not limited to Chanda Prescod-Weinstein (Prescod-Weinstein 2020), Lauren Chambers (Chambers 2017), Beronda Montgomery (Montgomery et al. 2014), Stephani Page (Page 2019), Ebony O. McGee (McGee and Bentley 2017), and Christine Grant (Grant 2015). This list, while illustrative of the keen interest that BIWOC have in understanding and theorizing their experiences in STEM, is far from complete. Many BIWOC have contributed in visible and invisible ways to the current discourse around the experiences of women of color in STEM.

Both the literature and lived experiences¹¹ of Black, Indigenous, women of color point to specific examples of structural oppression as described by Crenshaw’s intersectionality framework (Gutiérrez y Muhs et al. 2012). Such examples include, but are not limited to, “know-your-place” microaggressions (Mitchell 2018), “mistaken identity” (Williams 2014), and increased encounters of sexual harassment (Clancy et al. 2017). The NSF does not currently report data on gender non-conforming (Rasmussen et al. 2019) and sexual identities of STEM students and professionals in its demographic data. Despite evidence that heteronormative bias runs rampant in STEM (Cech and Pham 2017), analysis on the experiences of LGBTQIA+ individuals in STEM is severely lacking and data on the intersection of queerness and race is essentially nonexistent.

The Combahee River Collective laid out a clear description of the power of identity as a political tool to end the oppression of Black, Indigenous, women of color (Smith 2000). As a similarly powerful tool in STEM contexts, we anchor our intervention on science identity. We investigate the formation, development and evolution of science identity over time and with experience. We employ an interactionist perspective of identity (Herrera et al. 2012), which posits that identity is a combination of one’s individual agency and the societal structures that constrain individual possibilities (Brickhouse 2001); that is, how one thinks of themselves and how they are perceived by others. While individuals do construct and adapt their sense of self dynamically and over time, one’s construction is not completely independent of social contexts. We also adopt an identity-in-practice approach (Tan et al. 2013), which accounts for the dynamic construction of identity in communities of practice, like science spaces. These informal science spaces, in contrast to traditional science classrooms, are crucial to connecting one’s narrative identity (i.e., who they want to be) with their embodied identity (i.e., what they do). The degree to which those two conceptions of one’s identity overlap—through exposure to science contexts—increases the likelihood of successful STEM outcomes.

Carlone and Johnson (2007) undertook a seminal study of successful women of color in STEM disciplines to assess the aspects of science identity that are most influential for women of color pursuing undergraduate STEM degrees. They defined science identity as how women “make meaning of science experiences and how society structures possible meanings.” Their model accounts for the social construction of science identity, its situational emergence and habitually accessed nature (Elmesky and Seiler 2007; Seiler and Elmesky 2007). They suggest three components that contribute to science identity: (1) competence, (2) performance, and (3) recognition. According to their model, a woman of color with a strong science identity recognizes herself and is recognized by those she considers to be “meaningful others” as a science person. Importantly, for the present work, the type of “meaningful other” whose recognition is sought and/or valued depends on the type of science identity the women of color seeks to embody. Women of color who held either a research science identity or an altruistic science identity both regarded themselves highly as scientists. Those with a research science identity valued recognition from sci-

¹¹ <https://www.nature.com/articles/d41586-020-01741-7>.

entific meaningful others, whereas, those with altruistic science identities instead valued recognition from altruistic or non-scientific meaningful others. Furthermore, women of color in STEM with altruistic science identities engaged in cultural production, through which they navigated the often contradictory meanings of STEM identity in local and global contexts (Carlone and Johnson 2007). Powerfully, cultural production allows women of color to transform the meanings of science, who is a “science person” and what it means to be a woman of color in science. Instead of trying to assimilate into predominant notions of who a scientist is and their place in it, cultural production allows for women of color in STEM to completely redefine these concepts.

Another key component in developing a science identity is feeling a sense of belonging in STEM cultures. Wenger (1999) suggests three modes as belonging that aid in identity formation. Namely, (1) imagination, perceiving oneself as fitting into a community of practice; (2) engagement, the opportunity to create shared histories within a desired community of practice; and (3) alignment, placing oneself further along a desired track and in conversation with the broader context of a given community of practice. Wenger (1998) also suggest that these three modes of belonging are distinct, but not mutually exclusive and the essence of a given community of practice is in the use of all or some of these modes of belonging. In particular, alignment incorporates an analysis of collective power, which can expand one’s sense of what is possible. This amplification of power can increase one’s sense of agency beyond individual efforts and energy and toward a contribution to a larger whole.

Lastly, we draw on the literature about counterspaces. These shared spaces allow one to identify similar experiences within the STEM culture and find a sense of camaraderie, belonging and acceptance. When these spaces are specifically designed for students who have been marginalized in STEM spaces to counter those experiences, they are called counterspaces (Solórzano and Villalpando 1998; Solorzano et al. 2000). Ong et al. (2018) describe counterspaces as “locations of activity or thought that *counter the dominant culture in STEM*, offering the potential to disrupt historical power structures” (emphasis ours). They invoke counterspaces as a valuable place for women of color to persist in STEM. In particular, their conception of counterspaces can exist in the center(s) of mainstream science culture(s) and can be ideological and/or conceptual spaces (Lapidot-Lefler et al. 2015).

Ong et al. (2018) postulate that counterspaces are crucial sites of counterstorytelling (DeCuir-Gunby and Walker-Devose 2013; Delgado and Stefancic 2012; Solórzano and Villalpando 1998; Yosso 2002) and are informed by critical race theoretical notions of “self-identification” in Black feminism (Collins and Bilge 2020; Collins 2002) and “testimonios” in Latine feminist theory (Delgado Bernal et al. 2012). Furthermore, these counternarratives draw on Indigenous feminisms (TallBear 2014) by resisting the false dichotomy between being inside or outside of various communities of practice, electing instead to stand with communities and erase the implied boundaries between scientific and non-scientific meaningful others. This counterstorytelling creates and sustains a sense of belonging that women of color need to counteract microaggressions, individual and institutional racism, while offering the tools to productively exist in central STEM spaces like classrooms and departments.

3. The #VanguardSTEM Intersectional STEM Framework

Here we describe the #VanguardSTEM intersectional STEM praxis based on the theoretical frameworks presented above. Full details of the #VanguardSTEM origin story can be found in Appendix A. It bears noting here that we refer to ourselves as “VanguardSTEM”, whether we use the ‘#’ symbol or not. Our current model can be found in Section 5.3, but the process by which we evolved our framework is material to the construction of the intersectional scientific methodology, so we describe its origin here.

3.1. Development

The #VanguardSTEM intersectional STEM (iSTEM) framework was designed to be a virtual counterspace that uses cultural production to dynamically develop and sustain STEM identity by expanding the meaning of who a STEM person is to include a multiplicity of identities worthy of recognition by meaningful others (see Figure 1). We did this by creating a persistent, digital community of practice where three modes of belonging are employed to support the cultural and STEM identities of BIWOC in STEM.

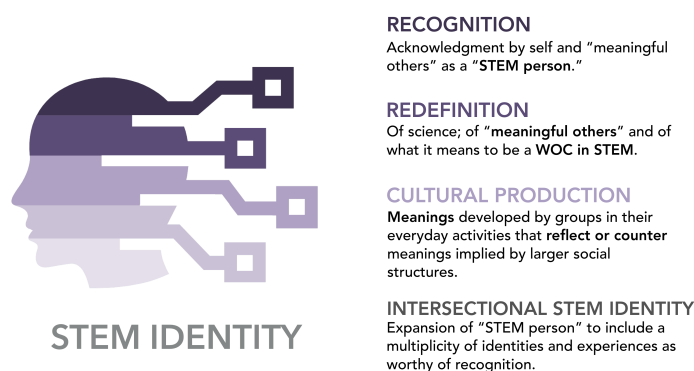


Figure 1. The earliest conceptions of the #VanguardSTEM intersectional science, technology, engineering and mathematics (STEM) identity framework and the literature and concepts from which it emerged (for example, [Carlone and Johnson 2007](#); [Ong et al. 2018](#); [Wenger 1998](#)). Our earliest models leaned heavily on recognition as a way to build STEM identity, using cultural production to redefine the meaning and contributions of women of color in STEM.

#VanguardSTEM and the iSTEM framework complicates, redefines and makes practical what it means to take up virtual and physical space with the thoughts, insights, concerns and successes of Black, Indigenous and women of color in STEM. Our tagline, "making, taking and changing space" for women, girls and non-binary people of color in STEM aligns with these critical justice frameworks. We assert, without apology, the right of women of color to self-advocate by fully representing themselves, their STEM identities and interests without assimilation into the dominant, and often oppressive, STEM culture. The interventions below have been imagined and developed by a team of Black women who are themselves in STEM and who are intimately aware of these barriers and oppressions, because they have personally experienced them. In addition to their lived experiences, the #VanguardSTEM team has also done extensive reviews of the concepts described above in order to develop a model that is informed by the literatures available in critical race theory, science and technology studies, cultural studies and social psychology. By incorporating both our experiences and expertise, we build original content and curate existing content to encourage our audience to redefine their notions of STEM, success, meaningful others and being a women of color in STEM as a means of dynamically creating a space for themselves that represents their narratives within and beyond STEM.

We have developed this iSTEM praxis informed by Queer, Black feminist theories in conversation with Latine and Indigenous feminisms, which not only takes into consideration these ways of knowing, but also the cultural sensibilities and power dynamics at play for women of color in both their STEM and broader social contexts. This intersectional standpoint is explicitly responsive to the innately intertwined and often fluid axes of race, ethnicity, gender identity, class, ability status, neurodiversity, religious affiliations, and so forth; and how people with a multiplicity of identities experience overlapping oppressions and interactions with and access to power.

We also acknowledge the complications of external assessment of identity and rely on our community members to authentically and honestly represent themselves and act in good faith towards the rest of the community. Our goal is not to police identity, so identity alone does not qualify or disqualify one from belonging in our #VanguardSTEM

space or to our community. Instead, we adhere to dynamically constructed ways of being, that prioritize Queer Black feminist stances and human-affirming behaviors through clear articulations of our community rules of engagement. Put plainly, we welcome anyone who respects our community into our #VanguardSTEM counterspace. With that same spirit of commitment, we remove bad actors, regardless of identity, who perpetuate oppressive behaviors and ideals that are detrimental to our community.

3.2. Deployment

#VanguardSTEM was born digital. We intentionally deployed a social media engagement strategy that prioritized community building in contrast to more traditional promotion, marketing, and public-relations purposes (Davis et al. 2014). Because there are fewer women of color in Ph.D. programs, we are often thinly dispersed across geographic locations, creating an urgent need for connection with advocates and community. Our intervention uses social media as a tool to extend beyond physical locality. It is well established that social media is a source of social capital through which a sense of belonging can be achieved via positive social media interactions (Lee et al. 2014; Valenzuela et al. 2009). Our use of social media engagement as a method of community building is based on the principle that there is “real world” social value in social media interactions. We posit that in this digital age, interpersonal connections made via social media have inherent value, comparable to real world, in-person interactions. This is what #VanguardSTEM capitalizes on to form a community with critical mass, in spite of the bounds of geography. Thus, we intentionally built a virtual space where Black, Indigenous, women of color and non-binary people of color could instantly and persistently feel connected to a community of like-minded individuals going through similar experiences and with similar STEM interests. Our endeavors in cultural production are essentially delivered to the palm of your hand.

We seek to translate our iSTEM framework into a consistent voice to provide space for women of color and non-binary people of color in STEM to advocate for themselves, their STEM identities and interests. We believed this consistent voice could be recognized by our community as belonging to and representative of women of color in STEM, not to speak for them, but to speak as members of the collective. In order to determine the #VanguardSTEM voice, we identified three forms of voice often exhibited on social media: professional, personal, and personas. We resisted a professional voice which could recapitulate established, but problematic STEM norms, that disavow the impact of identity, which is in direct opposition to the counterspace we are constructing. In contrast, a personal voice, while free to be defined by its own individual principles of communication, does not allow for a collective identity. By developing a #VanguardSTEM persona we establish a relationship with our community while speaking with the collective voice of the #VanguardSTEM community that fosters trust, reciprocity and opportunities for collective action (Valenzuela et al. 2009).

We write the same way we experience life: from a person-first perspective. Finalizing our communication strategy and language allowed us to develop consistency such that the #VanguardSTEM voice was consistent regardless of which team member was developing a given campaign. Our approach to brand recognition—voice recognition—prioritized personability, authenticity, familiarity and thoughtfulness in our language, as well as non-verbal communication such as striking images, engaging videos and soundbites to establish an interactive persona as opposed to a corporate brand as the public face of #VanguardSTEM.

Ultimately, the #VanguardSTEM voice feels like it belongs in the “#ScienceTwitter”¹² (Burks et al. 2018; Cheplygina et al. 2020; Heemstra 2020) community, but is still true to women, girls and non-binary of color in STEM. That is to say, we wanted to create a persona that demonstrated technical expertise and affirmed the cultural identities of these

¹² <https://astrobites.org/2020/01/17/you-should-get-twitter-for-science/>.

communities, thereby actively using cultural production to redefine what it means to be a woman, girl or non-binary person of color in STEM, while simultaneously creating a sense of belonging in STEM culture.

4. #VanguardSTEM Interventions

As a team of Black women in STEM, we rely on our own situated knowledges and scientific expertise to interpret the interventions we present here. We do not expect for our interventions to apply in every context, but we suggest they describe reality as it is for many women, girls and non-binary people of color in STEM, while illuminating a possible pathway towards creating STEM cultures and methodologies that reinforce the intersectional STEM identities of these communities. From the beginning we recognized the power of defining our narrative and engaging in new discourses that intertwine the cultural and scientific aspects of our identity. The long-form content that #VanguardSTEM creates is our offering to one another and to the world. It is our opportunity to share; it represents what we have to give and is, quite frankly, based on what we wish we received.

Because we have always been committed to making space for women, girls and non-binary people of color in STEM, having our own website where we can curate our own content is critical to the #VanguardSTEM iSTEM framework, as it leads to a hyperspace place-time where one can always go to find helpful resources, insight from other #VanguardSTEM community members and a reminder that they belong in STEM. In many ways, our website is like a persistent portal into the #VanguardSTEM hyperspace.

4.1. *We Are Here: Performance and Engagement*

#VanguardSTEM is an online community and platform that centers and highlights the experiences of women, girls and non-binary people of color in STEM. While social media allows us to find and interact with our community, our original programming allows us to explicitly define our #VanguardSTEM community values, share lived experiences, demonstrate scientific expertise and construct a hyperspace where our sense of rightful presence is affirmed. Our original programming supports STEM identity development by providing an opportunity for women, girls and non-binary people of color in STEM to demonstrate their scientific and cultural expertise. We recognize the power of autonomy to share our stories in our own constructed space, that “people may come to act differently within their social worlds, both by telling their own stories, and by hearing or reading those of others” (James 1996). By producing long-form content that is broadly applicable at a variety of career stages, #VanguardSTEM is able to call on our community to deploy bi-directional exchanges of situated knowledges and expertise within and beyond the current STEM culture and provide persistent opportunities to develop and evolve our STEM identities, outside the strictures of an often oppressive STEM culture.

4.1.1. “On the Vanguard”: A Live Show

The first long-form intervention we produced for our community was the live-streamed, web series entitled, “On the Vanguard: Conversations with Women of Color in STEM”, which launched in 2015 and aligned with our intersectional STEM framework. The show leverages counterstorytelling to increase opportunities for women, girls and non-binary people of color in STEM to be recognized as technical experts within their disciplines and the STEM culture while cultivating a stronger sense of engagement as a mode of belonging in the #VanguardSTEM community of practice.

The shows are theme-driven, closed captioned and livestreamed so that the #VanguardSTEM community can participate in real-time using social media (see Figure 2). By featuring a rotating panel of emerging and established women, girls and non-binary people of color in STEM to discuss issues that are important to us, thereby affirming our right to have our own narratives and spaces in which we interrogate the nuances of our experiences, trade advice and encouragement. In effect, we use the show and its content to amplify our experiences, as central to STEM discourse.

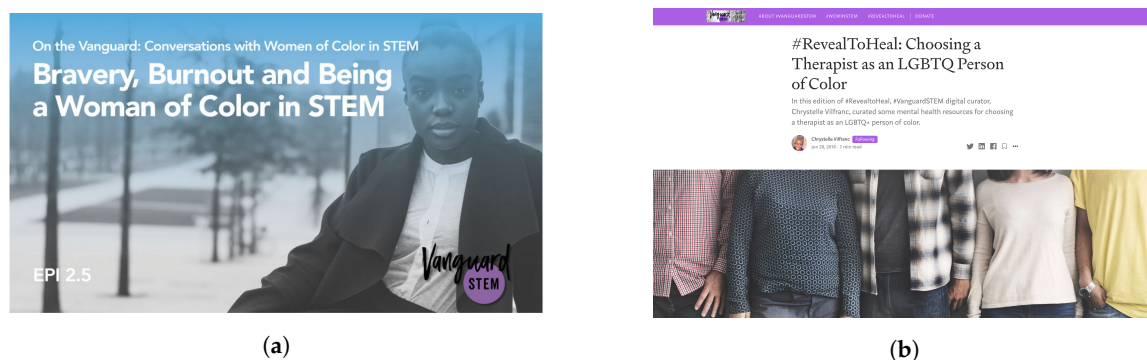


Figure 2. Artefacts from the #VanguardSTEM (a) live web series and (b) resource-driven curated digital content. Both examples make clear the standpoint of our materials and the audiences for whom they are intended. Anyone is welcome in our hyperspace, but we make clear that our hyperspace exists to center and highlight the experiences of women, girls and non-binary people of color in STEM.

One example that gives clear insight into how we use our iSTEM lens to conceive of and produce our shows is entitled, “A Wrinkle in Wakanda: Where Shuri Thrives”¹³. This episode was in response to the release¹⁴ of the Marvel Comic Universe movie¹⁵ *Black Panther*, whose record-breaking box office performance was widely attributed to the broad cultural resonance in the Black community. More than that, many Black women in STEM felt an even larger sense of resonance as it related to the character, Shuri, who was sister of Black Panther and a scientific genius. During this episode we theorized about the power of seeing the simultaneous acknowledgement of cultural and scientific identity recognized on the big screen; an unexpected embodiment of intersection STEM identity. It was only right then, that we discuss the importance of Shuri’s character to women, girls and non-binary people of color in STEM in our very own #VanguardSTEM hyperspace.

4.1.2. #VanguardSTEM Original Articles

Sharing our insights and experiences supports the development of a hyperspace as the #VanguardSTEM community wields transformative power in shaping the culture of STEM. If, by engaging with #VanguardSTEM original content, “one can discover the experiential logic behind these ideas, the ideas become less strange and the owners of the ideas cease to be strangers” (Jaggar 2015). Ultimately, we are able to use our long-form content to strengthen the #VanguardSTEM community and give an opportunity to engage with a voice and standpoint that is familiar, technically savvy and responsive to the current moment.

Two original series delineate our commitment to identifying, supporting and developing our rightful presence in STEM are the “Burnout, Bravery, and Being a Woman of Color in STEM” series (#BBBinSTEM, 2015; see Figure 2a), spoke to the challenges of existing as women, girls and non-binary people of color in STEM from a social and cultural context. The #TakeUpSpaceTuesday¹⁶ series (2018) affirms our community’s right to “take up space” rather than quietly suffer from isolation and exclusion. Both narrative-driven series are examples of reframing the experience of women, girls and non-binary people of color in STEM as they build scientific expertise. Indeed the series-opening piece encouraged readers to be “unapologetically yourself in whatever space, role or position you occupy...to take advantage of opportunities to acknowledge [one’s] identity and to make room for others to do the same.”

¹³ <https://www.vanguardstem.com/show-content/2018/3/1/season-1-episode-1-p7drj-m6nrh-8lwgz-2pf5t-cwgzz-p2wzh-hhyn7-mscdh-trx48-alzbn-n47zh-ww5p3-b48nl-xrynm-s2z3z-j65my-zbbsh-26mlt-edc6p>.

¹⁴ <https://www.forbes.com/sites/scottmendelson/2018/03/26/black-panther-more-box-office-milestones-as-soars-past-the-avengers/#4ac9c2b461d3>.

¹⁵ The Marvel Comic Universe is registered trademark of the Marvel Studios, a subsidiary of The Walt Disney Studios. We make no claim of ownership of any materials related to the major motion picture, Black Panther, or any character therein.

¹⁶ <https://conversations.vanguardstem.com/takeupspacetuesday-being-out-in-stem-a46e52acb95e>.

4.2. We Got This: Competence and Alignment

#VanguardSTEM also produces resource-driven articles with actionable strategies and insights to address the challenges women, girls and non-binary people of color in STEM face. Here, we aim to combine our iSTEM framework with thoughtful digital curation to inform and mobilize our audience to advocate for themselves, their STEM identities and interests. These interventions focus specifically on demonstrating competence and inspiring a sense of alignment with the broader community of women, girls and non-binary people of color in STEM and resist the sense of isolation and/or abnormalcy. By providing resources on topics relevant to our community, we help remove stigma and normalize the experiences of being women, girls and non-binary people of color in STEM.

4.2.1. #VanguardSTEM Resources and Digital Curation

Three #VanguardSTEM campaigns point to how we deploy iSTEM in our resource-driven and curated content relating to STEM-related professional development, mental health and relevant political issues; all from the standpoint of our #VanguardSTEM community.

The #OnTheComeUpOctober campaigns focuses on STEM professional development¹⁷ and navigating conference spaces. The #RevealToHeal series (see Figure 2b), named after Jay-Z's 4:44 album, provides resource-driven content related to the mental health and well-being of women, girls and non-binary people of color in STEM. This series includes, guides on finding mental healthcare professionals, for example, "Mental Health and Communities of Color"¹⁸, "Choosing a Therapist as an LGBTQ Person of Color"¹⁹, tools for dealing with mental health crises, for example, "My Triumph over Suicide"²⁰ and tips for navigating common mental health challenges while being in STEM professional settings, for example, "Mental Preparation for Conferences"²¹.

Lastly, we also interrogate political issues that disproportionately impact women, girls and non-binary people of color in STEM. For example, in 2017, the U.S. House of Representatives proposed legislation, *The Tax Cuts and Jobs Act*, that would have effectively increased taxes on graduate students by 400%²². While many media outlets covered this story^{23,24}, we found that the disproportionate impact this legislation would have on students of color was overlooked. In response, we created the #VSGradTax campaign and published a show and two articles^{25,26} on the impact of the proposed tax on women of color who were currently graduate students. This became one of the most highly engaged #VanguardSTEM campaigns, which was cited in the resource lists of the American Astronomical Society's Science Policy Committee²⁷, emphasizing the dire need for the perspective of women, girls and non-binary people of color in STEM.

4.2.2. Conference Crashing and Guerilla Mentoring

In 2018, #VanguardSTEM developed our "Conference Crashing" intervention, which was the first time we built programming that was designed to be deployed in physical space. Before Conference Crashing, all of our programming was designed for virtual engagement. In contrast, Conference Crashing brought the #VanguardSTEM hyperspace

¹⁷ <https://conversations.vanguardstem.com/my-top-5-need-to-know-application-tips-66221431de5>.

¹⁸ <https://conversations.vanguardstem.com/revealtoheal-mental-health-and-communities-of-color-4c25a62de69>.

¹⁹ <https://conversations.vanguardstem.com/revealtoheal-choosing-a-therapist-as-an-lgbtq-person-of-color-58a444527489>.

²⁰ <https://conversations.vanguardstem.com/revealtoheal-my-triumph-over-suicide-424f9e61b436>.

²¹ <https://conversations.vanguardstem.com/revealtoheal-mental-preparation-for-conferences-5687c6a6d9c>.

²² <https://www.cnn.com/2017/11/02/politics/tax-plan-republicans/index.html>.

²³ <https://www.wired.com/story/grad-students-are-freaking-out-about-the-gops-tax-plan-they-should-be/>.

²⁴ <https://www.cnbc.com/2017/11/16/house-gop-tax-plan-could-increase-taxes-for-grad-students-by-400-percent.html>.

²⁵ <https://conversations.vanguardstem.com/tax-reformed-out-of-the-grad-school-equation-from-the-first-year-667ada022d34>.

²⁶ <https://conversations.vanguardstem.com/tax-reformed-out-of-the-graduate-school-equation-e16d8a7fee4e>.

²⁷ <https://aas.org/posts/advocacy/2017/12/aas-action-alert-stop-graduate-student-tuition-tax>.

into the real world. This physical manifestation was designed to address all parts of STEM identity development (performance, competence, and recognition), but we specifically centered the demonstration of scientific competence by the #VanguardSTEM community in their respective professional conference settings. We explicitly wanted to crash conferences where women and non-binary people of color often feel invisible by providing a central hyperspace to increase their visibility as STEM experts with each other and their colleagues.

Conference Crashing was deployed in the main exhibit hall of the 5 major STEM conferences we “crashed.” With visual imagery and physical space that brought the #VanguardSTEM persona to life, our booth became a central gathering space for those who identified with #VanguardSTEM programming and content (see Figure 3). While increasing visibility of women and non-binary scientists of color, we were also interested in providing resource-rich engagement at our booth itself.

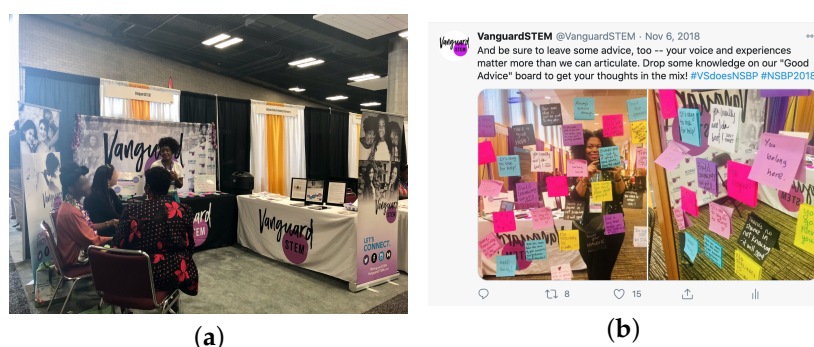


Figure 3. The #VanguardSTEM Conference Crashing initiative brought our previously digital-only content into the (a) real world to take up physical space and materialize our hyperspace at STEM conferences. We used the physical space to build up a “Good Advice” board (b) where visitors to our booth could leave advice or get advice, thus contributing to STEM identity of building alignment and a sense of connection to the community of women and non-binary people of color attending the same conference.

We also developed in-situ mentoring through our “Guerilla Mentoring” campaign (see Figure 4). Here we used the strength of our virtual connections to multiply our physical connections. We tweeted, using the relevant conference hashtag (see Figure 4a), to solicit mentors at the conference who identified as women and non-binary people of color to volunteer as mentors for emerging women and people of color in STEM “on the spot.” We view this particular deployment of mentoring to be incredibly important to our community as they are navigating the conference in real-time (see Figure 4b). Mentees might bring up questions about a request for an interview they were offered at the next booth, or ask for someone to review the opening few lines of the poster or talk they are presenting or ask more long-term questions. Also central to our Guerilla Mentoring initiative is that we showcase the iSTEM framework through the embodiment of our mentors; they were there, existing in real-life as STEM experts that have both the situated knowledges and scientific expertise to advise the #VanguardSTEM community in the middle of a STEM conference. Conference Crashing and Guerilla Mentoring render visible and central the intersectional STEM expertise of our community in the real-world. We were particularly moved when participants at AAAS pointed out that they did not realize there were so many women of color in STEM at the conference, until they came to our booth and saw so many of us materialize in one physical place.

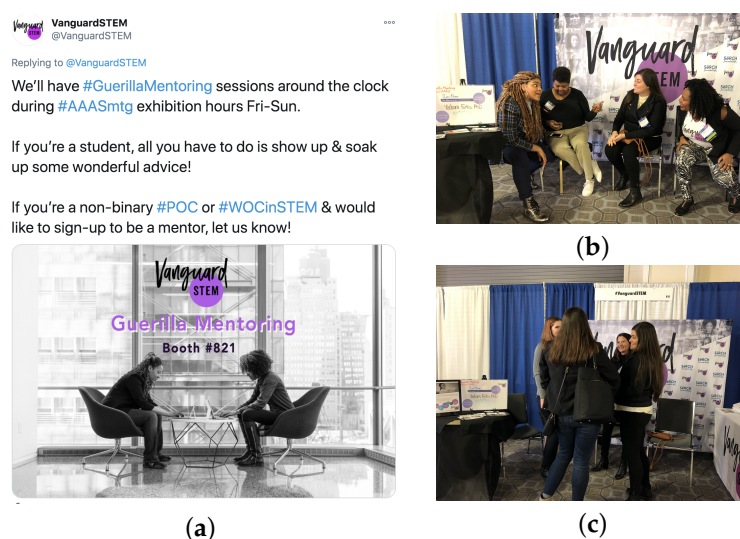


Figure 4. Core to the Conference Crashing initiative is Guerilla Mentoring, where we call upon our community of established women and non-binary people of color in STEM to mentor in-situ and in real-time emerging scholars in the central exhibit hall of a STEM conference. On the left (a) we show the call on social media to solicit mentors during the conference and on the right are two examples of (b) the sessions of Guerilla Mentoring that resulted from it. These opportunities to connect in STEM professional settings often lead to an immediate sense of belonging, camaraderie and joy (c).

4.3. Say Our Names: Recognition and Imagination

We use recognition as a tool to increase STEM identity and aid our community in imagining themselves as part of the STEM community of practice. Following the popular social media hashtag, #WCW (Woman Crush Wednesday), where every Wednesday anyone could publicly celebrate women in a variety of contexts, #VanguardSTEM launched #WCWinSTEM in 2016 to expand that trend to highlight women of color across various STEM fields and reinforce their STEM identities and their representation as STEM people. In keeping with our intersectional STEM framework, our goal was to highlight each person's STEM identity, while honoring their cultural identity.

#WCWinSTEM sparked a whole movement in the STEM community and diaspora as a model for featuring people of color in STEM. There are a few key points that set the #VanguardSTEM #WCWinSTEM series apart. First, the features are crowdsourced and based on nominations from the STEM community. This allowed for the identification of meaningful others within and beyond STEM contexts to recognize our community members as STEM people. Second, these features focus attention on a single person for an entire day. This is conceptually distinct from a one-time feature of an individual or a "roll-call" of several people at the same time, in that it allows us to move from only representation to demonstrating competence in and performance of their individual STEM identities.

Third, we developed medium-length original articles about each person we featured. For many of the individuals featured through our #WCWinSTEM, #GOCinSTEM and #QCWinSTEM campaigns, #VanguardSTEM feature articles are the only digital record of their STEM expertise, contribution to science, and their STEM journey. This has far-reaching effects for expanding and redefining what a scientist looks like or does. #VanguardSTEM works directly with our community to write their stories into existence. Fourth, we often used the feature series to invite those featured into the #VanguardSTEM hyperspace. This meant that not only were they getting a strong boost to their STEM identities on any given Wednesday, they were also being invited into a persistent community with others who might share various facets of their identity. Lastly, we did not focus our feature series on people who already had great prominence. We purposely avoided centering the "first and only" narrative of achievement from our features to combat the notion that one must somehow be better than a "regular" Black, Indigenous, woman/girl of color or non-binary

person to be successful. We intentionally highlight those who are early career and emerging in their fields of expertise. Through this broad distribution of who is worthy of recognition, we slowly shift the narrative of who gets to be a STEM person.

4.3.1. Woman Crush Wednesday in STEM (#WCWinSTEM)

We developed a conversation-style editorial article about each person featured by having them answer questions about their training, inspirations and STEM journey. As experts in our respective fields, we knew how to help them tell their STEM stories while maintaining their identities. Since our team is composed of Black women in STEM, we are uniquely capable of making space for all parts of a person's identity, while also curating the technical content of the feature content. This internal process was its own manifestation of imagination, because it often connected an emerging women, girls and non-binary people of color in STEM to someone further along their STEM journey. Through the #WCWinSTEM features, we built a process that mentored the candidates about how to describe their STEM identity and scientific expertise in ways that felt true to them.

We also wanted to highlight their wisdom, creativity, resilience and autonomy in devising the way they wanted to be perceived as STEM people^{28,29,30} (see Figure 5). This counterstorytelling again affirmed the ways women, girls and non-binary people of color redefine what it means to embody scientific and cultural expertise. Our featured scientists gave insightful advice like "there is no such thing as a science or engineering type" from Dr. Jayshree Seth, or from Dr. Alicia Cheek who said to "Never take for granted the way your story may resonate with others around you." This created yet another opportunity for our features to mentor others who may have experiences similar to their own.

Another theme from the series was that each person featured had mentors from both scientific and non-scientific contexts. This confirmed our initial understanding of STEM identity development that meaningful others could be inside and outside of STEM culture. In particular, we find that the combination of scientific and cultural meaningful others helped contribute to their conception of themselves as capable and worthy. Our #WCWinSTEM campaigns normalize exposure, taking that experience from a rarity to a common weekly learning experiences. They also serve as motivation for our community to keep pursuing their STEM interests. Many people have reached out to us, to express their appreciation for the regular distribution of profiles featuring people to whom they can relate.

As with all #VanguardSTEM programming, our #WCWinSTEM feature series is always evolving in response to the needs of our community. While we began with features that focused on women of color in STEM, we realized that the experiences and STEM identities of girls of color and non-binary people of color in STEM were also missing from the standard avenues for recognition.

²⁸ Lydia Jennings; <https://conversations.vanguardstem.com/wcwinstem-lydia-jennings-b-s-86e086631592>.

²⁹ Joy Johnson; <https://conversations.vanguardstem.com/wcwinstem-joy-johnson-ph-d-d7277d74da90>.

³⁰ Natalia Ramírez; <https://conversations.vanguardstem.com/wcwinstem-natalia-ram%C3%ADrez-vega-74e05d0571fb>.

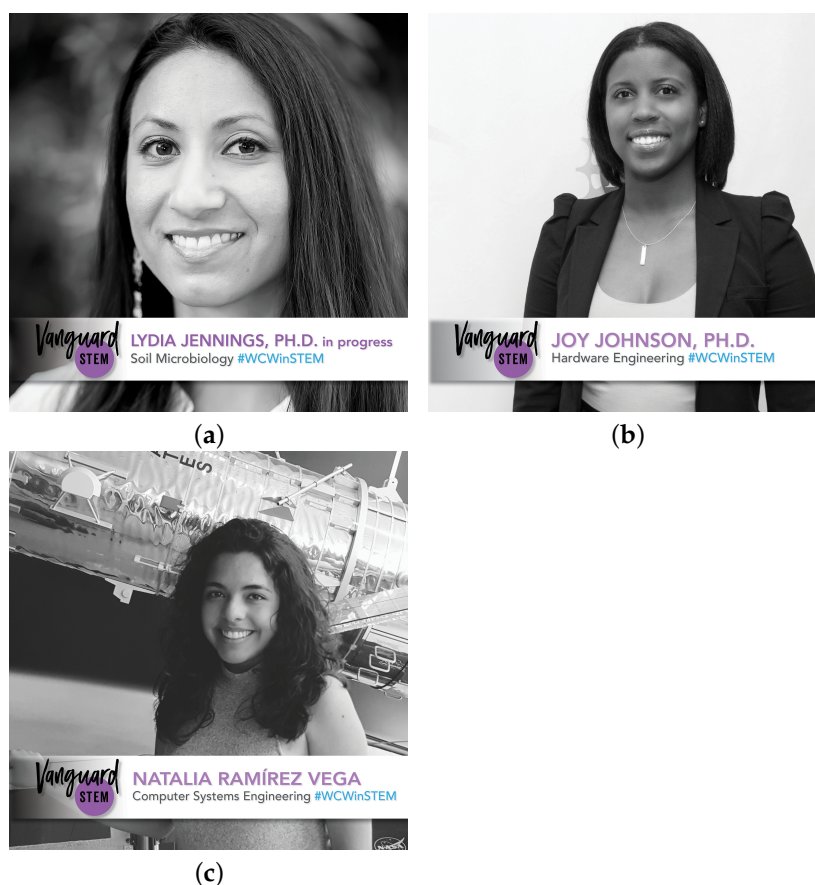


Figure 5. Above are three women of color in STEM (now-Dr. Lydia Jennings (a), Dr. Joy Johnson (b) and Natalia Ramírez Vega (c)), of the more than 100 “Woman-crush Wednesday in STEM” (#WCWinSTEM) features written and published by #VanguardSTEM over the last four years. These medium-length, science-driven features of women of color in STEM are often their first publicly available, in-depth articles about their STEM interests and identities.

4.3.2. Queer Crush Wednesday in STEM (#QCWinSTEM)

As a community built on the foundation of an iSTEM framework, #VanguardSTEM is uniquely positioned to facilitate meaningful conversations about the intersection of race/ethnicity and gender/sexual identity. Ward (2008) found that LGBTQIA+ organizations are perceived as centering Whiteness by prioritizing the interests of the White LGBTQIA+ community. Similarly, #VanguardSTEM observed that White students and professionals are often overrepresented in existing interventions serving the LGBTQIA+ community in STEM. This directly influenced our decision to create campaigns to highlight the lived experiences of queer women of color and non-binary people of color in STEM. Our goal was to address the lack of representation of Queer women of color and non-binary people of color in existing LGBTQIA+ STEM initiatives. In so doing, we were also able to address the deficit of LGBTQIA+ representation in #VanguardSTEM online content. We view this improvement to our content to be an example of the cultural humility that is necessary for the construction of a new STEM culture. Our hyperspace is constantly revealing what is, what it needs to be and what is yet to come.

In order to differentiate the #VanguardSTEM QCWinSTEM campaign from our #WCWinSTEM content, we developed supplemental interview questions, adapted our intake process and amended the visual language to hold space for those existing outside of heteronormative ideals and/or gender binaries while working in STEM. Nominees are always given the option to self identify as LGBTQIA+ women of color or gender non-conforming people of color, indicate their pronouns and opt into being featured as a QCWinSTEM instead of WCWinSTEM. Because “coming out” is a continual process

unique to each individual, all questions regarding gender and sexual identity are optional to allow nominees the ability to answer or abstain based on their own agency. We aimed to develop relationship with queer people of color, while also providing resources, visibility and recognition (see Figure 6³¹).

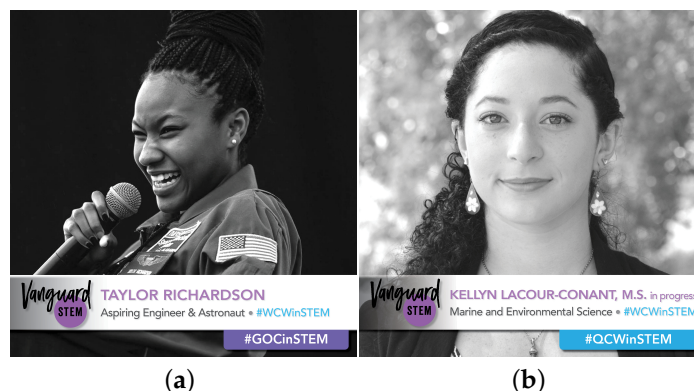


Figure 6. We continue to evolve and expand our programming to meet the needs and interests of our community. Using the framework we built for #WCWinSTEM, we developed and deployed a feature series for girls of color in STEM (GoCinSTEM; (a)) like Taylor Richardson, and queer and non-binary people of color in STEM (b) like, Kellyn Lacour Conant. These features allow us to continuously write our stories into existence without having to sacrifice who we are in the process.

4.3.3. Girls of Color in STEM (#GOCinSTEM)

Girls of color in STEM often build virtual followings to encourage other girls of color to share their STEM interests and affirm their STEM identities. Many girls of color become discouraged by the lack of representation of STEM lovers at their age, despite their clearly demonstration of interest in STEM. Thus they sought to create such opportunities within their peer communities. Indeed, #VanguardSTEM came into contact with many of the girls of color in STEM featured through their social media engagement.

As a result, in 2018 we expanded our content to include features of girls of color in STEM. These features followed the WCWinSTEM protocols, but with careful attention paid to protect their scientific and cultural identities as young, emerging scientists. We often worked closely with their parents or caregivers to craft thoughtful pieces which showcased their efforts and dedication to STEM. For example, we featured Taylor Richardson in 2017 (see Figure 6a)³², who regularly uses fundraising to bring awareness to issues related to STEM equity and social activism. Taylor is an incredible example of what it looks like to take up space in STEM.

With bright futures ahead for these emerging scientists, we endeavor to support them, their parents or caregivers, and their peers by presenting thoughtful, aspirational articles about their situated knowledges, STEM identities and interests. We have found this to be an impactful way to welcome girls of color into the #VanguardSTEM hyperspace and establish or support their presence in the broader STEM culture.

5. Discussion

We now discuss insights from our programming and our assessment of how that programming engages with and expands on the literature. We also introduce two concepts that represent the fluid edge of our thinking on STEM identity development: the #VanguardSTEM hyperspace (see Section 5.2) and an intersectional scientific methodology (see Section 5.3), which has emerged from our praxis (see Section 3).

³¹ Kellyn Lacour Conant; <https://conversations.vanguardstem.com/https-conversations-vanguardstem-com-qcwinstem-kellyn-lacour-conant-adaa42f9ec2c>.

³² Taylor Richardson; <https://conversations.vanguardstem.com/wcwinstem-taylor-richardson-3ae535977d3>.

5.1. Building STEM Identity in the #VanguardSTEM Community

By virtue of the #VanguardSTEM origin story (Appendix A), our community began with a focus on college-aged women of color in STEM. By consistently presenting original and curated programming, we built a community from which women of color in STEM could advocate for themselves and their STEM interests, without suppressing the full measure of their cultural and technical identities. Through engaging with our community we found that there was not sufficient STEM-related programming that simultaneously highlighted the cultural and scientific identities of girls of color and LGBTQIA+ people of color in STEM. Yet many girls of color were regularly interacting in our content, showing early interest in STEM and already forming their STEM identities (O'Brien et al. 2015). Relatedly, to our knowledge there was (and is) no LGBTQIA+ STEM organization with significant representation of people of color in STEM, which meant that Queer women of color and non-binary people of color in STEM still had to parse their identity to get the support they needed, if they received it at all. (Cech and Pham 2017; Ward 2008).

Based on these findings, we extended our programming to include profiles of queer and non-binary people of color, and girls of color in STEM through our #GOCinSTEM (2016, see Section 4.3.3) and #QCWinSTEM (2018, see Section 4.3.2) feature campaigns. We also invited girls of color and non-binary people of color to submit original pieces for publication by #VanguardSTEM, as well as curating content specifically focused on these communities (see Figure 6). While the particular concerns of these communities vary, the overarching sense of belonging to a welcoming and dynamic community provides fertile ground for building relationship, community and STEM identity. #VanguardSTEM is constantly asking and assessing how we can serve our community more effectively. By paying close attention to the STEM cultural landscape and our community's response to it, we continue to dynamically improve and expand our offerings.

Next we explore our engagement with STEM identity development as described by Carlone and Johnson (2007), who suggested that performance, competence and recognition as a "STEM person" by self and meaningful others was core to STEM identity development. They focused on recognition in STEM identity formation and suggested that women of color with strong STEM identities, were those who recognized themselves and were perceived by meaningful others as STEM people.

We use social media to build recognition and STEM identity, which allowed us to capitalize on and construct spaces of belonging and identity through social media platforms and their attendant algorithms to bring our content to our audiences. We came to realize that #VanguardSTEM uses the main currency of social media—influence—differently. We are interested in using influence to build STEM identity instead of using identity to build influence. We also found that to build a persistent STEM identity, we must not only use recognition to amplify the voices and experiences of girls, women of color and non-binary people of color in STEM, but we must also hold space for them to perform skills aligned with their STEM identity and show competence with those skills. Although we are using recognition to build STEM identity, we are not building "STEM influencers" per se; we are interested in the intersection of cultural identity and STEM identity. Science influencers play an important role in spreading information and excitement about science, but given our mission to build STEM identity and create a space where we can be our full selves, it is not our main goal. Furthermore, influencers can inadvertently propagate the false notion that one must be exceptional to pursue STEM interests. In contrast, #VanguardSTEM affirms that anyone with interest in STEM disciplines can build their skills and participate in science. One does not have to be the first, the only, the best, the fastest or the smartest to develop their STEM identity and/or be recognized as a STEM person. From these insights we infer that the three tenets of STEM identity, recognition, performance and competence must all be present to help develop a STEM identity, at least in the social media landscape. The latter two can work in concert with recognition, but recognition in the absence of performance and competence may not be effective in building long-term STEM identity. We will continue to explore this concept in our ongoing work.

We endeavor to extend the notion of STEM identity to account for the fact that a successful woman, girl or non-binary person of color in STEM does not have to choose between assimilation into or departure from STEM culture to be a STEM person. In this context, we draw attention to the interactionist perspective between forming a STEM identity (one's internal assessment of self) and being perceived as a STEM person (external assessment of other based on social constructs). Women, girls and non-binary people of color are often overlooked both in assessments of what a scientist "looks like" and who is centered in STEM narratives. Both of these oversights speaks to the perception of who holds scientific expertise. These oversights erase the rich technical insights provided by girls, women and non-binary people of color in STEM. Furthermore, the public (STEM-interested, non-expert) is denied opportunities to interact with a wide variety of STEM role models.

We took great insight from the cultural production that women of color with altruistic science identities demonstrate to redefine what it means to be in STEM, but we wanted to extend our interventions to account for the complex social web of which our communities are a part. We did not want them to have to choose between meaningful others inside or outside of STEM cultures or to have to situate themselves as inside or outside the cultural and technical communities they desired to engage with (TallBear 2014). We wanted to center girls, women and non-binary people of color in STEM culture with a sense of rightful presence Barton and Tan (2019) and culturally sustainable pedagogy (Ladson-Billings 2014). Rightful presence restructures power dynamics of who gets to legitimize or be legitimized in a given culture. We want to affirm the legitimate membership of our communities in the STEM context while also acknowledging and valuing the knowledge and experiences they bring to STEM culture. This framing also aligns closely with culturally sustainable community-in-practice, where #VanguardSTEM community members are dynamically forming their STEM identity using their own situated knowledges while simultaneously building proficiency in traditional tools and mores of the current STEM culture.

Our approach to cultural production does not end with the content we produce and share across social media platforms. The power of our interventions comes from an understanding of the algorithmic current that directs the flow of content to social media users. That is to say, in a realm where influence is defined by the number of likes, shares, and comments, our primary aim is not to influence all social media users, but to direct the algorithmic flow of content, and hence influence the social media environment, that each individual experiences. #VanguardSTEM interventions garner consistent interaction from unique users and consistent interaction with any form of content increases the likelihood that social media algorithms will present a user that same or similar content (Twitter 2020; Sprout Social 2020). Thus, while our long-term interest is to establish a more diverse depiction of what a scientist "looks like" on a large scale, we know that for an individual user, habitual interaction with #VanguardSTEM will increase the amount of content featuring women, girls and non-binary people of color in STEM that user is presented. Frequent engagement with #VanguardSTEM and persistent participation in our community alters an individual's algorithm to favor content that affirms their STEM identity. In a domain where racially-biased algorithms give preference to Whiteness³³, we seek to disrupt this flow of content and redirect our audience toward posts that are a stronger reflection of their lived experiences, their STEM identities and dynamically construct a virtual STEM space for them to thrive.

³³ <https://twitter.com/bascule/status/1307440596668182528?s=20>.

5.2. From Counterspace to #VanguardSTEM Hyperspace

#VanguardSTEM began with the intention to create a counterspace to cultivate STEM identity in women, girls and non-binary people of color in STEM. We now propose four tenets of the #VanguardSTEM iSTEM framework that provide an expansion on the literature (for example, [Ong et al. 2018](#); [Solorzano et al. 2000](#)). The iSTEM framework is a counterspace that is also: (i) virtual, (ii) persistent, (iii) multigenerational, and (iv) structurally focused.

By deploying iSTEM in the virtual space, we are able to dynamically use cultural production to construct a STEM culture we want to participate in while being our full selves. We intentionally use social media to create a central counterspace that is constructed in the public realm. This cultural production amplifies our own stories, alters the type of STEM-related content that our community receives and is instructive to others about how we want them to treat us.

Secondly, we maintain a persistent focus on STEM identity in the virtual space. By making iSTEM a persistent part of one's experience, we create the sense of longevity and reinforce the persistence in STEM identity development. This is different than, but complimentary to STEM diversity conferences which produce an incredibly strong sense of community and belonging, but typically only last a few days or a week. We designed the Conference Crashing campaign (Section 4.2.2) to thread these two experiences together for the women, girls and non-binary people of color in STEM who attend these conferences. In a word, #VanguardSTEM community members never have to leave this iSTEM space, which affirms their STEM identity and expertise. To our knowledge, by creating a persistent, virtual community of practice, we deployed a distinctly new type of counterspace for women, girls and non-binary people of color in STEM, which had not been theorized in the literature before we built it. We note, with deep reverence and respect, that Dr. Stephani Page created the #BlackandSTEM hashtag, around which Black STEM professionals rallied to form a virtual community for Black and STEM folks earlier in 2015. We view the contemporaneous construction of #BlackandSTEM^{34,35}, #VanguardSTEM and a handful of other digital communities to be the critical evolutionary branch of public counterspaces in a digital age ([Montgomery 2018](#)).

#VanguardSTEM fosters a multi-generational community approach by encouraging ongoing conversations between emerging and established women of color in STEM. This direct, real-time engagement allows our community to simultaneously and dynamically build peer-to-peer relationships and mentoring relationships. It also reinforces our commitment to and centering of the situated knowledges that are brought to bear by those more recently joining the STEM community and those who have been part of navigating, redefining and improving STEM culture for many years and through many channels of engagement, both public and private.

Lastly, we also extended the utility of counterspaces in a structural way. While counterspaces often help women, girls and non-binary people of color contextualize their experience and identify that they are not alone in their struggle, they do not, in and of themselves, create a new way of being and/or support the construction of a new STEM culture in which these communities are leading and valued members who are worthy of recognition. Counterspaces do not offer structural interventions on STEM cultures, but instead (and very importantly) create space for students to "catch their breath" in the midst of ongoing structural failures.

In describing the ways #VanguardSTEM is descended from and extrapolating on counterspaces, we draw on the speculative fiction concept of hyperspace, where a higher dimensional region of spacetime co-exists with the current Universe and can be accessed by some manipulation of the known world ([Westfahl 2005](#)). We define our #VanguardSTEM hyperspace to be a fluid construction of "place-time" that is born digital and enabled by social media culture, but materializes in the physical world for specific purposes, for

³⁴ <https://www.fastcompany.com/3027122/blackandstem-the-hashtag-as-community>.

³⁵ <https://blogs.scientificamerican.com/urban-scientist/you-should-know-stephani-page-and-blackandstem/>.

example, to catalyze the construction of STEM identity and reinforce the rightful presence of women, girls and non-binary people of color in STEM. #VanguardSTEM can be thought of as existing not just in opposition to, but outside of what is currently STEM culture. A high-dimensional space to be entered into or exited at any time by accessing one's STEM identity and scientific expertise. Thus, by engaging women, girls and non-binary people of color in STEM as subject-matter experts and (counter) storytellers, #VanguardSTEM deploys our situated knowledges to create a hyperspace.

Our priority is not to simply to find ways to belong in the current STEM culture, where our STEM identities are often marginalized and damaged. We are creating place-time within which our rightful presence and STEM identity is acknowledged and respected. This is why we consider #VanguardSTEM more than a counterspace. The content we create actively counters established STEM cultural norms and stereotypes about women, girls and non-binary people of color in STEM through cultural production and STEM identity development. We are building from the future a virtual space that meets our needs of our present. The #VanguardSTEM hyperspace allows for transport away from the strictures of discrimination and into a generative space of being exactly the kind of STEM person one wishes. This hyperspace is always available to, but independent of, the spaces we wish to counter and outside of the structural oppressions, which act like external forces (but not natural laws) on our community. In this hyperspace, instead of constantly responding to or countering the negative aspects of STEM culture as it is, we are actively creating new ways of defining oneself as a STEM person and directing the social media algorithmic flow in support of that goal.

Perhaps the last point to make about the #VanguardSTEM hyperspace that we created is directed at those who do not identify as women, girls and/or non-binary people of color in STEM. #VanguardSTEM is rooted in a Queer, Black Feminist epistemology, so our praxis and this manuscript are situated in that way. However, we know that to truly create a new STEM culture, we need the broader STEM community to drastically alter their behavior. Thus, we make our content publicly available so that anyone who wants to learn about the experiences of women, girls and non-binary people of color in STEM, and how to avoid negatively impacting our own cultivation of our STEM identities can also find resources. Many of the programs we have laid out also have some component designed to normalize the ways that our communities show up in the world based on their situated knowledges and scientific expertise and demonstrate how we want to be treated. As others engage with #VanguardSTEM content, what they will find is that we are not unique because we identify with and utilize an intersectional scientific methodology, any scientific investigator does. What is unique is that we, and other traditionally marginalized communities, must develop proficiency in so many other skillsets and ways of knowing in order to successfully navigate the current STEM culture. We are not to be pitied or condescended to; we are innovators who are ushering in new and better ways to approach and conduct scientific inquiry and our work has been featured in a number of contexts including [National Academies of Sciences et al. \(2019\)](#) and [Montgomery \(2018\)](#).

5.3. *Towards an Intersectional Scientific Methodology*

#VanguardSTEM is the manifestation of the dreams, hopes, aspirations, brilliance and vision of a group of Black women in STEM and co-constructed by women of color and non-binary people of color in STEM every time we engage the iSTEM framework in our hyperspace. Because #VanguardSTEM is composed of women of color in STEM, we bring our scientific skills, expertise and sensibilities to bear on our framing of the problems in STEM culture. We take ownership of our stories and offer a platform for women, girls and non-binary people of color in STEM to do the same.

As Black women scientists, we applied an experimental approach to our programming. We critique the systems that underwrite STEM because we are each personally invested in creating STEM cultures where we can thrive. This construction of our process, protocol and product are all informed by our experiences and our scientific expertise. Our hypothesis

driven approach to engaging our audience is founded upon our situated knowledges and an understanding that it endeavors to liberate. As described by Kim TallBear, our “hypotheses, research questions, methods, and valued outputs, including historical accounts, sociological analyses, and textual interpretations must begin from the lives, experiences, and interpretations of marginalized subjects” (TallBear 2014). Indeed, this situated knowledge opens up a hyperspace of possibilities for girls, women and non-binary people of color to be themselves in STEM.

The conclusions we have drawn would not be possible except in an experimental setup where we as individual scientists come together to collectively build towards full self-expression in both our cultural and technical identities. This can be seen in our strategic use of a #VanguardSTEM persona instead of the lauding of a particular individual or personality on the #VanguardSTEM team. We each see ourselves as critically a part of, but distinct from, the thing we are building. Thus, we believe that not only have the above insights allowed us to better understand and theorize the hyperspace we are creating and its intended impact on women, girls and non-binary people of color in STEM, but that we can incorporate this approach to into our conception of the science we do.

To that end, we introduce the intersectional science methodology (ISM), which extends our initial conception of intersectional STEM framework beyond the construction of STEM identity to include the process by which one constructs the science itself. While the classical scientific method (for example, Abbot 1885) suggests that “all established truths” fit within 3 steps: observation and experiment; hypothesis; and verification by new experiment, the ISM attempts to make clear (see Figure 7) the influence of standpoint, situated knowledges and scientific expertise through embodied observation, embedded context and collective impact of how one approaches their science. We describe each briefly, in turn, below.

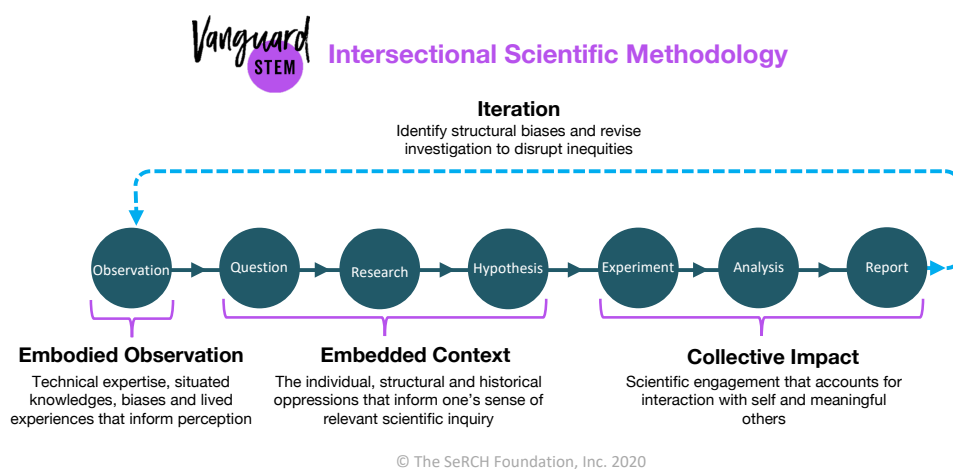


Figure 7. The #VanguardSTEM Intersectional Scientific Methodology. From left, circles represent the canonical scientific method. The purple brackets denote the ways that one’s cultural identities and experiences inform how they approach scientific inquiry as theorized in the present work. The cyan arrow represents the iterative nature of scientific experimentation and identifies an additional opportunity remove inequities in the process itself. As presented here, the influence of one’s identity and experience cannot be extricated from their scientific output and therefore presents an opportunity to improve scientific outcomes by being aware of the influence of embodied observation, embedded context and collective impact.

The first step in the intersectional scientific methodology is embodied observation, which we take to mean approaching the scientific method in a way that accounts for situated knowledges and scientific expertise; that is, that an individual’s perspective and experiences are a critical and unavoidable facet of observation. In other words, we all observe from somewhere; there is no such thing as an objective, uninfluenced perspective in a scientific context. By normalizing situated knowledges, #VanguardSTEM aims to regard lived experience as equally important as technical expertise; the intersectional scientific

method does not require one to leave their identity at the door of their STEM laboratory. In contrast, the intersectional scientific method requires one to acknowledge their perspective and biases as vital to authentic scientific inquiry.

Secondly, the ISM accounts for embedded context in the development and formulation of research questions. Embedded context acknowledges that what we perceive as worthy of scientific inquiry is not birthed in a vacuum. Anyone who is a scientist also has an identity that influences how they practice their science and what they deem worthy of inquiry. In the process of training in STEM fields we learn to ask questions for which we can find an answer. Through the ISM, we posit that identity informs which questions we consider to be valuable enough to invest in, while social and historical context (e.g., structural oppressions, marginalizations and inequities that are active in STEM cultures and broader society) determine how or if we are able to investigate these queries. While only recently entering the broader STEM discourse, these historical determinants are well-documented and deeply impact an individual's sense of rightful presence. Embedded contexts also address structural concerns relating to allocations of research funding and resources, financial solvency and resource availability at institutions of higher education, non-consensual participation in the medical research and education, not to mention the effects of the historical underrepresentation of women, girls and non-binary people of color in STEM (for example, [Shetterly 2016](#); [Skloot 2017](#); [Wilder 2014](#)).

Third, collective impact intentionally uses tools of scientific inquiry, specifically experimental construction, design and data analysis for generative, restorative and creative purposes that benefit one's perceived community; in contrast to science for science's sake. Women of color and marginalized people are more likely to enter STEM disciplines in order to use those skills to provide solutions to structural shortcomings that can only be solved using STEM tools ([Hoppe et al. 2019](#)). Thus, the construction of the experiment, data analysis and mechanisms and scope of reporting are informed by the impact on the individual and the communities (i.e., meaningful others) that they seek to serve. It should be noted that women, girls or non-binary people of color pursue STEM pathways for a variety of reasons that may or may not include the correction of social and technical injustices. However, our aim here is to assert that every person participating in STEM culture takes on an experimental design, analysis schema and reporting protocol that has an impact on others. Such collective impact need not be accidental, and in the case of many women, girls and non-binary people of color is often the foundational goal.

Lastly, the intersectional scientific method necessitates dynamic and iterative assessment of our results. Through each step of the process, one should critically evaluate any concurrent structural biases and revise the process of scientific investigation to disrupt such inequity. This is why #VanguardSTEM and its interventions are constantly evolving; we are applying the intersectional scientific method to create and maintain a hyperspace for our community which informs our observations, hypothesis, methods and results. As we deploy what we have come to understand are our experiments, we are constantly being informed by our situated knowledges and the shared experiences of our community which influences both our approach and the final result—what the #VanguardSTEM hyperspace looks like and the many ways to enter, exist in and evolve it. In short, #VanguardSTEM is core to our scientific inquiry.

6. Summary

Black, Indigenous, women of color, and non-binary people of color are underrepresented in STEM with respect to their fraction of the U.S. population. This is generally attributed to some deficit in individual students or demographic groups, like lack of technical ability or interest, despite significant data to the contrary. Critical race theory, cultural studies and Black, Indigenous and Latine feminist theories have long ago identified the structural oppression that impact women of color in society. Those same oppressions, power dynamics and discriminations are at play in STEM culture.

We therefore hypothesized that BIWOC were leaving STEM because their STEM identity was being disrupted due to structural oppression based on their racialized and gendered identities. Thus, we developed the iSTEM praxis and created a #VanguardSTEM hyperspace where women, girls and non-binary people of color could gather without leaving any part of themselves at the door, while redefining our notions of what it means to be a woman, girl and/or non-binary person of color in STEM. We encourage our community to redefine what it means to be a STEM person who is worthy of recognition, whom they considered to be meaningful others and what the STEM culture should look like. By consistently presenting original and curated resources that espoused these values, we built a community that could and would advocate for ourselves and our STEM interests.

Beyond our intersectional STEM identity framework, we realized that our positions as Black women in STEM and part of the #VanguardSTEM team uniquely positioned us to think about how our situated knowledges and scientific expertise helped us to construct #VanguardSTEM. We realized that while we employed a scientific approach in our theorizing about and developing programming using cultural production (our intersectional STEM framework), we had developed our own sense of the scientific process that intertwines our cultural identities and technical expertise (the intersectional scientific methodology). Thus, #VanguardSTEM is part of our science and our orientation towards the world. We now posit that our intersectional scientific methodology is a model for how anyone can and should approach the process of scientific inquiry.

The purpose of this special issue is to “tell the stories that will save us, heal us, and extend our lifelines.” #VanguardSTEM endeavors to do this healing work from inside of (and beyond) the current STEM context. We have built a virtual community of Black, Indigenous, women of color and non-binary people of color in STEM who are redefining what it means to be a scientist and do STEM. Our intersectional scientific methodology exists in and was created from the #VanguardSTEM hyperspace, specifically to provide respite, healing—and perhaps most crucially—a generative space that is not solely a response to an often oppressive STEM environment. In sharing the origin story of the #VanguardSTEM hyperspace, we hope to model an example of what healing in existing STEM contexts can look like and what dreaming beyond it can create. Furthermore, in continuing to share #VanguardSTEM, we hope to continue catalyzing STEM identity development in BIWOC and non-binary people of color in a hyperspace that reflects our full selves and the place-time we inhabit. We proudly draw on the speculative fiction concept of hyperspace. Every time we co-create and engage with STEM content we create another universe of possible futures. Our hope is that new, different and liberatory STEM interventions can continue to evolve from the freedom-seeking lineage from which we ourselves drew inspiration.

At its core, #VanguardSTEM is a timeless love letter from the Black women in STEM who created it to all Black, Indigenous, women of color, girls of color and non-binary people of color in STEM. It is a hyperspace we navigate into, around and out of, to reaffirm our rightful presence in STEM culture. Through #VanguardSTEM, we are dynamically creating ways to say that we are here; we love STEM and we love ourselves. We are not sorry that we are the people we are, living in the bodies we inhabit. We are not willing to sacrifice who we are to study what we love. We do not agree to remain in STEM spaces that do not acknowledge our humanity and we have the agency, insight and creativity to build the STEM cultures we want. We will build a future we belong in by creating it everyday.

Author Contributions: All authors contributed to the construction and completion of this paper. J.C.I. conceived of #VanguardSTEM in 2015. Since then, the conceptualization, methodology and data curation that is presented here has been collaboratively developed by (alphabetically): N.V.B., L.J.C., A.H., J.C.I., D.N.L. and C.L.V. All team members contributed to writing—original draft. Isler provided project administration; Isler and Harriot provided writing—review and editing, and formal analysis. A.H., N.V.B. and C.L.V. constructed the visualizations and images that appear in this draft. We encourage the reader to review the #VanguardSTEM genealogy to see a more narrative accounting

of how we built #VanguardSTEM, but in the end, we built it together from our collective magic. You're welcome. All authors have read and agreed to the published version of the manuscript.

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Abbreviations

The following abbreviations and hashtags are used in this manuscript:

STEM	science, technology, engineering and mathematics
BIWOC	Black and Indigenous Women of Color
POCinSTEM	People of Color in STEM
GOC	Girls of Color
LGBTQIA+	lesbian, gay, bisexual, transgender, queer or questioning, intersex and asexual
ISM	Intersectional Scientific Methodology
iSTEM	intersectional science, technology, engineering, and mathematics
#WCW	woman crush Wednesday
#WCWinSTEM	Woman Crush Wednesday in STEM
#QCWinSTEM	Queer Crush Wednesday in STEM
#RevealToHeal	Reveal to Heal; mental health campaign
#BBBinSTEM	Burnout, Bravery, and Being a Woman of Color in STEM
#ConferenceCrashing	programming toward establishing #VanguardSTEM hyperspace at professional conferences
#GuerillaMentoring	#VanguardSTEM triage mentorship campaign

Appendix A. #VanguardSTEM Genealogy

Given the subject of this special issue, we thought it was important to include a brief summary of the #VanguardSTEM origin story and evolution. We worked collaboratively as a team to build the interventions described here, but we also wanted to shine a little light on each member of the team.

#VanguardSTEM was founded by Dr. Jedidah Isler (@jedidahislerphd; astrophysics; she/her) in 2015 at Syracuse University, to digitally connect emerging and established women of color in STEM in real-time. This idea came to Dr. Isler in response to request from a group of women of color in STEM who were then students led by Jasmine Y. Johnson, to “mentor while being mentored.” Later in 2015 when Dr. Isler moved to Vanderbilt University, she expanded the programming, made it publicly available and founded a non-profit, The STEM en Route to Change Foundation, Inc. to formalize the program. She has been honored to steward this organization up to this point as President and Chairperson of the Board. Dr. Danielle N. Lee (@DNLee5; evolutionary biology; she/her), a prominent mammalogist and science communicator was a founding Board member for this organization and has offered unwavering support for the organization ever since. From coining our conference mentoring program as “Guerilla Mentoring” to signal boosting, event planning, organizational guidance on the Board and providing hearty laughs along the journey, Dr. Lee is the best hype-woman an organization could ask for.

In 2016, Natasha Berryman, M.A. (@NvBerryman; neuroscience; she/they) joined the #VanguardSTEM team as a project manager, bringing with her the wealth of talent she’d cultivated while working as a content strategist and technical program/project manager in the years preceding her graduate studies. Berryman held many positions while on the #VanguardSTEM team, contributing technically through the development of various visual and written assets, as well as conceptually by partnering with Dr. Isler to develop organizational strategy and protocols, and to contribute (and help materialize) thought leadership. In all, her contributions include content strategy, development and management; team management and professional development; graphic design; fundraising and grant management; research design and data management; serving as a producer and occasional co-host of the show; and more. Much of the visual language and written voice that #VanguardSTEM is known for was developed by Berryman. As just one of many examples, the graphic design of the show fliers and thumbnails constituting the first six seasons of the show were her expert designs. She also wrote two of the most popular articles on the platform—the first within the #BBBinSTEM (Bravery, Being and Burnout in STEM) series titled, “STEM+Society: An Op-Ed on Race Relations and STEM;” the second as part of the #VSGradTax series titled, “Tax Reformed Out of the Graduate School Equation.”

We also welcomed Dr. Léolène J. Carrington (@leolenejean; immunology; she/her) and Chrystelle Vilfranc (@GiveHerthePhD24; cancer and cell biology; she/her) that same year. Chrystelle’s science communications creativity birthed two #VanguardSTEM initiatives: #RevealtoHeal and #WCWinSTEM. Inspired by the popular social media trend highlighting admirable women as one’s “Woman crush Wednesday” or #WCW, Vilfranc proposed a campaign in which #VanguardSTEM featured a woman of color in STEM every Wednesday on our social media platforms as our “crush,” utilizing the hashtag #WCWinSTEM. Then when rapper Jay-Z, released the 4:44 album (2017), Vilfranc, who is also a Brooklyn native, deeply connected with the song: “Kill Jay Z” and a certain set of lyrics, “Cry... we know the pain is real, but you can’t heal what you never reveal.” Those lyrics inspired the written series we now refer to as #RevealToHeal: a mental health series for #WOCinSTEM. Chrystelle’s creative vision will continue to help guide the evolution of science communication.

Léolène, an active member of the #VanguardSTEM online community, expressed interest in joining the #VanguardSTEM team citing a desire to broaden the impact and reach of #VanguardSTEM as an ambassador at the University of Michigan where she was then a postdoctoral researcher. Carrington also skillfully helmed our #WCWinSTEM campaigns, which had become #VanguardSTEM’s primary and most consistent intervention.

Carrington continued the work that Vilfranc created with the weekly conversation-style features that required direct engagement with featured women and non-binary scientists of color via email and social media nominations. Carrington oversaw the nomination process and communicated with the nominees to build the articles. Her signature grace and style brought additional insight to each feature.

The year 2017 brought Anicca Harriot (@13adh13; biochemistry and molecular biology; she/her) to the #VanguardSTEM team. Anicca first engaged with #VanguardSTEM as an undergraduate student searching for community and camaraderie. Notably, when Harriot authored a viral tweet calculating the angle of her dab, a popular dance move, she felt that #VanguardSTEM was the only outlet to cover the story while creating space to acknowledge her identity as a Black woman in STEM. Harriot had demonstrated significant social media prowess as a social media intern at NASA Langley Research Center and expressed interest in transitioning to a social media management position on the #VanguardSTEM team upon the completion of her undergraduate studies. She quickly found her footing as the #VanguardSTEM Social Media Coordinator and LGBTQIA+ Engagement Specialist in July 2017, assisting in developing language and graphics central to the roll out of the #RevealToHeal campaign. Drawing attention to this deficit also emphasized the need for a new campaign to highlight the experiences of those in the #VanguardSTEM community who do not conform to gender binaries. #QueerCrushWednesday (QCW), which our team launched in June 2018, was the first #VanguardSTEM campaign with the explicit goal of engaging gender non-conforming POCinSTEM and LGBTQIA+ WoCinSTEM.

This special team brought you the #VanguardSTEM presented here and we cannot wait to see what the future holds.

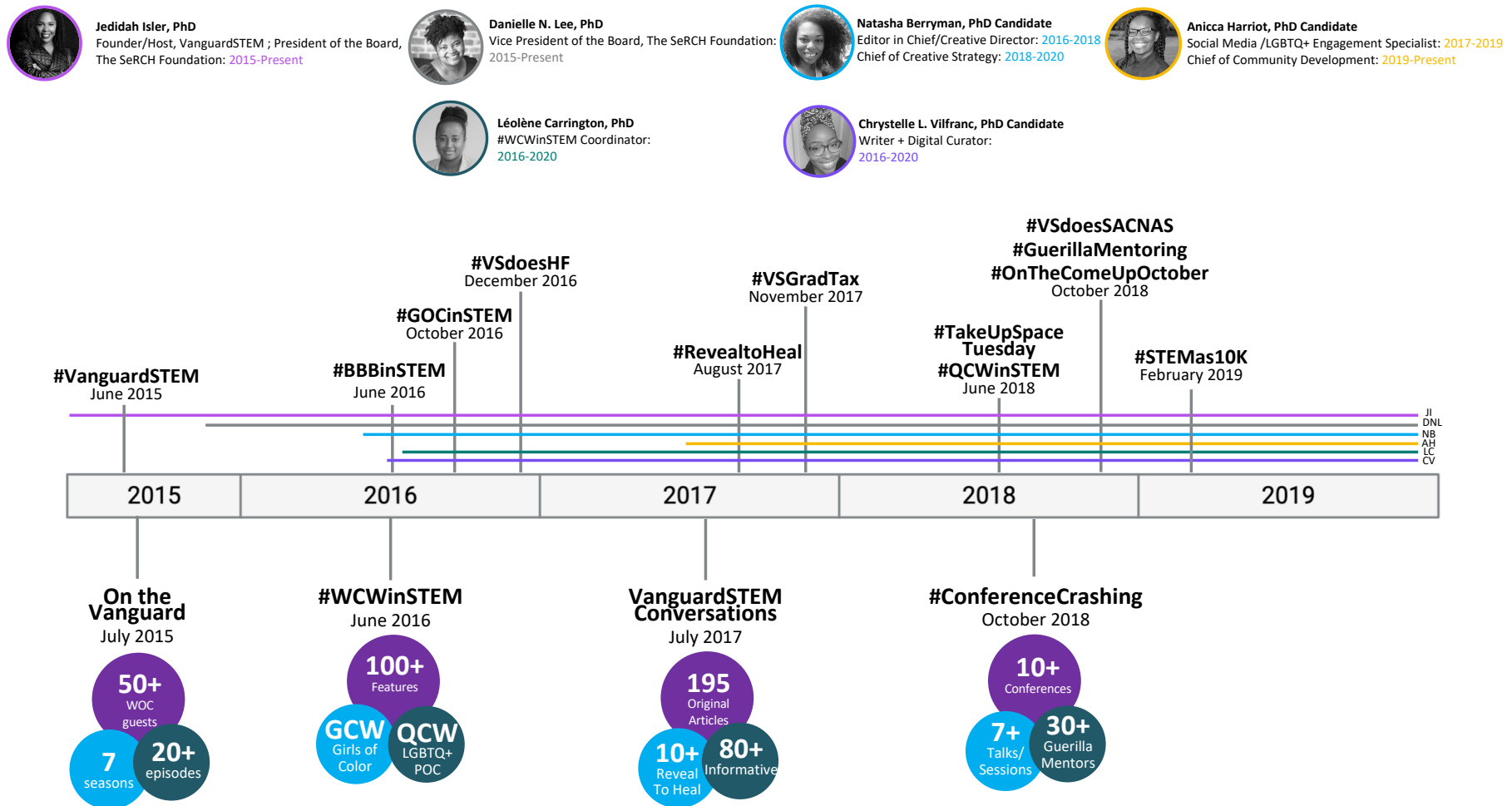


Figure A1. Pictured above are the team of Black women who conceived of and executed a comprehensive set of praxis-driven programming that we believe has changed the digital STEM landscape. #VanguardSTEM is a collaborative effort that has grown and evolved as we brought together our situated knowledges and scientific expertise.

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