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Sound of Science:
Music as a means for equity in STEM education

By

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Introduction

As the expansion of science, technology, engineering, and math (STEM) learning has emerged as a top priority for both educators and policymakers, conversations regarding equity and representation in STEM fields have also garnered substantial (and warranted) attention in the public eye (Handelsman and Smith 2016; US Department of Education 2020). Demographic statistics in STEM employment and degree conferment point to stark disparities involving an overrepresentation of White and Asian men, while women, Latinxs, and Black people remain underrepresented in those fields (Kennedy et al. 2021). Scholars have developed several concepts and tools to redress these inequities, including the notion of cultivating a "STEM identity," as well as the importance of integrating arts into STEM (i.e., "STEAM"). This paper will explore the intersection of STEM identity development with the use of music-specific STEAM pedagogies. By analyzing the trends in STEM identity literature through the lens of various sociological and educational frameworks, this paper examines the ways STEM-music organizers produce STEM identities in their participants. The findings of this paper have conceptual implications for educators, policymakers, and academics interested pursuing equity and justice in STEM.

Bell et al. (2018) define "STEM identity" as a particular "strand of science learning" in which students "think about themselves as science learners and develop an identity as someone who knows about, uses and sometimes contributes to science." As the concept of STEM identity has garnered increasing attention from scholars and the public as a way to increase STEM participation, the curricular and pedagogical practice of interdisciplinary STEAM programs has simultaneously gained momentum in the cultural and policy zeitgeist. States across the country have begun to endorse STEAM

programs in education policy as a strategy to broaden participation in, and deepen the impact of, STEM learning (Dell'Erba 2020; Arts Education Partnership 2020). A review of the STEAM landscape reveals that a growing number of music-integrated STEM (STEMM) programs articulate specific organizational commitments to redressing inequities in STEM participation. Although STEM identity literature and STEAM/STEMM organizations appear aligned in striving for equality of opportunity in STEM education, scholars have provided relatively minimal analysis of how the two might interact with one another. This research therefore seeks to place the objectives of STEMM programs in direct conversation with the concept of STEM identity cultivation. The central question is: "how (and why) do STEMM organizers and facilitators incorporate music into STEM learning to support the cultivation of a STEM-identity in students from underrepresented populations?"

In pursuit of potential answers to the research question, this paper will first provide context before outlining the methodology. The work will then present a critical review of the relevant literature, provide STEMM case studies with organizer/facilitator interviews, and ultimately conclude with implications for STEM-music program organizers and STEM educators. The literature review itself has been organized into four sections: 1) general grounding theory on schooling and identity to frame the research, 2) the relationship between gender and STEM identity, 3) the relationship between ethnoracial identity and STEM identity, and 4) music and identity. The analysis of these sources, supplemented with data from case studies and interviews, reveals that the integration of music in STEM learning creates opportunities for the type of critical,

culturally responsive, socio-politically driven learning environments demonstrated to cultivate STEM learner identities and empowered students.

Background and Significance

In a job market increasingly characterized by a lack of upward mobility for historically marginalized populations, the continued rise in demand for higher-paying STEM jobs implies that such opportunities *do* exist given the correct education and training.[1] Providing access for students from disadvantaged backgrounds to these critical educational opportunities should therefore be a consideration for educators, scholars, and policy makers interested in alleviating inequality in society at large. To best provide students access to the potential upward mobility offered by STEM skills, current researchers suggest that developing STEM identities in students creates the lasting impact necessary for them to pursue those careers. On the other hand, recent evidence indicates that children's biases regarding intellectual potential academic identity emerge between the ages of five and six, which then persist and play a role in the underrepresentation of women and marginalized minority groups in higher education STEM degrees (Bian et al. 2017; Leslie et al. 2015). Although many models of STEM intervention seek to create positive, engaging, and experiential learning environments to expand the popular understanding of who, precisely, might develop a STEM identity, persistent stereotype threats and promises continue to inform the degree to which an individual might see herself as a "STEM-person" (and thus develop a STEM-identity). For example, if young girls have not seen female STEM professionals, either in their everyday lives or in the

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[1] The United States Bureau of Labor Statistics projects occupations in the STEM field to grow 8% between 2019 and 2029, compared with just 3.7% for all occupations (Zilberman and Ice 2021).

media, they are less likely to view themselves as capable of embodying STEM identities (Steinke 2017). Much of the research on STEM identity focuses on how the curricula and delivery of STEM learning environments interact with identities in ways that either deepen or weaken a student's affinity for the subjects. By incorporating this STEM-identity research into practice, programs advocating for inclusivity might more effectively structure their curricula to have lasting impacts on their participants.

In light of the positive effects of culturally relevant education (discussed at greater length below), the notion that music might be able to bridge a STEM cultural gap for underrepresented students makes intuitive sense. Music as a cultural product shares an intimate relationship with cultural identity, and extensive research has been conducted on its reciprocal role as an influence on and reflection of group and individual identity (Tarrant et al. 2002). Especially for historically marginalized populations, music can represent a crucial source of support and cultural affirmation (Carter 2003; McConnell et al. 2016; Delgado 2009). Particularly where STEM-learning is concerned, integrating music into the curriculum may provide a social and/or psychological mechanism that fosters an alignment between STEM and the student identity that allows for a deeper, more ingrained connection with the subject matter.

As the number of STEMM organizations has grown throughout the country, programs have adopted a wide range of curricula. A survey of the STEMM field suggests a pattern of implementing music tools and sensibilities tied specifically to Black music culture. Chicago-based Afrorack introduces electrical engineering concepts to under-resourced Black youth through modular synthesizers and electronic music; Atlanta-based STEM-SPin teaches various math and computer coding concepts with hands-on DJ-ing

and turntablism; MC^2 utilizes hip-hop as a pedagogical strategy to reinforce STEM learning. While many of these organizations appear to – either implicitly or explicitly – focus on Black inclusion in STEM, insights gained from analyzing their practices and strategies might be useful in other ethnoracial and gender inclusivity initiatives. It bears noting that there exists the potential to frame the solution to this issue of representation in terms of supplementing the school system with programs such as these, giving students the opportunity to *choose* to participate. Although addressing the matter is beyond the scope of this project, this understanding essentially involves an abdication of school responsibility to the students. The problem results from ineffective, pedagogically unresponsive science programs in the nation's schooling system. STEMM programs must be considered not as an alternative, but as a model from which to draw pedagogical and curricular strategies to improve STEM learning at the systemic level.

Methodology

Exploring how and why music might facilitate STEM-identity development necessitates braiding together several branches of identity formation theory that have been researched independently, but not in relation to each other. A critical literature review grounds the research in the broader schooling-identity experience of marginalized groups underrepresented in STEM, provides insights into the current landscape of STEM-identity formation, analyzes the processes by which music – and music education – influences identity formation, and implements theoretical frameworks to better understand how these aspects of identity overlap and intersect.

To address how, why, and to what extent STEMM initiatives strive to cultivate STEM identities in their students, I conducted interviews with STEMM organizational leadership, program founders, and facilitators. This portion of the research entailed six in-depth, forty-to-ninety-minute interviews with STEMM educators throughout country. I found and contacted my respondents through a combination of Google searches, education oriented non-profit directories (e.g., GuideStar), and lists of attendees and speakers at conferences dedicated to STEMM education (e.g., *Voices*). Relevant keywords for my searches included various combinations of the following key terms: "STEM," "music," "education," "instruction," "science," "technology," "engineering," "math," "physics," and "acoustics" (e.g., "music technology education"). To be eligible, the respondents had to be current leaders, founders, or facilitators of programs that integrate music with at least one of the four STEM components (science, technology, engineering, and math). Once I identified a STEM-music integrated organization to include in the study, I ascertained willingness to participate by contacting the organizers either indirectly through a link on their websites, or directly if the potential respondent listed the requisite information publicly (e.g., LinkedIn account, email, direct message, etc.). In the interest of participant anonymity, I have here altered their names, and the names of their respective programs (unless respondents expressly insisted I use their true identities). Given the constraints of the pandemic, I conducted and recorded the interviews over both online video-call services (e.g., Zoom and Skype) and phone calls.

After the calls, I transcribed and coded the interviews using MAXQDA. The first round of coding involved "Open Coding," which meant breaking the data down into more succinct, digestible components (Saldana 2013). I chose this strategy for my initial round

of coding because it was more than sufficiently flexible to capture the diverse range of information conveyed throughout the interviews. This process facilitated a breakdown of the data while ensuring that all the valuable information would be captured. The second round of coding involved "Descriptive Coding," where the relevant data was further collapsed into a single word or brief phrase indicating a general theme or topic (Saldana 2013). Applying descriptive codes throughout the interviews brought forth salient, repeated thematic components within the data. I then grouped similar codes together under larger umbrella categories and sorted the categories by document to identify their prevalence throughout the interviews. The topics discussed in the "STEMM Organizer Interviews" section reflect the larger categories that constituted important themes of interest across most, if not all, interviews. These categories were ultimately selected because of their ostensible foundational nature to the work of the various STEMM organizations.

I acknowledge that my methodological choices have limitations. For example, the interviewee selection process did not provide a random sample of respondents. Furthermore, the time constraints of this project necessitated a sample size which may be considered smaller than is ideal. However, given the newness of the STEMM paradigm, samples of convenience – while imperfect – still yielded meaningful insights. The rich quality of in-depth interview data provides important benefits to the research that offset or outweigh the costs of a smaller sample size. The following critical literature review, case studies, and interviews have produced foundational knowledge regarding the processes by which STEMM programs cultivate STEM identities to expand STEM engagement and participation to underrepresented youth.

Critical Literature Review

General Theories of Identity Formation in Schools

Understanding the processes by which students conceive of themselves generally as "learners" may help contextualize STEM identity formation. Diane Reay (2010) asserts that students' identity formation occurs discursively and is mediated through aspects of identity that are imbued with socially constructed meaning, such as race, ethnicity, sexuality, disability status, class, and gender. Through students' interactions with their peers and institutional actors, they articulate elements of their identities both explicitly and through subtle, internalized, unconscious processes. These negotiations play an important role in constructing the social identity of the student, which in turn informs student formation of "learner identities," which Reay defines as conceptualizations students have of themselves as learners. Students develop learner identities through a process of self-construction driven by feedback from others, especially peers and institutional actors (e.g., teachers and counselors) (Reay 2010).

The social identity of a given student inevitably becomes deeply intertwined with their process of learner identity formation (Reay 2010). Ethnographic work such as Amanda Lewis' *Race in the Schoolyard* highlights how social identity may come to define learner identities for certain groups of students. Lewis' observations of an urban elementary school classroom revealed a stark overrepresentation of Black boys receiving suspensions and other disciplinary actions. Furthermore, Lewis observes that these boys, as well as their classmates, came to understand their "disruptive" behavior as a natural consequence of racial and class identities (Lewis 2003). Through repeated patterns of

social-identity-driven punishment, the resulting learner identities came to be perceived by the boys themselves, their peers, and the institution as troublemakers in opposition to the mission of the school. Lewis's account therefore supports Reay's assertions that social identities, discursively produced through peer and institutional interactions, play a critical role in shaping how students conceive of themselves as participants in the education system at large. Students may thus be sensitive to gender- and ethnoracial-biased patterns of discourse or representation surrounding STEM, which might then have an impact on how those students make sense of their ability (or lack thereof) to pursue and/or claim a STEM learner identities.

In addition to learner identity formation, this research also intersects with the literature on culturally relevant education. The animating premise of culturally relevant pedagogy is that education practices are more effective when they align with and affirm the distinct, extracurricular sociocultural identities of students (Gay 2010). To analyze how the hypothesis works in practice, Dee and Penner (2017) assessed the impact of Ethnic Studies course offerings at three San Francisco high schools, each focusing on cultural awareness, ethnic identity, and consciousness of ethnoracial-based oppression. They found large, statistically significant effects for students of color across a range of measurements including attendance, grade point average, and credits earned. The fact that the study assessed only three schools in a single city raises some questions regarding the external validity of the results. On average, San Franciscan politics famously (or infamously) tend towards the progressive side of the political spectrum, and the high cost of living in the city necessitates a certain level of financial stability among its residents. One must therefore question what influence the economic and sociopolitical climate of

the surrounding community might have on the results of studies such as this. Nonetheless, the findings demonstrate promising effects that validate the concept of culturally relevant education and underscore the importance for future investigation, especially regarding the inclusion of underrepresented groups in STEM (or any field of study for that matter).

Dee and Penner's causal assertions regarding the impact of culturally relevant education on schooling outcomes are convincing not just because of their empirical basis, but also because they align with Reay's understandings of social and learner identity formation. As evidenced by Dee and colleagues, Ethnic Studies courses made efforts to affirm the distinct cultural identities of students from historically marginalized groups. By cultivating an environment that allowed students to experience validation of their social identities, the high school, as an institution, facilitated the development of more engaged learner identities from "at-risk" populations (Dee and Penner 2017). Jonathan Rosa's *Looking like a Language, Sounding like a Race* provides a salient example of a missed opportunity for a Chicago high school to increase student engagement by implementing culturally relevant education. Rosa observed educators and administrators of New Northwest (a predominantly Latinx high school) lamenting the challenges of motivating students to engage with school-sanctioned literature. Rosa also found, however, that students *did* engage with literature outside of the school's required reading list when the content of the books aligned with their sociocultural experience (Rosa 2019). Because of state-imposed restrictions to focus solely on works that fit into hegemonic conceptions of "school-appropriate," the leadership of New Northwest missed a valuable opportunity to affirm the experiences and identities of students *through* enhancing their relationship with school literary objectives. Dee and Penner's empirical

evidence and ethnographic accounts such as Rosa's thus demonstrate how culturally relevant education has the potential to meaningfully contribute to positive learner identities in students.

The concepts of learner identity formation and culturally relevant education take on greater depth when considered alongside Prudence Carter's conception of non-dominant cultural capital. Pierre Boudieu asserts that cultural capital is derived from the accumulation of cultural knowledge and consumption of cultural goods which then organically produce one's "habitus" (a sociocultural matrix of behaviors, beliefs, and dispositions) that provides an individual with social, cultural, and institutional advantages (or disadvantages) as a result (Bourdieu 1986). Schools institutionally value and reflect middle-class habitus, therefore favoring middle-class students while disadvantaging lower-class students and reproducing existing structures of social inequality. Conventional understandings of cultural capital assert that the middle-class (and upper-class) "has" cultural capital, while the working- and lower-class *lacks* cultural capital. Prudence Carter introduces an essential wrinkle to this theory with the concept of "non-dominant" cultural capital. Carter asserts that socially and economically marginalized groups of students do, in fact, have their own forms of cultural capital that, while rejected by schooling institutions, confer distinct advantages in their respective cultural milieu. For Carter, the school's inability to recognize, affirm, or validate the marginalized students' cultural capital contributes to their lack of school "attachment." Carter identifies this resulting lack of attachment as a powerful force driving differential academic achievement between various groups of students (Carter 2005).

The potential connection between validating non-dominant cultural capital and school attachment ties back into the earlier discussion regarding culturally relevant education and the significant impact of Ethnic Studies offerings on student engagement and performance (Dee and Penner 2017). Furthermore, Carter's assertions complement Rosa's observations regarding New Northwest High School and the administration's failure to recognize and integrate literature into the curriculum that would have resonated with the cultural identity of their student body (Rosa 2019). These complementary ideas surrounding non-dominant cultural capital and culturally relevant education practices – as well as their potential to positively impact student learner identities – therefore provide an important theoretical foregrounding for understanding how, and why, music might effectively bridge potential cultural gaps in STEM learning.

Gender and STEM Identity

Kim et al. (2018) employ a social identity theory lens to review the empirical literature on STEM-related psychological experiences of adolescent female students. Kim and her colleagues found that fostering social connections such as those with female mentors, instructors, and role models comprise an essential indicator of program success (Kim et al. 2018). Such connections are analogous to those that students make with those people whom Carter (2005) terms "multicultural navigators," individuals who "harvest" and share cultural resources from within and beyond their communities to bridge divides between dominant and nondominant cultures. These multicultural navigators play a crucial role by simultaneously validating the nondominant culture of marginalized students and providing them with the information needed to traverse the cultural gap to

succeed in dominant-culture contexts (Carter 2005). While Carter's ideas center around racial identity and school achievement, Kim et al.'s (2018) findings demonstrate that the concept of multicultural navigators applies to gender as well.

Kim et al. (2018) also found that programs specifically intended for young women of color were more likely to encourage embodying STEM identity when the curricula integrated culturally relevant pedagogy. Specifically, programs that focused on generating feelings of interpersonal connection, community, and commitment to a cause "greater than oneself" were particularly successful in fostering STEM identities in young African American students (Kim et. al 2018). Yet another critical point of analysis for Kim et al. (2018) involves the conception of STEM identity as a social identity unto itself, with distinct ingroup and outgroup formation processes. The researchers assert that programs should target White, male students, as well as educators and administrators, to foster changes in the social environment that will help redefine normatively held beliefs regarding *who* precisely belongs in STEM. For example, by teaching the contributions of female STEM professionals to the field, programs can contribute to shifting the socially constructed image of the "typical" STEM professional. These findings therefore support the empirical results from Dee and Penner's study on culturally relevant pedagogy and its impact on student engagement and achievement, as well as Reay's hypothesis that institutional and peer affirmation of, and alignment with, student social identities fosters positive learner identities.

Race/Ethnicity and STEM Identity

Nasir and Vakil (2017) ethnographically examined student experiences in STEM-focused academies in urban schools to suggest how STEM programs might be restructured to promote STEM identities in ethnically or racially marginalized students. In support of Kim et al.'s (2018) findings, Nasir and Vakil (2017) observed that culturally relevant pedagogy provides a crucial element for imbuing the STEM identity in underrepresented students of color (e.g., Black and Latinx). This culturally relevant pedagogy becomes especially effective when integrated with a social justice curriculum, and the authors assert that when administrators design these programs intentionally, they create powerful opportunities to "disrupt negative racialization and inequality" (Nasir and Vakil 2017). Their description of Lupe and Candice, two female students of color at Prep (one of the study's academies of interest), highlights how such intentionally designed programs create opportunities for students of color, and young women of color, in particular to position themselves as authorities in relation to both teaching and learning classroom concepts. The program's curriculum actively encouraged class discussion about racial and gender inequity and injustice, and Candice and Lupe took advantage of the space by coding and creating a computer game where users create a female-scientist avatar (of any variety of skin tones) and progress through the game by defeating condescending (White) male "enemies," while building solidarity with other female coders and scientists throughout the game. Prep's pedagogical structure therefore recognized and validated students' unique identities by creating an institutional space for learning content to tie directly to their experiences with racial (and gendered) oppression in school and in their communities (Nasir and Vakil 2017).

With respect to disrupting negative racialization processes, Nasir and Vakil (2017) point to a "culturally neutral" rhetoric surrounding STEM learning. The authors assert that when educators, policymakers, academics, and the general populace frame STEM as a "politically and culturally neutral" area of study, student experiences and knowledge regarding marginalization become delegitimized (Nasir and Vakil 2017). As I noted in my review of writing by Rosa (2019), Carter (2005), and Reay (2010), when the sociocultural identities of students are disregarded and devalued, student engagement and achievement suffer. Over time, repeated institutional disregard for the identities of underrepresented ethnoracial minorities ultimately produces a gendered and racialized conception of STEM as a normatively male, White or Asian field (Nasir and Vakil 2017). Furthermore, the concept of "culturally neutral" discourse ties into Amanda Lewis' observations in *Race in the Schoolyard* regarding "colorblind" race discourse in schools. Lewis sees that the colorblind language adopted by educators, administrators, and parents causes race relations to take on a more insidious and less tractable character, leading to feelings of confusion and alienation for students of color (Lewis 2003). This disregard of URM sociocultural identities and the casting of STEM as a "colorblind" set of disciplines simultaneously entails an affirmation and validation of White sociocultural identities. White, middle class social and cultural identities characterize the normative, default, and ostensibly "colorblind" cultural structure in the American school system (Carter 2005; Lewis 2003; MacLeod 2009; Lareau 2015). In other words, it is important to consider that *all students* have sociocultural identities and that the negation of the identities of students of color often entails the uplifting of White, middle-class identities. The design of Prep's program therefore disrupted negative racialization patterns in STEM by deliberately

cultivating an environment where those culturally neutral norms could be explicitly and actively challenged (Nasir and Vakil 2017).

Music and Student Identity

Tarrant et al. (2002) review the literature on music and identity development and find evidence suggesting that, during adolescence, individuals engage more frequently and intimately with music than any other forms of media. They observed that listening to music is "*the* most preferred leisure activity," regarded by many as "one of their most special, important, or treasured possessions" (Tarrant et al. 2002, 135). Granted, the authors write from a pre-social media-era perspective, and adolescent media consumption habits have likely changed dramatically in the last two decades. A more recent 2019 survey, however, revealed that, for girls aged 8-18, listening to music continued to represent their favorite media activity, and for boys, music consumption comprised the number two media activity behind watching online videos (Rideout and Robb 2019). Tarrant et. al (2002) utilized data from a UK survey study to identify the primary reasons why adolescents listen to music and found that, just behind "fulfilling emotional needs," adolescents listen to music to manage and maintain a particular self-image. As in Kim et al. (2018), social identity theory and the maintenance of in- and out-groups comes into play. Specifically, Tarrant et al. (2002) suggest that music may contribute to identity formation by facilitating inter- and intragroup social relations. In other words, different forms of music function as symbols that signify group affirmation and/or allegiance. In *Shades of White* (2002), Pamela Perry describes the ways students incorporate music as an accessory to their identities to indicate belonging to specific groups. For example,

although metal music may seem explosive and aggressive to some, White students who listen to the genre disparage hip-hop with terms such as "angry" and "violent" (Perry 2002). Although hip-hop and metal both contain seemingly violent sonic elements, alignment with one genre or the other becomes a signal of one's place in the social and racial landscape. In the context of STEMM programs and STEM identity formation, the specific genres or tools educators implement (and where those genres and tools fall on the dominant-non-dominant cultural capital spectrum) may therefore implicitly signal either a reflection or rejection of the students' cultural capital. Given the weight and importance adolescents assign to music, the cultural relevance music affords for STEMM programs may therefore contribute to the creation of a space that validates the nondominant cultural capital of marginalized students and cultivates positive STEM learner identities.

Assessing the relationship between formal music education and students from marginalized backgrounds may also yield valuable insights for STEMM programs. Eurocentric, bourgeois norms dominate formal music education in America. The curricula available across the nation's high schools features almost exclusively Western-based "high arts," such as concert band (present in 93% of high schools), choir (in 89% of high schools), and orchestra (in 36% of high schools). With respect to more "non-traditional" forms of music education, only 16% of schools offered a guitar ensemble class, 13% offered "music technology," and a meager 5% offered contemporary/pop/rock ensembles (Elpus 2017). As suggested by the lack of measurement in the above-cited national survey, "multicultural music education," "world music," or other ethnic studies equivalents appear to be conspicuously peripheral in formal music education. Additionally, in critical music education research, terms like "multicultural music

education" and "world music" have come to imply disingenuous, "inauthentic" lessons that expose students to international content without providing political or sociocultural context. These culturally displaced educational platitudes ultimately essentialize the very cultures well-meaning educators allegedly seek to appreciate (Hess 2013).

Just as STEM education becomes culturally neutral (Nasir and Vakil 2017), music education without intentional sociopolitical and cultural objectives – such as educating students on the history and legacy of racial oppression – becomes similarly colorblind while deprioritizing the minority student experience. Juliet Hess (2017) asserts that the music education system in America operates through a "paradigm of White supremacy" by adopting a stance of "terminal naivety," defined here by the intent to remain ignorant to current events and structures that shape society. Hess suggests that terminal naivety nurtures the persistence of overrepresented "Whiteness" in music education (in terms of the participants, educators, and curricula), which may play an important role in the lack of ethnoracial minority participation (Hess 2017). In relating Hess's work to that of Carter (2005) and Reay (2010), one might argue that dominant cultural capital defines the current music education landscape, and the implied devaluation of non-dominant cultural capital means students with certain social identities may be restricted from developing musical learner identities. Hess thus proposes that music educators have a responsibility to adopt critical race theory (CRT) and praxis into their curricula and pedagogy to assist in dismantling racial oppression in and beyond the classroom (Hess 2017). According to Kimberlé Crenshaw, one of the founding CRT scholars, critical race theory involves the practice of interrogating all social and political structures to reveal the underlying machinations of normalized, hegemonic racial inequality (Crenshaw et al. 1995). A CRT

perspective in music education would therefore demand that educators facilitate discussions (both among themselves and with students) regarding the subordination of non-White cultures in the music classroom – and what might be done to rectify the history of educational marginalization.

The integration of socio-politically-conscious, culturally responsive curricula and pedagogy into music education has had promising results. Findings from a quasi-experimental music education study comparing a "music concept" control group with a "sociocultural context" treatment group support Hess' CRT-integrated suggestions. Abril (2006) examined a multicultural music education intervention where predominantly White, middle- to upper-middle-class fifth-grade students received general music education from a specialist over a period of about five months. Two classes were randomly assigned to either a "music concept" or "sociocultural" group. The music concept group used more formal elements of music education and, in addition to music-making experiences, the specialist discussed cultural information about the music (including geographic origins, language, and the meaning of the various pieces). The sociocultural group participated in the same music-making practices, but the lessons focused on the "construction of knowledge about unfamiliar performance styles, sounds, and cultures" (Abril 2006). The specialist contextualized the songs with interactive discussions regarding how musical meaning may be contingent on an individual's social and cultural position. Students in the sociocultural group were also asked to engage critically in dialogue about how prejudice and stereotypes may affect their listening experience.

Abril (2006) found that students in the "sociocultural context" treatment group demonstrated large and statistically significant effects with respect to awareness, sensitivity, and/or valuing of other people and cultures. The results also showed that the only students who indicated negative affect toward unfamiliar music came from the "music concept" group. This finding supports Hess's (2017) claims and suggests that multicultural exposure alone may be insufficient to bridge intercultural gaps. Integrating education on social context with exposure, as achieved through the facilitation of reflexive sociocultural dialogues in class, however, may facilitate the reduction of such gaps (Abril 2006). Furthermore, evidence from several international case studies suggests the meaningful potential for similar sociopolitical, culturally responsive music education to both facilitate the construction of positive self-identities and foster empathetic intercultural relations (Nethsinghe 2012; Southcott and Joseph 2010; Joseph 2012).

The importance of music in general for adolescents may help explain music's efficacy in expanding STEM learning. We need additional context, however, to better understand how underrepresented student groups might engage with music in a classroom. The literature on music education provides this context by demonstrating 1) the potentially detrimental effects of the current cultural homogeneity and 2) the potential value in redressing this homogeneity. Overall, the literature on this topic supports the previously discussed studies on gender and ethnoracial identity in STEM that point to the critical importance of validating non-dominant cultural capital to nurture marginalized social identities which may then develop into active learner identities. Although culturally relevant pedagogy may be necessary for breaking down barriers to entry for

underrepresented minority students, it is not sufficient to contribute to the dissolution of systemic barriers that will continue to circumscribe their lives outside of class. As the evidence outlined above suggests, integrating contextualizing, sociocultural classroom dialogues into culturally relevant pedagogy deepens educational impact by facilitating active, critical engagement from the students and demonstrating tangible relevance of the lessons to their lived experience (Abril 2006; Dee and Penner 2017; Nasir and Vakil 2017; Hess 2017).

STEMM Organizer Interview Findings

To investigate how the above concepts and theories manifest in the STEM-music context, I interviewed a total of six respondents from four organizations.[2] "STEM-Spin," an NSF-funded nonprofit organization, embeds STEM concepts within DJ- and turntable-focused curricula and pedagogy to facilitate deeper engagement among underrepresented student groups in STEM. From STEM-Spin, I interviewed Les Chase (CEO), Dr. Parzi Teher (Director of Operations, Research, and Evaluations), and Dr. Teresa Lang (Chief Education Executive). I also interviewed Dr. Dan Pane, the Program Coordinator from "MC^2," which utilizes a hip-hop driven pedagogy to teach science concepts to primarily Black and Latinx high school students in New York City. From "Women Run the Booth" (WRTB), a San Francisco-based organization dedicated to increasing female and gender-diverse participation in audio engineering, I spoke with Education Director Kelsey Han. Finally, I met with Afrorack's founder and facilitator Aaron Guice to discuss his

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[2] With the exception of Aaron Guice and his Afrorack program, the names of all organizations and respondents have been altered to respect the privacy of the individuals and their respective organizations.

approach to introducing STEM concepts to Chicago's underserved communities through modular synthesis.[3]

Despite notable differences in the technical execution of the various programs, the interviews revealed meaningful similarities in the pedagogical approaches organizers deploy to pursue the common goal of expanding STEM learning among underrepresented populations. Overall, the organizers use culturally responsive STEM-music education 1) to develop a positive relationship between the students and STEM topics; 2) to expand notions of who "belongs" in STEM (i.e., the STEM identity); 3) to foster student ownership, agency, and leadership within the programs; 4) to empower students beyond the STEM context; 5) to build community and networks of support for the students; and 6) to create a space to acknowledge and discuss sociopolitical themes and ideas as they intersect with the students' lived experiences. All organizers, except for one, also demanded consideration of inclusivity beyond their focus populations.

Throughout the interviews, respondents noted the importance of the students' relationships with the STEM fields. Dr. Pane of MC[2], for example, intimates the ostensible challenges traditional science education imposes on students, especially marginalized students of color: "We're intimidated by the discipline of science, because of our experiences." To overcome potential hurdles of intimidation, MC[2] strives to help students recognize the compatibility between their identities and STEM subjects. The curriculum involves students composing science-themed rap lyrics, and often these compositions connect lessons learned in the classroom with the lived experiences of

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[3] "Modular synthesis" refers to a specific type of music production where individual components (or "modules") of a synthesizer (an electronic sound generator typically played with a piano-like keyboard) must be manually "patched" (connected) in a specific order to produce the desired sound.

writers outside of school. By re-contextualizing an intimidating discipline within a more familiar, accessible cultural framework, MC^2 essentially attempts to reduce the identity-driven barriers to entry for STEM learning. Similarly, Dr. Teher discusses STEM-Spin's objective in "destigmatizing" STEM subjects:

> I think people think about science as being something that you take a lab […] like it's chemistry, it's something that's more technical. But science, for me, is just exploring your surroundings.[4] I do remember my first microscope when I was in grade school for Christmas, I loved it. Just being able to use something […] having a microscope, being able to understand your surroundings a little bit better [like in] nature, [looking at] a leaf.[5] I think that music can do the same thing. Whether it's the technology of the physics behind it or the electronics that's behind it, it's just sort of a way to explore STEM. Music is a way to explore STEM in the same way [as] nature […] the point is "how do you destigmatize something by making it more accessible, more natural, understanding how it's connected to other things" is a way to, I think, make STEM more accessible to kids in particular.

These ideas of exploration and play appear in the work of each of the organizations in one way or another: STEM-Spin ends every class with an unstructured "playground" segment, in which students can freely interact with each other and the DJ equipment; Afrorack's workshops encourage students to experiment with the synthesizers, make mistakes, and learn through hands-on playtime with the gear; the WRTB youth series "Sound Gals" involves each of the participants actively collaborating and creating original works of art over the course of the program. Each of these initiatives facilitates student engagement with traditionally intimidating STEM fields in contexts specifically constructed to spark curiosity, encourage self-expression, create positive experiences, and ultimately connect the students with STEM in a tangible, relatable manner. Many of the respondents brought up the inextricable links between music and STEM as an essential

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[4] I use the ellipses in brackets throughout this paper to indicate omitted sections of the interviewees' responses.
[5] I have placed brackets around words that I replaced or added for grammar and/or improved clarity.

component in fostering this tangible relatability. When asked about how WRTB integrates music with STEM, for example, Kelsey Han replied:

> I don't really think that they (music and STEM) are different. I think that we're not necessarily integrating them so much as shining a light on the parallels that already exist. It's sort of like [a] conversation that I've had for many years working on the advocacy end of arts education where I'm moreso advocating that the enrichment of any curriculum we're building really rests on any student's capacity to be a multifaceted creator, whether they're creating scientific analysis or creating an engineering platform or creating a giant painting, it's all kind of connected, so I think I'm more of a STEAM person. They're all connected, they're all one and the same.

Les Chase had similar thoughts when asked about why he thought STEM and music integration was important: "Music is not only fundamental [to] our humanity, but it lends itself to science, [because] it *is* science." [6] These STEMM organizations thus utilize music to make abstract STEM concepts less threatening and more relatable, while also providing opportunities for students to engage with STEM through a lens of play and exploration.

By cultivating environments for URM and female students to develop these positive relationships and associations with STEM, these organizations essentially create cultural and psychological space for the development of STEM identities. Across all the organizations featured in this study, nearly every respondent identified the lack of representation as a serious barrier to STEM accessibility for their respective target populations. Notably, they frequently cited the importance of incorporating culturally relevant and responsive teaching strategies as a means of challenging the internalized marginalization such lack of representation inevitably produces. Dr. Pane, speaking to MC^2's hip-hop pedagogy, explains:

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[6] Emphasis taken from original recording.

When we talk about hip-hop in particular, hip-hop is a culture that empowers historically marginalized and oppressed groups. Right, when we think about how hip-hop started in the South Bronx, Black and Brown youth who had little to nothing, they found resources, they put things together, they made sense of things to create things for their community, to empower their voices, to share their story, to share their narrative. When we talk about hip-hop and STEM, science is a discipline where historically marginalized groups don't see themselves, right? When we learn about science in the United States, across the world generally, but in the U.S. it's through a Eurocentric worldview. If you go to school in the U.S., you will leave school thinking that science, STEM, science and mathematics, was created in Europe, created and made sense of in Europe. But that doesn't acknowledge the contributions of Black folks, [or] other groups that have been historically marginalized, and students of color have a hard time seeing themselves […] as part of the discipline. When we talk about music and hip-hop and leveraging that, it's a way to leverage students' voices, their worldviews, and their experiences as it relates to science. Which, in that discipline, there's little to none of that there. So it's using hip-hop and the genre as a conduit to learning science, it's the connecting piece.

In explicit terms, Dr. Pane has posited the capacity for hip-hop to act as a culturally responsive "conduit" to alleviate the potential identity friction historically marginalized groups might feel in relation to STEM fields. Han described a similar problem with respect to how the arts can be used to cultivate a more inclusive STEM identity:

I think a lot of that comes down to the intersectional perspective of anything that we're trying to approach because so many people of color and gendered folks are underrepresented in these fields. We just need to make sure there are more of us at the forefront of this innovative technology. Then more people can get involved, and we can diversify the field. That's where I'm coming from. The thing is, anyone with STEM identity is just anyone who is excited about STEM. And [they] shouldn't be marginalized in any way.

Later in the interview, Han explains what culturally responsive pedagogy looks like in the Sound Gals context, asserting that "it's just about responding to the whole student and making the curriculum itself completely student-centered and responsive and reactive to […] the student's [lived] experience." Consider Kim et al.'s (2018) findings regarding the importance of female STEM mentors in disrupting preconceived, gendered notions of

STEM identity, especially in the context of culturally relevant and responsive pedagogy. As an organization owned and operated entirely by women and gender-diverse people, WRTB provides young girls the resources and mentorship necessary to see themselves as engineers, scientists, and creators. Chase suggests that the representation of STEM identities in the media might also influence student affinity toward STEM subjects:

> STEM identity is a Ferris Bueller, […] or Spider-Man, Peter Parker. But you don't have that type of Ferris Bueller for all communities. So you can pull out all these STEM identities but it's not associated with all communities […] So, STEM-Spin is just letting the student know that he or she can be productive in STEM and identify with STEM and understand it's not just that you're the teacher's pet or whatever. It's knowing that you understand and appreciate science and math and use it in your own way.

Dr. Teher echoes the importance of representation as it relates to identity:

> It is important because you want to see yourself in something that you love in particular […], when you see someone doing something you're interested in and they look like you, may have a similar story to you, it does change the way that you see yourself and the development of your own identity as being able to do that, being able to DJ or to be a scientist or to be an artist.

Later in the interview, Dr. Teher elaborates how:

> [STEM-Spin] uses a cultural lens to engage students and use music as a way to help students, in particular students of color, cope with challenges they have in their lives and to have a different identity which hopefully leads to better outcomes for [them] […] It's the use of music and turntabling to promote STEM learning specifically. And that music is science, it is physics, it is math. and making that connection for students.

Throughout these STEMM organizations, culturally sensitive approaches to STEM education therefore act as a strategic means of countering pre-existing understandings of STEM identities among URM and female students.

Aaron Guice's experience with Afrorack provides an important perspective on the impact of adapting pedagogy to the social, cultural, and economic identities of the students. Like the leaders of other organizations focusing on ethnoracial inequities in

STEM (MC^2 and STEM-Spin), Guice believes that integrating music alleviates the tension URM youth might feel in relation to STEM. He also problematizes the historical relationship between the Black community and technology:

> Integrating music and STEM makes it completely accessible. It helps to immediately give voice to people who are underrepresented. It helps them express their stories, and it helps them build healthy relationships with technology. Most often in Black communities, you don't have healthy relationships with technology because of the expense so we're not encouraged to explore, handle or even own certain pieces of technology so there's always sort of this, maybe not fear, but reluctance to really participate.

> I've been in classes where the kids have been frozen with fear because they believe that they're going to break it and somehow be liable (unintelligible) so that fear of financial burden that they will put on their families has literally frozen some children and stopped them from learning.

> [In one class, the] kids were really scared to touch […] the synthesizers because they were scared they were gonna break it. So I picked it up and then I dropped it. Then, after I dropped it, most of that fear was gone because I took the relevance away from the finances, how much it cost, and just made it an object again.

In this example, being culturally responsive meant Guice recognizing and being sensitive to student tension due to the community's relationship with technology. To help the students connect with the program, Guice had to navigate the students' concerns regarding potential economic liability. Such a socioeconomic component – and the resulting lack of exposure to, and experience with, technology – should therefore be a consideration for educators, policymakers, and organizers seeking to expand STEM learning to URM students through culturally responsive pedagogy.

The program coordinators each emphasized the importance of student ownership and autonomy within the culturally relevant strategies utilized by their respective organizations. Dr. Pane, in discussing how teachers can implement the hip-hop pedagogy of MC^2, asserts:

I just tell teachers that, "You have to be vulnerable, and if you're not willing to be vulnerable this is not gonna work." Because vulnerability means going to your students and saying, "Hey, I don't know this, can you support me in making sense of this," and engaging in that learning together. And that's one of the main points that we really try to emphasize with teachers, that when engaging in a hip-hop pedagogy or any type of hip-hop activity, it's really about empowering the students, and that's a way of empowering the students, a teacher coming to the student and saying, "I don't know, how can you support me?" Empower the students and give them the agency to support you in making sense in that.

Han expresses a similar sentiment regarding the culturally responsive strategies in

WRTB:

It's just about responding to the whole student and making the curriculum itself completely student centered and responsive and reactive to what the student's experience is and what the student is experienced in and just making sure it's youth driven work instead of adult driven. The core of the curriculum is about what [the students] are interested in, what they want to see, where they see themselves and who they want to be. So […] it's not us filling them with knowledge, it's us sharing knowledge and building out and empowering what they already have and what they already know.

For Afrorack as well, Guice reinforces the importance of letting the curiosity and

interests of the participants guide their experience in the workshop:

In one of the workshops we wrote, is how do we build something that interacts with [SoundSketch] – how do we build something ELSE, how do we create, let's learn how to make our own PCBs, our own circuit boards, and attach them to SoundSketch and make them interact. [7] So we're hoping that it's sort of a gateway into curiosity. So we tried to make that very literal by making the windows [to see into the synthesizer]. After that, it's supposed to spark curiosity and help kids really find an entry point into [electronics].

[Overall], it is about creating a safe space that's staged for mistakes and then being ok with those mistakes. That's the most important [thing] […] It's just about creating a safe space to fuck up, to mess up.

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[7] SoundSketch is an Afrorack-developed synthesizer with a dry erase casing for students and instructors to draw their own diagrams on the device. Afrorack asserts that allowing teachers and students to draw directly on the synth's frontplate "[erases] the 'boundaries of language, culture and musical ability'" (Smith 2021).

The Afrorack workshops appear to share similarities with STEM-Spin's "playground" concept in that Guice encourages the participants to freely experiment and explore the electronics in a relatively independent manner. While WRTB, MC^2, and Afrorack feature student-driven curricula in more explicit terms, STEM-Spin centers the sociocultural identities of the students in a more top-down structure, in which program facilitators adhere to a specific curriculum to scaffold STEM lessons and skills over the course of the four-week program. Despite STEM-Spin's more clearly delineated curricular structure, however, the prevalence of daily "playground" time for student exploration and experimentation demonstrates that the organizers recognize the importance of student-led activity. Providing the space for students to engage with the material on their own terms thus appears to comprise a foundational component of culturally responsive pedagogy in STEMM programs.

By encouraging students to engage with the material from their own worldviews and cultural contexts, STEMM organizers effectively nurture community building among their participants. In the STEM-Spin "playground" time for example, Chase observes:

> You'd have some students who are more extroverted and jumping on the turntables right away, [along with] students that were more introverted and […] personalities [would interact] where they might clash in a normal session. And watching some of the students work through these problems and sharing their music, that's a great part about it […] Students are able to not only manipulate music, but share music with their peers on what music they like or relate to and their peers are able to do the same. So after the [structured] sessions you can kind of see enemies become friends, and introverts shine, and extroverts more willing to help or even stepping back a little bit […] I think when you get students in there working together on stuff that they like or are curious about […] there's more room for growth.

As students progress in the MC^2 program, Dr. Pane highlights the importance of

collaboration and constructive feedback from peers as an integral component of

empowering the participants:

> Over time, we notice students just gaining confidence, we notice students saying just "I can do science, I want to do science, it makes sense to me. I listened to that rap, and, whoa, I didn't make that connection." Even through the process we have students critiquing and being critical of each other's songs to support each other throughout the process.

Lesley Han cites a high demand among women, inspired in part by the opportunities

afforded by the COVID-19 pandemic, to pursue STEMM and develop connections with

other like-minded women interested in audio engineering:

> I think there could be some silver linings with the pandemic where it forces people to look inward and think about the things that are important to them, to build home studios and teach themselves a lot [about] the gear and a lot of the STEM [concepts] […] And also [to build] their networks and the community around a lot of this […] The last adult class that I put out for our engineering course […] sold out in 36 hours so I had to add a second section of it.[8] And I think it's just because people want to learn, they want the access, they want to be a part of these things. It's not like women and gender expansive people don't want to be well respected engineers in the field. We just need more access. So the more stuff that WRTB does, the more of us there will be.

For Aaron Guice and Afrorack, the notion of community building emerged in the context

of building out workshops in a post-pandemic context. Guice asks, "How do you have a

community project where people are allowed to behave in a communal way [with] people

laughing and touching the synthesizers. That's an important part of learning and

experiencing, we all experience it together." This notion of access to a community that

supports skill development among underrepresented populations is a common thread

throughout in this study. For any population experiencing marginalization or

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[8] While WRTB's Sound Gals youth program is free of charge, their adult audio engineering classes require paid registration.

stigmatization as an "outgroup" – such as women and URM in STEM (Kim et al. 2018) –

these spaces for community development represent an integral support system as a

vehicle to "re-norm" their identity as a group that belongs.

As is evidenced from the experiences of the respondents, ensuring organizational

capacity for sociopolitical discourse constitutes a substantial component of the

burgeoning URM and female STEMM communities. In STEM-Spin, facilitators

deliberately initiate discussions regarding the history of the social, political, and

economic conditions that produced the music, DJing, and turntablism.[9] Dr. Teresa Lang

explains:

> I think the opportunity is for kids not just to enjoy emotional attachment to
> the audio aspects of [the curriculum], but to use […] the text that's
> communicated [in the lyrics] or what the feelings suggest as a way of
> understanding what these individuals […] were experiencing at the time
> that generated this creativity, this creative product. And I think that is
> where these things come together. That there's the opportunity for kids to
> learn about what was happening in the lives of these people that generated
> this emotional representation that's been caught as audio and communicated
> through a turntabling experience.

Additionally, Dr. Teher describes the importance of having professional DJs come into

the STEM-Spin classroom to share their experiences with the students. She also goes on

to explain how these visits can lead to less explicit, but equally important, opportunities

for social justice discourse:

> We might [have an artist visit the class] and talk about their lives, talk
> about where they're from, and relate it to the students' experience. […] We
> do talk about identity development as well […] Our goal is to have
> [students], especially students of color, develop this other identity for
> themselves […] [to challenge tracking] when that happens […] so they
> know it's possible for them to do more advanced work, and to want to do
> more advanced work. So I think there are more direct and indirect ways that

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[9] Turntablism refers to a performance technique involving at least two turntables and an audio mixer to either
transition between songs or combine elements from multiple songs together to produce original musical content.

social justice is woven into the curriculum, but it's definitely a part of the STEM-Spin approach, curriculum, programming and training for teachers.

Both of these quotations underscore deliberate efforts by the STEM-Spin organizers to speak to the social, economic, and cultural position of the artists and innovators of the genres and the technologies used in the classroom. As Kim et al. (2018) and Nasir and Vakil (2017) suggest, connecting these sociohistorical and contemporary texts to the lived experiences of the students (as Teher describes) has a profound impact on connecting the students' identities with the material. Overall, however, most of the STEMM organizations weave these social justice themes into their curricula through implicit, indirect means facilitated by adherence to best culturally responsive practices.

The more student-led, culturally responsive structure of MC^2, WRTB, and Afrorack means that, in those programs, sociopolitical discourse emerges more organically as the students bring their social and political experiences to the classrooms and to their artistic expression. Lesley Han explains such structures best:

> I think any course that we have as a group of girls and gender-expansive people, they're being taught by a woman or gender-expansive person, something like [that in] engineering is inherently political.[10] Most of our teachers are people of color, most of our students are people of color. Us gathering, sharing knowledge, that in itself is a revolutionary act. Our sheer existence is political, so that to me is where a lot of that happens […] If your curriculum is culturally responsive that means it does have components that are related to the students' personal experience. And those personal experiences could be about politics, and food or Ariana Grande or whatever it might be, if that's where the conversation goes that's where the conversation goes as long as you're making it relevant and thoughtful and giving them also the concept of academic rigor with that assessment.

In other words, for groups that have experienced systematic marginalization in fields like STEM, gathering as a community to develop those skills and nurture that identity

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[10] The term "gender-expansive" refers to "someone with a more flexible gender identity than might be associated with a typical gender binary" (Wamsley 2021).

represents an act of defiance against structures of oppression (e.g., racism, xenophobia, misogyny, transphobia, etc.). Furthermore, in allowing the students to ultimately shape the direction of the curriculum with their sociocultural identities, WRTB and Sound Gal staff must be capable of facilitating potentially challenging sociopolitical conversations when they arise. Dr. Pane describes how students in MC^2 utilize the exercise of composing rap verses to connect science concepts to their personal experiences:

> One of the main goals of the program is to encourage students to draw connections between science content and their lived experience so that's a benchmark in how we assess students and how they participate in their science raps. So in that, right, we're not deliberate in saying you have to talk about a social justice issue, but the demographic of the students we're working with and being in the context we're in, we notice that the lived experience that the students want to critique and challenge are those that are sociopolitical. So if students are talking about education systems, they're talking about race, they're talking about sexuality, they're talking about gender expression. They're talking about all these things because they've lived and experience these challenges when it comes to social justice. So they're talking about these things and drawing connections to science content and making sense of their realities and lived experiences.

Like those in WRTB and Sound Gal, the MC^2 students bring their experiences to the curriculum, and culturally responsive pedagogy inherently demands that the facilitators be sensitive to the social, cultural, economic, and political positioning of those students. How the participants choose to incorporate their personal experiences into their STEMM expressions is ultimately up to them, but, given that these programs seek to empower disenfranchised communities, sociopolitical conversations appear likely to occur.

The structure of Afrorack, especially with respect to the specific tools Guice implements to educate participants, results in a different take on sociopolitical discussions. Guice explains that, with synthesizers:

> We tend to talk about things in the future tense. This idea of Afrofuturism, this idea of a world beyond or an existence beyond what we're experiencing

now […] imagining that the tools we're using now are a in a way a part of this timeline uninterrupted by trauma. And that's super important because especially in the Black community, there's a lot of things going on, so whether you're talking about enslavement, or you're talking about gang violence, poverty, or there's sort of trauma that we're all trying to work through. Being able to use that meditative process to sort of teleport to a place where we can see ourselves participating in this reality where we're unaffected by that trauma, opens up this huge window of opportunity for community growth and also personal growth.

Afrofuturism refers to a movement in art and fiction featuring futuristic or science fiction themes that incorporate elements of Black history and culture (Crumpton 2020). Author Mark Dery, credited with coining the term in his 1994 "Black to the Future" essay, defines Afrofuturism as, "Speculative fiction that treats African American themes and addresses African American concerns in the context of twentieth-century technoculture – and, more generally, African American signification that appropriates images of technology and a prosthetically enhanced future." He then asks the reader, "Can a community whose past has been deliberately rubbed out, and whose energies have subsequently been consumed by the search for legible traces of its history, imagine possible futures?" (Dery 1994). Nova Sparks, author of the *Dome* trilogy, states that in Afrofuturism, "We see the possibilities of a society of Black men and women that is steeped in our history, but also embraces our advancement while protecting both as a means for survival. Seeing this can and has inspired more of us to invest in our communities, to continue to dominate in the STEM field and the arts, and to move forward in our quest to reach back into our communities by creating opportunities and guidance for our youth" (Crumpton 2020). With Afrorack, Guice pursues precisely that: creating experiences for marginalized Black youth to envision access to unbounded possibilities in both science and art. As in WRTB and MC[2], these conversations emerge

from student-led exercises and the lived experiences of the students ultimately inform

how they and the facilitators discuss these sociopolitical concepts. Whether the

organizations in this study included deliberate set-pieces in their curriculum for

sociopolitical dialogue or allowed the students to incorporate sociopolitical themes

organically as a function of their lived experiences, each of the programs recognized the

importance of social justice themes in their respective curricula. Through commitments to

culturally responsive pedagogical practices, all STEMM program organizers interviewed

here exhibited profound desire to facilitate meaningful sociopolitical dialogue to validate

the experiences and distinct cultural capital of their participants.

Although MC^2, STEM-Spin, and Afrorack articulate specific commitments to

redressing enthnoracial inequities in STEM, the respondents in this study stressed that

their respective programs have emphasized inclusivity beyond the underrepresented

groups. Dr. Pane discusses how the demographics of MC^2 classrooms depend on the

location of each program, which they have implemented in a variety of cities:

> [We] traditionally work in New York City, so [the classes are] mainly
> Black and Latinx students. But we've done MC^2 in other places like in
> Toronto, and Jamaica, and Houston.[11] And we've done it in predominantly
> White schools as well and had [similarly successful] results.

Pane goes on to discuss the importance of inclusion in STEM for society at large:

> [We need to be] providing recognition, but also providing opportunities for
> students to see people from diverse backgrounds and their contributions to
> science and taking a step further when it comes to pedagogy and
> instruction, engaging in science in a way that is culturally responsive, not
> just in a way where we're privileging whoever is the "smartest" and we're

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[11] Dr. Pane brings up Toronto and Houston as meaningful case studies in the context of the program's inclusivity
due to the diverse demographic composition of those cities. Toronto's racial composition is, according to the 2016
Census, 50.2% White, 12.7% East Asian, 12.3% South Asian, 8.5% Black, 7.0% Southeast Asian, 2.8% Latin
American, 2.0% West Asian, 1.1% Arab, 0.7% Aboriginal, 1.5% two or more races, and 1.3% Other (Statistics
Canada 2017). According to the US Census Bureau, Houston's racial composition is 57% White, 45%
Hispanic/Latino (includes individuals in other races), 22.6% Black, 6.8% Asian, 2.2% two or more races, 0.3%
Native American, and 0.1% Native Hawaiian (United States Census Bureau 2020).

not privileging just White men, because that's what the science discipline has [historically] privileged. […] Look at the world, the STEM fields are growing at a rapid rate. Jobs are growing, opportunities are growing, but also the need for competent people in STEM, who have STEM skills […] It's super important for us to have students, embark and engage in those fields, and if we're not doing our best and our due diligence to encourage all students, right, not just black and brown, but all students, to pursue careers in STEM, but in a way that authentically recognizes them, that authentically represents them, then we're doing a huge disservice not just to the students but to the nation.

Dr. Teher's perspective expands on the assertion that culturally responsive science education for students of color has the potential to resonate with and "authentically recognize" most, if not all, students, regardless of their ethnoracial identities:

The intended demographic [of STEM-Spin] is […] all students. It's our approach to just make sure that we *also* reach students of color. [12] If we can make this program accessible to students of color it's going to be accessible to all students. I think the challenge that with other programs that they're intended to reach all students, but the approach is often just for say, White males. So I think when there is the intention of specifically reaching students of color and using a culturally specific approach, it's accessible for all students including White students and Asian students. I think it's the reason why hip-hop and rap is so accessible […] it's because it's a universal story […] [And] it's not just hip-hop and rap. There are all sorts of genres that are part of, and embedded in, the program.

In other words, the organizers of these STEMM programs recognize that being culturally responsive to underrepresented students of color does not inherently exclude White and Asian (i.e., dominant identity) students from enjoying the benefits of the curriculum. The concept of "Universal Design" (UD) involves designing products and spaces with the intention of use for all people across as wide a range of characteristics as possible (Mace 1997). Although scholars, engineers, and scientists developed the UD paradigm with consumer products and spaces in mind (examples include curb cuts, automatic doors, closed captioning on TV sets, etc.), educators and academics have since sought to apply

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[12] Emphasis taken from original recording.

UD principles to educational settings (Burgstahler 2009; Seok et al. 2018; Minow 2013). Of the seven principles that guide UD sensibilities and aesthetics, the first, "equitable use," is of greatest consequence to this inclusivity discussion in STEMM programs. A fundamental, and particularly germane, tenet of the equitable use principle asserts that design should "avoid segregating or stigmatizing any users" (Mace 1997). As the literature and respondents have revealed, the intimidating, unwelcoming, and potentially hostile learning environment of conventional STEM education therefore fails to nurture a universally accessible space for all students. Centering Black culture need not occur at the expense of other ethnoracial groups, especially when (in the case of hip-hop and DJ concepts) one considers the ubiquity of Black culture, particularly Black *music* culture across the country and throughout the world, regardless of the listeners ethnoracial or national identity. Rather, centering Black culture creates meaningful opportunities for diversity and inclusion in STEM across the ethnoracial spectrum.

In the case of WRTB's Sound Gals program, the question of resonating beyond the target demographic is not a relevant one to ask. Making STEM, especially with respect to audio engineering, accessible to women and gender-diverse people of all ages comprises the fundamental objective of the organization. The stark underrepresentation of women in most of the fastest growing STEM fields necessitates the development of communities led and occupied by women and gender-diverse people.[13] The gender disparity in Afrorack's attendance highlights the need for organizations such as WRTB:

> **Dana Maier-Zucchino:** Would you say it's two-thirds male and one-third female? Or is it smaller than that even?

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[13] With the exception of health-related fields, women remain underrepresented among college graduates – Bachelor's and advanced degrees – in most of the STEM majors, including math, physical science, engineering, and computer science (Fry et al. 2021).

Aaron Guice: Smaller than that […] We had two girls who were with us for the first couple weeks and then they disappeared. I'd say, maybe that's more of a cultural thing, where electronics and heavy machinery is seen as more suited as males than females, but yeah it tends to be that way. And maybe there needs to be more growth in our communities separate from this.

DMZ: My next question was [actually], what do you think might help alleviate that tension there, what would it take to get more young girls about the Afrorack program?

AG: Yeah, it's tough. I think just sort of being able to challenge traditions. And I think that will start a trend.

Guice's experience with female participation in Afrorack appears to exist in tension with the high demand exhibited by women and girls in Lesley Han's WRTB and Sound Gal workshops. Ascertaining the roots of the conflicting experiences for these two organizers ultimately falls beyond the scope of this project and attempts to explain this phenomenon with such relatively limited information would be little more than conjecture. Future researchers would do well to conduct participant surveys and/or interviews to better understand the gender disparity among Afrorack's participants. Nonetheless, the existence of this disparity highlights the value of female and gender-expansive centered programs and spaces like WRTB and Sound Gals in the struggle for holistic equity in STEM fields.

Discussion and Implications: Moving Forward

Given the proliferation of STEMM programs committed to redressing inequities in STEM participation, reaching a deeper understanding for how music supports STEM identity development has invaluable implications for such programs. Generally, the literature and evidence from the interviews point to the notion that culturally relevant and

responsive pedagogy fosters participation of underrepresented populations by reflecting and validating the non-dominant cultural capital of those populations. STEMM educators and program administrators also appear uniquely positioned to meaningfully empower their students and challenge broader societal inequity and injustice by developing capacity for sociopolitical discourse in the classroom.

Grounding this project in schooling identity paradigms such as Reay's (2010) social and learner identities, culturally relevant pedagogy, and Carter's (2005) non-dominant cultural capital has provided foundational insights regarding the ways gender, ethnoracial identity, and music pedagogical practices intersect in STEMM programs. Across the STEM identity and music education literature, validating the social identities and non-dominant cultural capital of underrepresented student groups appears as a crucial component in the inculcation of desired learner identities. Colorblind discourses pervade both STEM and music education, which allow normative, hegemonic ideologies to create boundaries regarding who has access to STEM and/or music identities (Hess 2017; Nasir and Vakil 2017). Without conscious, intentional validation of underrepresented students' sociocultural experience and non-dominant cultural capital, these students are likely to experience identity friction in the classroom.

To reduce this identity friction, encourage participation, and denaturalize the boundaries that exclude young girls and ethnoracial minorities from STEM, STEMM programs appear to be moving in a productive direction. Overall, the interviews with STEMM organizers demonstrated compatibility between the literature and the pedagogical strategies at the various organizations. For example, recall that Kim et al. (2018) find that the presence of female role models greatly improves STEM affinity

among young women. The female and gender-diverse leaders, educators, and staff at Women Run the Booth and Sound Gals therefore provide their participants with the type of mentorship statistically demonstrated to cultivate STEM identities in young women. Furthermore, MC^2, WRTB, Afrorack, and STEM-Spin all cited community building as a foundational component of their culturally relevant pedagogies. The Kim et al. (2018) and Nasir and Vakil (2017) findings regarding the important role of community building in fostering greater engagement from people (especially women) of color thus applies across all the STEMM organizations interviewed in this study. In the four organizations studied here, culturally responsive pedagogy acknowledged and respected the non-dominant cultural capital of the participants by a) contextualizing STEM instruction through culturally relatable frameworks, and b) creating space for student-driven ownership of their experience within the various programs. In MC^2, Afrorack, and WRTB, the student ownership component essentially characterizes the entire participant experience, while in STEM-Spin student autonomy was bounded within a specific period of time at the end of each class. The culturally relevant pedagogical approaches of STEMM organizers also reflect insights from the findings from Abril (2006), Hess (2017) and Nasir and Vakil (2017) by developing the organizational capacity for sociopolitical discourse. This also increases the capacity of STEMM organizations to further validate the cultural capital of their participants by demonstrating sensitivity and respect for the students' social, cultural, political, and economic identities. For URM students, the culturally responsive pedagogy of STEMM programs embodies a path to inclusivity and equity in the STEM fields, especially given their ability to resonate and succeed with learners outside of the specifically articulated demographic. The potential for gender

disparities to characterize even programs dedicated to social, political, and economic equity, like Afrorack, underscores the need for community building programs like WRTB and Sound Gals with female leadership and mentors. Per Kim et al. (2018), redressing gender inequities in STEM also demands that men in these fields (including STEMM organizers and participants) reflect and consider how they might structure programs and foster discourse to broaden female STEM inclusivity.

This exploratory study has illuminated the need for future research on the activities of STEMM programs, as well as their role and impact in education and society at large. STEM-Spin and MC^2 have both collected data demonstrating positive results on student outcomes, particularly with respect to student engagement and their ability to identify with STEM fields (Emdin et al. 2016; Spencer et al. Unpublished). More data must be gathered, however, as these programs continue to grow, expand, and develop. For example, quantitative data might be gathered on student test scores in math, science, and even language arts, to determine how such programs affect participant performance compared to students receiving more traditional instruction. Future should interview participants in these new pedagogical practices to gain a deeper understanding for how the students experience STEM identity cultivation through these programs. Such interviews might also reveal meaningful discoveries regarding the social-emotional impacts of STEMM programs, as well as the importance of such impacts on the student experience. Longitudinal studies might also determine the impact of these STEMM interventions on potentially life-defining student decisions such as college major and career selection. Alternatively, interviews in the longitudinal studies might uncover insights as to the benefits of STEMM programs beyond the academic and professional

decisions of students. Furthermore, research should be done to explore STEMM's efficacy and strategies in the broader STEAM landscape. Such research might investigate what advantages (and/or disadvantages) music brings to STEM learning that other arts may or may not afford to the fields. Additionally, although the STEMM leaders interviewed here assert that their respective programs resonate beyond their target demographic, participant data collected by future researchers of such programs might empirically reinforce (or rebut) those claims. The intersection of music and STEM therefore represents fertile ground for valuable research to deepen our collective understanding of how students come to embody a STEM identity and what the overall effect of that identity exactly is as it relates to the way those students navigate the world around them.

Both music and STEM education programs play a crucial role in formation, affirmation, and/or rejection of learner identities as mediated by social identities. The empirically demonstrated impact of culturally relevant pedagogy on students in both music and STEM validates the work of the STEMM educators and organizers interviewed in this study as they align their courses with the social identities of their target demographics, be that through the tools they implement (i.e., turntables, or synthesizers), the styles they invoke (i.e., hip-hop, electronic dance music, jazz, etc.), or simply through who they are and what their identities symbolize in positions of authority and power. Without considering potential issues of identity friction, STEM programs in schools may only reach students who already consider the subject as a potential piece of who they are or might become. The STEM instruction status quo largely precludes populations with the greatest need from taking advantage of the STEM path for potential social mobility.

Absent intervention, these patterns serve to perpetuate the cycle of socioeconomic, racial, and gender inequality. Beyond the STEM classroom, STEMM spaces also provide radical opportunities to empower marginalized students by engaging in and supporting sociopolitical discourses that challenge, critique, and dismantle historical structures of oppression at large. The activities of music-integrated STEM programs are thus justified by powerful theoretical and empirically demonstrable foundations. STEMM organizers like those interviewed in this study therefore fundamentally disrupt and abrade the gendered and ethnoracial boundaries that currently circumscribe normative conceptions of the STEM identity.

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