# (Designing for) learning computational STEM and arts integration in culturally sustaining learning ecologies

Dionne N. Champion, Eli Tucker-Raymond, Amon Millner, Brian Gravel, Christopher G. Wright, Rasheda Likely, Ayana Allen-Handy and Tikyna M. Dandridge
*(Author affiliations can be found at the end of the article)*

Received 31 January 2020
Revised 30 June 2020
12 August 2020
16 August 2020
Accepted 5 October 2020

## Abstract

**Purpose** – The purpose of this paper is to explore the designed cultural ecology of a hip-hop and computational science, technology, engineering, and mathematics (STEM) camp and the ways in which that ecology contributed to culturally sustaining learning experiences for middle school youth. In using the principles of hip-hop as a CSP for design, the authors question how and what practices were supported or emerged and how they became resources for youth engagement in the space.

**Design/methodology/approach** – The overall methodology was design research. Through interpretive analysis, it uses an example of four Black girls participating in the camp as they build a computer-controlled DJ battle station.

**Findings** – Through a close examination of youth interactions in the designed environment – looking at their communication, spatial arrangements, choices and uses of materials and tools during collaborative project work – the authors show how a learning ecology, designed based on hip-hop and computational practices and shaped by the history and practices of the dance center where the program was held, provided access to ideational, relational, spatial and material resources that became relevant to learning through computational making. The authors also show how youth engagement in the hip-hop computational making learning ecology allowed practices to emerge that led to expansive learning experiences that redefine what it means to engage in computing.

**Research limitations/implications** – Implications include how such ecologies might arrange relations of ideas, tools, materials, space and people to support learning and positive identity development.

**Originality/value** – Supporting culturally sustaining computational STEM pedagogies, the article argues two original points in informal youth learning 1) an expanded definition of computing based on making grammars and the cultural practices of hip-hop, and 2) attention to cultural ecologies in designing and understanding computational STEM learning environments.

**Keywords** STEM, Informal learning, Dance, Computational making, Cultural learning ecologies, Culturally sustaining pedagogies, Hip-hop pedagogy

**Paper type** Research paper

## Introduction

Hip-hop, science, technology, engineering, and mathematics (STEM) and computing have evolved as cultural practices that have become ubiquitous in the lives of Black and Latinx youth. Like all social and cultural practices, they are subject to, and constitutive of, the

This work is supported through a grant from the National Science Foundation, DRL #1842272 and 1842278. Part of this project was originally carried out at TERC in Cambridge, MA.

Information and Learning Sciences

2398-5348
DOI 10.1108/ILS-01-2020-0018

values, ideologies, relationships, histories and resources of the individuals engaging in the activities. However, STEM disciplines are often considered objective and "culture-free," when in fact they are the products of implicit White hetero-European value systems (Griffin *et al.*, 2015; Medin and Bang, 2014).

Bang (2015) calls attention to emergent issues when perceptions of cognitive and developmental pathways are shaped by positing White, US, middle-class values as universally normal, natural and right. When this happens, Whiteness becomes a conduit for white dominance and privilege and the subordination of others (Sammel, 2009) in ways that impact disciplines such as STEM and computing. For example, formal STEM learning environments can require the suppression of knowledge and practices that do not support Eurocentric and Westernized perspectives (Aikenhead and Elliott, 2010). STEM education has historically required assimilation through the removal of cultural markers and signifiers that were not seen as beneficial for the expression and assessment of knowledge (Aikenhead and Elliott, 2010; Emdin, 2016; Rosebery *et al.*, 2016). Similar arguments can be made for research on computational thinking in STEM, where limited criticality has surfaced in the literature (Wilkerson *et al.*, 2020). When Whiteness is used as the rubric for structure, other ways of sense-making and cultural processes are undervalued and overlooked, and minoritized youth can struggle to fully engage and prosper in academic settings when their cultural wealth is undervalued (Yosso, 2005).

Culturally sustaining pedagogies (CSPs) reject assimilation and colonization for the pursuit of cultural pluralism. CSPs fully recognize that contemporary communities of practice are rich in resources for learning in formal settings, while also critiquing those practices and examining them for their own inequitable power relations and marginalizations (Paris and Alim, 2014, 2017). Furthermore, CSPs value, affirm and include youth culture in the learning process. As such, this paper presents an empirical design-based research (DBR) study of a culturally sustaining learning environment for Black and Latinx middle-school aged youth (Paris and Alim, 2014, 2017) that combined cultural practices of hip-hop and computational STEM within the learning ecology of a dance center.

In our analysis, we examine the learning environment and the learning processes within it from the perspective of cultural learning ecologies (Lee, 2008). Through a close examination of youth interactions in the designed environment – looking at their communication, spatial arrangements, choices and uses of materials and tools during collaborative project work – we show how the learning ecology, designed based on hip-hop and computational practices and shaped by the history and practices of the dance center where the program was held, provided access to ideational, relational, spatial and material resources that became relevant to learning through computational making. We also show how youth engagement in the hip-hop computational making learning ecology allowed practices to emerge that led to expansive learning experiences that redefine what it means to engage in computing. Finally, we discuss the implications for this ecological perspective on designing culturally responsive learning environments using hip-hop based education (HHBE) practices to expand the ways minoritized youth experience computation.

## Theoretical framework

We draw on three theoretical orientations in ways that informed our design and subsequent analysis in an explicit attempt to create and understand a learning environment that is welcoming and nurturing for minoritized youth. We argue that:

(1) cultural ecological perspectives help to shape the design and understanding of computational STEM learning in expansive ways;

(2) hip-hop can inform culturally sustaining engagement in computational STEM; and

(3) *making grammars*, as an expansive definition of computational STEM, open possibilities for understanding learning in integrated computational STEM learning spaces.

*Cultural ecologies and repertoires of practice*

Our use of culture as a construct refers to the historical and socially shared practices in which communities or groups of people engage. Culture is created, re-created and remixed every day. Rather than something that is isometric with an ethnic group, culture can exist on different scales of group size, group type and time. Cultural ecologies are the landscapes of culture, they refer to environments that are constituted from the historically situated practices, artifacts, relationships, ideas, rules and spatial arrangements that people engage with in families, affinity groups, institutions and larger social arrangements (Lee, 2008, 2017; Rogoff, 2003). Gutiérrez and Rogoff (2003) use the phrase "repertoires of practice" to explain what people know how to do with these resources and how they think about the world.

Computing and hip-hop, and engagement with media texts in general, are ubiquitous in contemporary youth cultural ecologies. As such, they are resources for sense making that youth use with more or less emphasis to construct themselves and their participation in different spaces (Dolby and Rizvi, 2008). Repertoires of practice lend an understanding of each person as a multicultural being and each of our social interactions as intercultural (Warren and Rosebery, 2011). In this view, hip-hop, computation and learning are constituted through intercultural practices supported by historically and culturally situated ecologies in which youth live (Lee, 2008; Nasir *et al.*, 2006). At the same time, cultural ecologies are powered, affording access and nurturing pathways for some and not others, depending on different settings. Hip-hop, for instance, as a male dominated industry, can be marginalizing for Black women and girls (Pough, 2015), just like STEM (McGee and Bentley, 2017). Our learning environment however, supported Black girls to participate as they drew on multiple kinds of resources, including hip-hop.

*Hip-hop as culturally sustaining pedagogy*

Through methodologies oriented toward decolonizing learning, CSP highlight various means by which youth cultural practices can be sustained alongside and intertwined with more canonically academic cultural practices (Alim and Paris, 2017; Paris and Alim, 2014). As part of our design, we imagined "new trajectories and forms of agency in learning processes for youth in vulnerable circumstances" (Gutiérrez, 2016, p. 187), conceptualizing learning through hip-hop as a means for actualizing a CSP (Paris, 2012).

HHBE is one of numerous ways to actualize CSP (Alim and Haupt, 2017; Kim and Pulido, 2015; Ladson-Billings, 2019; Paris, 2012). Hip-hop, as a cultural movement, has the potential to raise student consciousness (Akom, 2009; Duncan-Andrade and Morrell, 2005; Kuttner, 2016) and can be incorporated into learning spaces to engage young people (Covington *et al.*, 2018), including giving them a voice within the curriculum (Emdin, 2016; Paul, 2000). While HHBE research has often occurred in humanities classrooms (Duncan-Andrade and Morrell, 2005; Kim and Pulido, 2015), there has been some research using HHBE in science education (Adjapong and Emdin, 2015; Emdin, 2010) computer science education, (Gorson *et al.*, 2017) and software design for learning (Pinkard, 2001). In most cases, including those referenced here, the primary pedagogical approach has been to incorporate one or more of the foundational elements (MCing, DJing, B-Boying, graffiti and knowledge of self) (Afrika Bambatta in Chang, 2009) into learning environments.

However, there is more to hip-hop than the artistic elements. Secondary elements of hip-hop such as collaboration, competition, remixing, sampling, performance and identity-building also contribute to HHBE (Love, 2014; Marsh, 2012; Petchauer, 2012). Our work leverages both artistic and secondary elements of hip-hop for learning computation, situating young people's "dynamic cultural dexterity as a necessary good and see[ing] the outcome of learning as additive rather than subtractive" (Alim and Paris, 2017, p. 1).

Our definitions of hip-hop elements are inclusive of those found in HHBE literature and yet different. They rest on responses from youth and hip-hop practitioners who participated in focus groups about what hip-hop meant to them. We used those definitions to inform the creation of design principles for our hybrid space. Those principles included: claiming and creating space for self and others, breaking down and building up, interactivity, making-do, authenticity and self-expression. We found some of these same principles in the practice of computational STEM. For instance, interactivity and self-expression are hallmarks of hip-hop practices that include call and response, relationships between DJs and dancers (Abdurraqib, 2019) and rap battling (Alim, 2006) and of current participatory cultures with digital technologies (Jenkins, 2009). Breaking down and building up sounds to make songs in hip-hop (9th Wonder in Mass Appeal, 2015) is similar to decomposing problems in order to solve them and create solutions in computational thinking (Shute *et al.*, 2017). Hacker culture, making-do, has always been a part of hip-hop and cultures of the Black Atlantic, such as when Grandmaster Flash broke open his mixer and created his own cueing system to listen to one record while he was playing another (Hot 97, 2016; Christopher, 2018). As such, our work sought to bring hip-hop and computational practices in line with each other for the purpose of learning both, not as using computation to serve in the creation of hip-hop artistic practices, or hip-hop as motivation for learning computation as others have nimbly done, (Gorson *et al.*, 2017; Magerko *et al.*, 2016) but to guide the ways in which we constructed the learning ecology of the camp and to expand definitions of computation in more culturally sustaining ways (Eglash *et al.*, 2013a, 2013b).

*Making grammars: a frame for understanding computational STEM and the arts*

We use making grammars as a means of describing computation, where computation is framed as inquiry distributed across people, materials and questions in a specific context (Humphreys, 2004). Making grammars offer a way of theorizing how people relate to and engage with materials as they make things. It is grounded in a foundational definition of computation: creating and combining rules that encourage different kinds of expected and/or emergent behaviors (Knight and Stiny, 2015). Computation defined in terms of making grammars is a process of developing rules and observing (or sensing) the behaviors they produce. Knight and Stiny (2015) define making grammars as "*doing* and *sensing* with *stuff* to make *things*" (p. 13). For instance, programming (doing) and seeing (sensing) code (stuff) to make a program (thing) is an example of making grammar. As people do and sense with stuff to create things, they make decisions about how to put materials together–they create rules for the ways in which parts interact. Depending on the outcome, they iterate on what they do. To put that more tangibly, imagine a young person arranging commands to tell a graphic (in Scratch) to move up and down on the screen when the laptop mic senses loud noise nearby. The tacking back and forth between the code and how it behaves in response to noises yields a Scratch program that the young people can run for their friends, where little versions of themselves dance on the screen. This vision of computation highlights the performative aspects of making (Knight, 2018), where evolving sets of rules and results are bound to time and place. As such, we utilize making

grammars within an ecological framing to suggest a new way of thinking about computation in context, relocating computation as an ecologically situated activity rather than an individual cognitive accomplishment, as often happens with computational thinking (Wing, 2006).

In describing computation as making grammars, it becomes important in our analysis to:

- describe how people are manipulating materials, be they physical, virtual, or both, to make a product; and
- describe how people create and employ sets of rules to produce desired or expected results, with unexpected outcomes informing redesigns.

Paying specific attention to how rules and relationships organize computational STEM and art-based activities, *computational making* understood through the lens of making grammars becomes a way to re-envision computation.

From these three theoretical perspectives we designed a learning environment for the emergence of a hip-hop computational STEM learning ecology. The learning ecology included aspects of the environment that were intentionally designed, histories of the dance center that were leveraged in the design, and aspects that emerged as new ideas were brought in and co-developed with participants. The ecology we built stemmed from three main cultural traditions: hip-hop; computational STEM; and the material, historical and programmatic ecology of a dance school. In the following section we describe the designed learning ecology.

*STEMCees – Hip-hop computational STEM camp*

The 60-hour camp was designed to function as four 15-hour activity sets (10 a.m.-1 p.m. Monday-Friday), one implemented in each week and broken into old school (hip-hop history and electrical engineering), new school (contemporary hip-hop and programming digital media), future (Afrofuturism and physical programming) and block party (designing an interactive space and learning multimedia project planning). These themes intentionally focused attention on the evolution of both hip-hop and computational STEM, presenting both as sets of cultural practices that grow and change.

The themes offered youth ideational resources to draw from. For example, the first theme, old school, introduced participants to electrical engineering as part of the history of hip-hop (e.g. the invention of the crossfader to switch between records) and engaged participants in explorations of circuitry through creating paper circuits. Activities connected hacking and making-do practices of hip-hop pioneers like Grandmaster Flash to the work that youth participants engaged in as makers. Introducing hip-hop pioneers in this context also allowed youth to discover how hip-hop practices like hacking were used to claim space and disrupt power structures.

The second theme, new school, focused on parallels between hip-hop music production and relevant computational practices. Participants learned to program computational art through an object-oriented drag and drop programming language (e.g. Scratch) and to program music through free music production software (e.g. Apple GarageBand, drum programming). These activities focused on developing understandings of how problems can be broken down and component pieces can be built up together to make things work.

The third theme, the future, focused on embodied computing, integrating hip-hop music and dance with computational practices. Participants physically explored computing programming concepts such as conditional "if/then" statements, sequencing, parallel processing, multiple embedded patterns and do-while loops through hip-hop music/dance

integration. They used what they learned to develop group projects that they would present at the end-of-camp block party.

The block party itself was a festival-like showing of participant work where parents, family and community members came together to observe, interact with and enjoy participants' work. The structure and activities for the third and fourth week were conceptualized by the facilitators based on the youth participants' ideas about the kinds of projects they wanted to work on and were agreed upon by the youth. Groups did not come up with their own projects, but participants had an opportunity to choose the group and the project they wanted to work on after hearing what all the project options were. They took the projects ideas and ran with them, changed them, or scrapped them altogether, finished what they could, reassessed as they went along and shifted their projects based on their evolution. The diversity of participatory modalities (e.g. dancing, designing, DJing) provided participants with multiple ways to engage in shared experiences. The set of collective experiences provided a variety of pathways for authentic expression and engagement, so that by the end of camp, individuals could choose the activities they wanted to concentrate on.

*Material resources.* As activities were centered around making with people and materials, it was important to design the space so that tools and materials were readily available and easy to reach while also encouraging participants to think about hip-hop and computation as interactive. We filled the makerspace with inexpensive, recycled and found materials (i.e. cardboard, string, wire, paper, felt, glue) along with other tools (scissors, box cutters, screwdrivers, hammers, pliers) allowing for multiple entry points for exploring ideas. Youth had access to other materials and tools, including drills and screwdrivers, LED lights, wire, aluminum foil and copper tape, batteries and tools for soldering, as well as littleBits and programmable devices including: Makey Makeys and micro: bits. Coding platforms, such as Scratch, were all blocks-based. We also set up workstations with access to a limited number of tablets, laptop computers and electricity.

The large dance studios had a turntable and performance speaker systems that played music from a laptop or mobile device. Participants were encouraged to bring in and play their own music, which created authentic opportunities for them to claim the space as their own. They often played songs from YouTube or that they had downloaded from the Internet, but they were also able to play records that had been left in a bin at the studio for some years, at one point serving as vital music sources for the school.

*Relational and spatial resources.* The program took place in a dance studio with large mirrored rooms and a makerspace area, a carpeted room with table and chairs. Participants had access to open floor space in the dance studio to develop ideas through movement, music and art. These spaces allowed youth to spread their work out and to leave their works in progress in place overnight.

Participation in activities was structured to support collaboration. There were two main participation groupings for activities, whole group and small groups. Participants did not typically work individually. Whole group activities included morning circles, afternoon sharing, dance warm-ups and freestyle dance circles that eventually became part of the daily routine. They also included discussions where the youngest participants were invited to contribute, and their ideas were received and respected with the same import as older ones. During these activities, everyone was focused on each other in the same space. Whole group activities provided opportunities for self-expression and to practice being a good audience and giving feedback. Whole group activities generated routines for getting camp started in the morning, winding down at the end of the day and for building community.

In various small group activities, participants were placed in multi-age and multi-level groupings, reflecting way the dance center has been run historically. People switched from

group to group so that everyone was expected to be able to work with everyone else, rather than stay focused on one project or with one group of friends for the length of the camp. The purpose of switching small groups was to make them accountable for each other. They had to get to know one another and learn everybody's name and call them by it. It was also intended to develop their flexibility in how they communicated and shared ideas with each other.

All of these resources, those from hip-hop, computational STEM, the culture of the school and participants' own experiences and ideas contributed to what emerged through participants' active creativity. Our research questions focus on how youth used those resources in computational making, connecting the resources in the cultural learning ecology with the learning and activities that took place within it.

*Research questions*

Within a designed culturally sustaining computational making ecology for middle school youth, in what ways do youth use resources from the built and emergent cultural learning ecology to learn and participate?

*RQ1.* How did the ideational resources, making grammars of hip-hop and computation, become resources for participation?

*RQ2.* How did material, relational and spatial resources open up possibilities for computational engagement and emergent practices?

## Methods

We used DBR (Brown, 1992; Cobb *et al.*, 2003; Design-Based Research Collective, 2003) to design, implement, study and iterate on the learning ecology. As part of our DBR, we engaged qualitative interpretive methods, seeking to highlight meanings and perspectives that were important to the participants (Denzin and Lincoln, 2008).

*Design research team*

Our project team is interdisciplinary, comprised of learning scientists in STEM, a computer scientist, engineers and engineering educators, urban education and identity scholars, community center directors and youth educators. All members participated in designing the learning environment and research methods including creating research questions, as well as designing data collection and approaches to analysis. The camp was run by Dr. Champion, the director of the dance school where the camp was held. Camp staff included young adults who were either dance instructors at the studio or rising seniors and first year college students. Older staff were facilitators and led breakout activities. Younger staff were considered mentors and worked alongside the younger campers as co-learners and guides. All instructors and mentors, and one of the research assistants, had been campers in similar programs run by the director in years prior.

*Participants and setting*

The camp was initially aimed at serving 20 middle school aged people and notice of the camp was made to the public in the late spring. However, a range of ages attended because families often asked to sign up siblings and other relatives. We made the choice to accommodate all and to shift our program design to reflect the authentic demand from the community. A core group of the summer camp participants had previous relationships with the arts center or with one another as dancers. As such, they had shared histories for

working together in the space. There were 29 participants, aged 6–17. Twenty-eight identified as African American and/or Black. One identified as Puerto Rican. Twenty-three participants identified as girls and six identified as boys. Staff included four instructors, one male and four mentors, one of whom was male. Twenty campers were new to the space and 9 were returning dance school students, sometimes since they had been three or four years old. In the example below, there are four girls and three female staff members – two adult instructors who switched off and a high school mentor.

The small city where the camp took place is predominantly African American (86 %) with a relatively high poverty rate (more than 25% of residents live below the poverty line). However, the arts center program draws a diverse group of students from the region, extending beyond the city limits to attract children from neighboring cities. While the vast majority of children from those communities who chose to participate in the program are Black, it would be a gross oversimplification to consider them a monolithic group. Participants came from a wide range of socio-economic backgrounds, family structures, school types (public, private and charter) and experiences with science, technology and dance.

The material, historical and programmatic characteristics of the dance center were also important to the learning ecology. The center housed a dance school as well as several music and martial arts classes. The dance school taught ballet, hip-hop, tap and other dance forms to children from very young ages through high school. Every year it put on a performance for Black History Month, The Spirit of the Baobab Tree. When the opportunity arose, the center also held summer programming that included STEM content along with dance-based programming. As a community program in a city where opportunities, options and safe spaces are limited, the center generally finds ways to accommodate any youth who want to participate in its programming. This often leads to a wide range in participants' ages, and as a result, much of the center's educational activities focus on nurturing collaboration across ages. For example, multi-age, multi-level group work was a valued practice at the center, as was a focus on encouraging self-expression. The four-week summer camp was no different. Families who were familiar with the center's programming brought children in the target age group as well as older and younger siblings to sign up for the program.

### *Data collection*

Data were primarily collected from daily observations and post interviews by two primary participant observers. Observations included collecting data from field notes; audio, video and photographic recordings; artifacts; and informal interviews. Video and audio recordings were made of all whole group activity and most small group activities using three stand-alone cameras and two head cameras.

### *Data analysis*

Analysis for this paper focused on video data of group project work, which offered rich information on the resources that participants used in interaction as they developed hip-hop computational making projects for the block party. We began analysis by applying a holistic-content analysis (Lieblich *et al.*, 1998) to gain a global impression of data. In addition to ongoing analysis of the corpus at large, we used data reduction methods to review data points that were dense with codes and practices that more explicitly reflected the intersection of computational making and hip-hop.

With this subset of data, we coded for participants' use of resources in the cultural ecology, how their design decisions aligned with design principles of the ecology, and for making grammars, which included decisions about how to put the materials together, and

rules they created for the ways in which parts would interact. Through iterative processes of axial coding, we identified subthemes and common themes (Corbin and Strauss, 2008), including ideational (hip-hop and computational), material, relational and spatial resources, and formulated meaning through clustering (Creswell and Poth, 2018). To contribute to trustworthiness in interpretation we focused on the context and intentions of local actors and used multiple data sources as described in data collection (Schwandt, 2000).

After data were analyzed through multiple conversations and repeated reading and viewing of data, we created analytic memos for the themes. We used multi-perspectival analysis, including all eight members of the research team, as a triangulation method for confirming our interpretations (Graneheim and Lundman, 2004; Patton, 1999).

Our analysis produced understandings of the ecology that were descriptive, interpretive and theoretical (Maxwell, 1992 in Miles *et al.*, 2014). In the findings sections, we present both thick description and analysis. Next, we share our interpretations of one illustrative example about what and how youth were participating and learning, and theoretical conjectures about cultural practices that contribute to culturally sustaining learning ecologies.

## Findings

Through discourse, video stills and narrative description, we have constructed a case that shows how the hip-hop computational making learning ecology provided access to ideational resources, including making grammars and relational, spatial and the material resources of the dance center in integrated culturally responsive ways that allowed practices to emerge. Additionally, hip-hop/computational themes of breaking down and building up, claiming/making space for others' self-expression, authenticity, interactivity, making-do manifested through their work.

### *DJ Makey Makey battle station*

The DJ Makey Makey Battle station was designed and constructed by a group of five girls, Darnisha (16), Ashanti (13), Lexie (15), Elanna (6) and Nylah (8). Darnisha, Ashanti, Lexie and Elanna, appear in this analysis as Nylah missed the last week of camp. The girls were aided by two adult instructors, who switched off sitting with the group and guiding them, and a high school mentor who also contributed ideas and guiding questions. The instructors and mentor are part of the cultural ecology of the dance center, constructing the space as intergenerational and, through their positions as dance teachers and students, as authentic. Their fluidity in and out of the group added to the multi-age character of the group with no one adult as instructor.

The battle station, intended to have block party guests face off with one another to see who could make the coolest mix, was constructed using cardboard, paint and two Makey Makeys connected to two laptops. Two opposing "DJs" could test their skills by touching foil "buttons" on the cardboard interface. Each DJ's "turntable" console had six "buttons" connected by wires to a Makey Makey and a laptop. The laptop ran a program, designed by the girls, on the Scratch programming platform. The girls created a program to play an a cappella rap vocal track (Will Smith's "Jiggy With It") when the start button was touched and had other sound effects options that would play when the other buttons were pressed (Plate 1).

The group engaged in a process of creative production that included:

- designing and building the structure from cardboard that would support DJing activities while accommodating both laptops and both Makey Makeys;
- building the circuits that would connect the foil buttons to the devices;

- designing the aesthetic features of the battle station;
- designing and building headphones that would keep each DJ connected to the Earth/ground button on their Makey Makey without using their hands; and
- creating a scratch program, which required finding, selecting and editing music and sound effects; testing different sounds; and troubleshooting issues with their program.

The project's physical construction was guided by hip-hop principles of interactivity and making-do. Group participation drew on the material and relational resources of the dance center and hip-hop, allowing the participants to claim space for themselves. They also used the ideational/making grammars of hip-hop and computation to construct the functioning program. Our analysis focuses closely on the work the girls did to collaboratively create the Scratch programs that would control each DJ's music options. We begin by describing their process, which began by searching for a song to use. The girls sat in a group around a laptop on the floor and discussed song options:

*Discourse Excerpt 1*

Darnisha: I don't – we should do like a um – Are we gonna do like a vocal song or an instrumental?

Elanna: I think we should do an instrumental.

Ashanti: It's up to y'all.

Lexie: Um [. . .] Instrumental.

Darnisha: Instrumental [. . .] so, okay.

Elanna: I think we should do instrumental.

Darnisha: What if we [were] able to get a song that didn't have like [. . .] the backing track? It was just like a [. . .].

Ashanti: Vocals?

Darnisha: Vocals [. . .] and then they added their own beat to it.

Ashanti: That would be cool.

Facilitator: So, pick an a cappella song and then what button they press makes the music behind it?

Darnisha and Ashanti: Yeah.

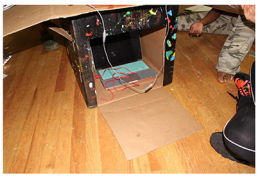


**Plate 1.**
The Makey Makey DJ Battle Station

Next, the girls began searching for an a cappella song on YouTube, deciding to look for an "old school" song by Tupac. They played clips from a few videos, immediately stopping the videos and telling six-year-old Elanna to cover her ears when they heard inappropriate language. They struggled to find a hip-hop song that did not have profane language. Eventually, 15-year old Lexie suggested a clean song, Will Smith's Summertime, and played it for the group.

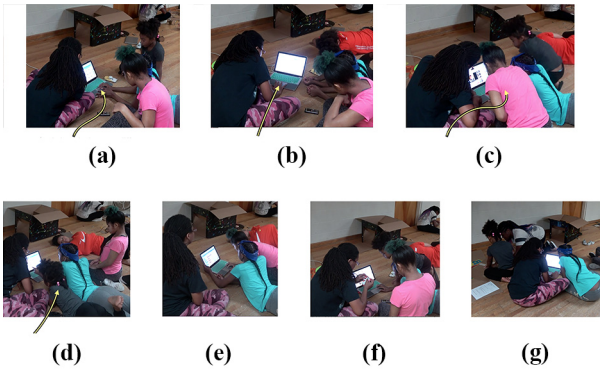
As they worked to develop their program, Ashanti took the lead operating the computer, navigating through program windows, and programming in Scratch as all four girls contributed ideas and suggestions. While Ashanti did most of the typing, the girls' orientation around the laptop shifted multiple times, and they slid the computer back and forth to one another as they talked through and executed their plans and ideas. They listened together and shared the screen in order to make decisions about which sounds to use and how to alter the program they were creating. Everyone contributed to the programming, making suggestions and helping to problem solve even when they were not touching the computer. Their various spatial arrangements can be seen below in Figure 1 and reflect the ways the dance center resources contributed to the cultural ecology as we will discuss.

The group refined their Scratch program through an embodied recursive process of iterative testing. Step by step, as in Discourse Excerpt 2, they ran bits of their program, breaking it down and building it back up, to make decisions about how to tweak it for the experience they wanted to create:

*Discourse Excerpt 2*

Ashanti: Echo? or no.

Darnisha: Let's see how it sounds (plays sound with echo).




**Notes:** (a) Ashanti tries out different sounds in the scratch library; (b) Darnisha troubleshoots an issue with scratch; (c) Lexie searches for a clean hip hop song; (d) Elanna selects a sound from the scratch library; (e) Ashanti passes the laptop to Lexie so that she can add to the scratch program; (f) Darnisha examines the Makey Makey while Ashanti adds sounds to scratch; (g) Darnisha and Ashanti refine sounds in scratch while Elanna works with a mentor to construct a prototype of their cardboard interface

**Figure 1.**
Changes in spatial orientation as the group developed the code for their project

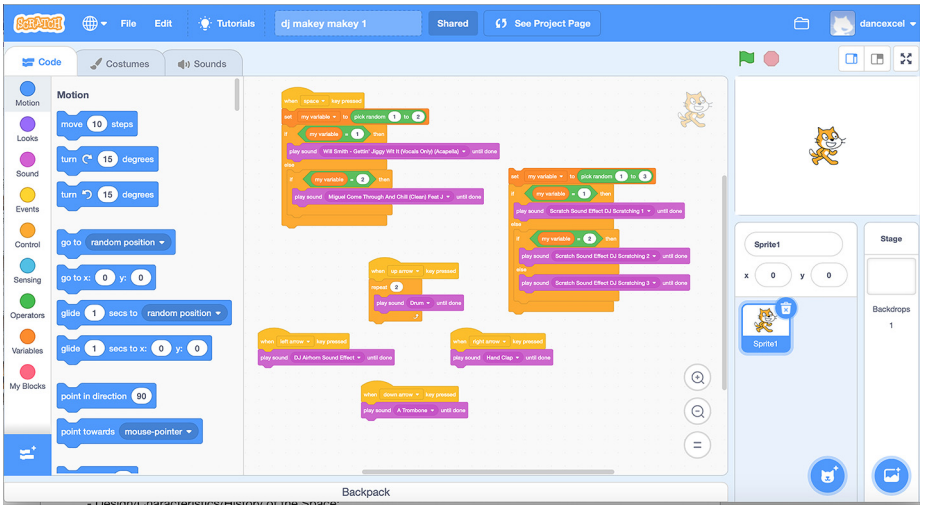



**Figure 2.**

Darnisha: No, they probably just want it single. Just make it single. Get rid of the echo. (plays sound again).

Ashanti: Yeah.

Ashanti: Now you can hear it. Should we echo the clap?

Darnisha: Yeah probably.

Lexie: Yeah, echo the clap.

Darnisha: Well, they might- they- they're gonna do it themselves.

Lexie: Oh yeah.

Ashanti: So, you want it to be single? Okay.

Lexie: That one's good.

Ashanti: (plays clap sound four times, plays echoed sound).

Elanna: (points to screen) Okay. Can you try this one [. . .] and then try that one.

Darnisha: You like both of them [together]?

Lexie: Like if they play it over and over again to the rap it's gonna sound good.

Elanna: Can we do this- Let's try this one.

Darnisha: That means we will need another cord.

Lexie: Yeah, but then- But if we're gonna add all these sounds [. . .] 'cause it has- it shows how many buttons we probably will need.

Through multiple iterations, the girls listened to and edited sounds to make them fit with rap vocals. They tested each sound, listening along with the vocal track and made minor tweaks to slow down certain sound effects; add echoes or not; and make others louder, longer, or faster. Listening together, they discussed and decided on how to cut the music up and add pauses so that the periods would match when users played the sound effects over the vocal track. They tested each sound combination using the laptop keys first, then the Makey Makey.

The girls in this example engaged in computational STEM using a different set of resources than is typically available in computational STEM spaces. The context, design principles, structures and activities contributed to a cultural ecology with expanded resources for computational doing. The hip-hop computational STEM ecology provided valuable opportunities to utilize ideas, materials, tools, bodies and relationships to one another as resources for their computational making.

*Ideational resources/making grammars and emergent practices.* The rules and values of hip-hop and computation, both salient in this setting, became ideational resources that helped the girls engage in and make decisions about integrated computational STEM and art-making through making grammars. We defined *making grammars* as the process of developing rules, observing (or sensing) the behaviors they produce, then making decisions for further development based on those outcomes, in ways that are bound to both time and place. The girls' design required the production of rules and a rule-based system. They created the rules of engagement – both for their potential users and for the system of materials, tools and code they arranged – through an integrated process of proposing and altering the sounds they wanted to use and the ways those sounds mapped onto the physical buttons. They made decisions about their program based on the combination of sounds that emerged from each choice, utilizing the making grammars of both hip-hop and computation.

Their making was also performative, bound by their collective aims. The hip-hop rules of interactivity, creative and competitive self-expression and rhythmically mixing beats and sounds for audience reaction all factored into the design of their project. Another rule they chose to apply was finding a clean song that would be appropriate for the whole audience, including the six-year-old in the group. In applying these rules they thought about themselves and the people who would be using the battle station. They were deciding the rules that would help other people become DJs. Their *doing* – the identification and placement of sounds (stuff) – was aided by their *sensing* the qualities of the music and imagining the ways they wanted people to interact with their thing, the DJ battle station.

As they practiced programming in scratch by importing various sound effects, they quickly shifted from programming with random sounds (i.e. animal noises, piano sounds) to searching for sounds that would complement their rap vocal track (drumbeats, claps, sirens, etc.). They even considered recording and importing their own hip-hop sound effects. Their choice of music for the vocal track, Will Smith "Gettin Jiggy Wit It," was selected because of its danceable feel and tempo. They wanted to use a song that would move the crowd. They bobbed their heads as they tested different sound effects played over the vocal track, making decisions about how to edit based on how the sounds fit with the lyrics as well as how it made them move. They decided to input multiple sound effect tracks instead of one long music track in order to give users "something they can play around with".

The girls created an interactive hip-hop environment, not just a program for a computer to run. They engaged in a full-embodied experience to create a full-embodied experience. To design for others, they had to consider not only the code, but the physical design, including things like how the foil buttons would need to be labeled, the use of vinyl records for authenticity, the need for two Makey Makey set ups so that DJs could sit across from one another and operate independently, and the use of headphones with a foil contact touching

the ear that connects the user to the Makey Makey so that listeners could use both hands to DJ. Utilizing physical programming, circuitry and the manipulation of music and sound effects, the girls created the conditions for users to participate in an immersive computational experience that would allow them to experience the work of the DJ with computational tools.

The integration of computational STEM and hip-hop was clearly exemplified in the way in which they created the earth, or ground, contact that was needed to complete the circuit when participants would be pressing the buttons. They put the earth in fake headphones made of cardboard. In that design element alone, they integrated the rules of hip-hop, engineering and computing and the historical character of the cultural ecology of the dance space. That is, the construction of the headphones is an emergent phenomenon that resulted from those rules applied in a making grammar. They wanted someone to interact (DJ) in authentic ways and in doing so claim space through battling (hip-hop). So they attached the ground (engineering) in a place where the person could a) use both hands to play the battle station rather than hold the ground contact wire in their hands (hip-hop and computing) and b) simulate the functional role that headphones would play if the DJ were cueing up the next record. But they had to make do (hip-hop) with the stuff they had, the cardboard and copper tape.

*Material resources and emergent practices.* The girls' project benefited from the availability of relatively low cost, accessible materials. Many materials available in the makerspace were inexpensive craft or scrap materials like cardboard, which is often used for prototyping in engineering design because it is cheap and relatively easy to manipulate. The girls used the scrap material to build prototypes to test their scratch program with the Makey Makey. Scratch and Makey Makey are designed to make trying out code and material connections to code quick and fun. The girls tested many different versions of their design, modifying the design based on the program they created (as they were creating it) and modifying the program based on their prototype testing. Whereas testing in engineering environments can sometimes cause one to imagine a controlled experiment, the testing that got the girls to a product they were proud of involved sharing of headphones and incorporating discarded cardboard and paper pieces that had been scrapped by other groups into a new prototype. The girls' final design, also made of cardboard, was modeled after DJ equipment and turntables (they looked at old equipment and drew their design) and utilized old vinyl records that were available as part of the history of the dance studio space. Thus, the design principles created opportunities for emergent practices that were informed by cultural practices, relational histories and the materials and tools made available.

*Spatial and relational resources and emergent practices.* The girls in this example were collaboratively co-present as programmers and hip-hop makers. The hip-hop computational STEM ecology provided them with a set of relational and spatial resources that they utilized to collaborate. Space allowed the girls to be able to move, to spread out and to cluster around the laptop. The freedom to move allowed them to utilize their bodies as tools for thinking about computational STEM and hip-hop together. In an open studio space, with a laptop on the ground, various piles of cardboard, adhesives and hand tools spread across floor-level stations, members of the group built the physical DJ Makey Makey components as they contributed ideas to the code, verbally, to whoever had the laptop in front of them. The laptop changed hands fluidly, with a gentle slide across the bare floor to another participant. While this does not sound like the description of a lab where people learn computational STEM skills, the processes they demonstrated mirrors effective ways to design collaborative solutions. The lack of desks, the line of sight and sound enabled the girls to develop a collaborative practice that helped them stay connected in real time. The

physical layout of the studio contributed to flattening hierarchies and allowed the group of students to hold conversations that considered alternate perspectives, agree upon constraints and contribute to a product featuring everyone's fingerprint, without everyone typing. Their work was not divided up into parts for different people to work on when it was their turn. Their collaboration favored emergent co-expertise among the group members, not necessarily expertise distributed across them.

Collaboration happens often in artistic mediums. In hip-hop, songs are often released by an artist, featuring other artists. The process for creating such songs can reveal fascinating collaboration processes that some artists credit for improving the overall quality of the song (and satisfaction with the result). For example, rappers Busta Rhymes and Eminem used a turn-taking remote collaboration process to record the song, "Calm Down." In an interview (Power 106 Los Angeles, 2014), Busta discusses this unique form of collaboration, which he credits for advancing his song lyric-writing craft. He worked remotely by recording a verse then sending it along with the chosen beat to Eminem to add on a second verse. The verse that Busta heard from Eminem gave him new ideas for his own verse, so he re-recorded an updated verse and sent a new version to his collaborator, who, in turn, updated his verse with new ideas and style. This process repeated until the two artists produced a track that featured verses that they both knew they would have been incapable of creating by themselves. Each artist advanced the other's learning and creativity.

This method of asynchronous communication mirrors one way that people who seek to write a computer program or application with others work to build a collaborative project. In our space, the girls communicated with one another in real time, using words, gestures, body language and by dis/approving of programming choices being made. Their final product demonstrates that co-present collaboration and turn-taking with a collaboratively-written computer program can lead to a product that achieves a level of sophistication that any individual involved might not have expected they could produce. While we did not capture every moment of making the project, we did capture almost all of it. In our recordings, suggestions were accepted from everyone, questions were always acknowledged and responded to; no one was ever shut down as they respectfully co-constructed knowledge. Even with an intergenerational group, in which the older girls practiced some "othermothering," (Collins, 1986) seeking to protect the youngest group member from exposure to profanity, the girls allowed everyone to contribute on their own level in their own way, without needing to be an expert programmer or take on that identity. The structure allowed participants to explore multiple pathways and entry points into the computational conversations. Their engagement in the hip-hop making learning ecology allowed collaboration practices to emerge that led to expansive computational STEM learning experiences.

## Discussion

This study provides insights into framing computational STEM learning through a lens of learning ecologies, the design of those learning ecologies and the ways in which designers of those ecologies might arrange relations of ideas, tools, materials, space and people to support minoritized youth in learning and positive engagement in integrated computational making spaces. Specifically, it shows how an ecology can support engagement by providing a structure for making grammars that draws on youth social and cultural practices, relationships and histories instead of suppressing them in lieu of Eurocentric and Western practices and perspectives that have historically been seen as more aligned with the study of STEM and computing (Aikenhead and Elliott, 2010).

HHBE research has highlighted many ways that hip-hop music, practices and culture have been utilized to engage historically marginalized youth in learning over the past three

decades. That research has evolved from studying hip-hop as a way to bring relevance to disciplinary content (Marsh, 2012; Love, 2014; Kelly, 2020), to studying hip-hop text as content (Love, 2014; Evans, 2020), to utilizing hip-hop as a way to reimagine pedagogical practices (Petchauer, 2012; Kelly, 2020). We build on this body of work by expanding understandings of hip-hop principles of making/claiming space for self and others, breaking down and building up, interactivity, authenticity, making-do and self-expression for the design of informal computational STEM spaces.

Furthermore, an expanded definition of computation, based on making grammars helps to relocate computation as an ecologically situated activity, foregrounding the material, ideational, spatial and relational resources that are involved in computational making. Computational making, in this study, was shaped by many aspects of the ecology, including ideas from hip-hop and black culture and the historical practices of the dance center. The above example shows how the girls' computational decisions were guided by hip-hop rules of interactivity, creative and competitive expression and rhythmically mixing beats and sounds for audience reaction. Other group projects were guided by the rules of freestyling, the evolution of hip-hop dance over time and Afrofuturism. Prioritizing the creative experience and performative aspects of making, positing computation as a tool, resource and process for hip-hop making rather than an end game, made learning computation part of a cumulative experience for youth who identified as artists and/or makers, and the arts framing encouraged girls to participate, disrupting traditional power structures in STEM and hip-hop.

Youth were also supported by spatial and relational resources. The dance center's focus on movement presented opportunities for exploring algorithms through choreographic activities and embodied programming games, which invited multiple pathways for exploration and opportunities to participate. Other center practices, which encouraged working in intergenerational groups and engaging in processes of sharing, receiving feedback and critique, created space for youth to learn from and teach each other. Welcoming of everyone's ideas into the space shaped decisions and rule-making and understandings of how rules influence bodies, objects and code. Having the freedom to move around, to shift materials and share tools and devices allowed for collaborative computational practices to emerge. Encouraging fluidity in collaborative arrangements allowed participants to engage in programming, recursive testing, iteration and troubleshooting in ways that looked remarkably different from collaboration in most computational spaces. This included working in multi-age groups, which became robust sites for collective computational meaning-making where youth were able to engage in rule-making along multiple dimensions and build collective understandings.

## Implications

We have situated hip-hop among a constellation of resources in a learning ecology, attending to ways that hip-hop elements, ideas and structures for participation can function as tools for exploring computation in that ecology. This framing expands notions of hip-hop beyond the five original practices (DJing, MCing, BBoying/BGirling, Graffiti and Expression of Self), providing new ways to understand hip-hop as a resource for learning and bringing HHBE theories of teaching and learning into alignment with 21st century practices of hip-hop and education. Focusing on hip-hop's deeper structures, we have presented (1) an ecological framing for computational making based on making grammars and (2) a set of hip-hop design principles that are grounded in hip-hop culture.

Activities were designed to encourage interactivity and self-expression. Youth were challenged to create their own computational hip-hop innovations by making-do with materials

available in the space. They explored breaking down and building up technology and codes, as well as exploring rules and patterns as algorithms through music- and dance-making. Group projects challenged them to re-imagine the outdoor space as their own interactive computational hip-hop space, encouraging them to claim the space as their own through self-expression and create spaces for others to express themselves. Youth projects were ultimately made for others to claim space at the culminating event, the block party. The block party authentically celebrated hip-hop culture through a public event and was an intentional opportunity to engage and teach local communities, increasing exposure to computational making for others across participants' larger cultural ecologies.

Through this work, we argue for a critical re-imagining of computational STEM learning opportunities for Black youth that centers their whole selves within an ecology, rather than centering curriculum or content. Too often, STEM programs are designed with unexamined assumptions about their cultural ecologies and assumptions that designs for learning should focus on programming and activities (Aikenhead and Elliott, 2010; Emdin, 2016; Rosebery *et al.*, 2016). Hip-hop is a way to ecologically situate computational making within a set of culturally sustaining practices. This framing pushes us to rethink repertoires of practice and resources within computational making cultural ecologies. Educators must transform ecologies for learning, not merely assimilate learners into the already marginalizing computation and STEM ecologies that have continued to persist, particularly for populations who have not been positively impacted by past and current predominant pedagogies and remain underrepresented in STEM and computing fields.

## References


Abdurraqib, H. (2019), *Go Ahead in the Rain: Notes to a Tribe Called Quest*, University of Texas Press, Austin, TX.

Adjapong, E.S. and Emdin, C. (2015), "Rethinking pedagogy in urban spaces: implementing hip-hop pedagogy in the urban science classroom", *Journal of Urban Learning, Teaching, and Research*, Vol. 11, pp. 66-77.

Aikenhead, G.S. and Elliott, D. (2010), "An emerging decolonizing science education in Canada", *Canadian Journal of Science, Mathematics and Technology Education*, Vol. 10 No. 4, pp. 321-338.

Akom, A.A. (2009), "Critical hip-hop pedagogy as a form of liberatory praxis", *Equity and Excellence in Education*, Vol. 42 No. 1, pp. 52-66.

Alim, H.S. (2006), *Roc the Mic Right: The Language of Hip-Hop Culture*, Routledge. New York, NY.

Alim, H.S. and Haupt, A. (2017), "Reviving soul (s) with Afrikaaps: hip hop as culturally sustaining pedagogy in South Africa", *Culturally Sustaining Pedagogies: Teaching and Learning for Justice in a Changing World*, pp. 157-174.

Alim, H.S. and Paris, D. (2017), "What is culturally sustaining pedagogy and why does it matter?", in Paris, D. and Alim, A. (Eds), *Culturally Sustaining Pedagogies: Teaching and Learning for Justice in a Changing World*, Teachers College Press, New York, NY, pp. 1-24.

Bang, M. (2015), "Culture, learning, and development and the natural world: the influences of situative perspectives", *Educational Psychologist*, Vol. 50 No. 3, pp. 220-233.

Brown, A.L. (1992), "Design experiments: theoretical and methodological challenges in creating complex interventions in classroom settings", *Journal of the Learning Sciences*, Vol. 2 No. 2, pp. 141-178.

Collins, P.H. (1986), "Learning from the outsider within: the sociological significance of black feminist thought", *Social Problems*, Vol. 33 No. 6, pp. S14-S32.

Cobb, P., Confrey, J., diSessa, A., Lehrer, R. and Schauble, L. (2003), "Design experiments in educational research", *Educational Researcher*, Vol. 32 No. 1, pp. 9-13.

Corbin, J. and Strauss, A. (2008), *Strategies for Qualitative Data Analysis. Basics of Qualitative Research. Techniques and Procedures for Developing Grounded Theory*, Sage Publications, Thousand Oaks, CA.

Chang, J. (2009), *Dancing on the Through-Line: Rennie Harris and the Past and Future of Hip-Hop Dance*, Democratic Vistas, Vancouver.

Christopher, R. (2018), *Dead Precedents: How Hip-Hop Defines the Future*, Repeater, London.

Covington, A.C., Allen, A. and Lewis, C.W. (2018), "Culturally sustaining pedagogy and hip-hop based education: a professional development framework in rap cypher and battle to promote student engagement and academic achievement", *Student Engagement and Participation: Concepts, Methodologies, Tools, and Applications*, IGI Global, pp. 1008-1017.

Creswell, J.W. and Poth, C.N. (2018), *Qualitative Inquiry and Research Design: Choosing among Five Approaches*, 4th ed., Sage, Thousand Oaks, CA.

Denzin, N.K. and Lincoln, Y.S. (2008), "Introduction: the discipline and practice of qualitative research", in Denzin, N.K. and Lincoln, Y.S. (Eds), *Strategies of Qualitative Inquiry*, Sage Publications, Thousand Oaks, CA, pp. 1-43.

Design-Based Research Collective (2003), "Design-based research: an emerging paradigm for educational inquiry", *Educational Researcher*, Vol. 32 No. 1, pp. 5-8.

Dolby, N. and Rizvi, F. (Eds) (2008), *Youth Moves: Identities and Education in Global Perspective*, Routledge, New York, NY.

Duncan-Andrade, J.M. and Morrell, E. (2005), "Turn up that radio, teacher: popular cultural pedagogy in new century urban schools", *Journal of School Leadership*, Vol. 15 No. 3, pp. 284-304.

Eglash, R., Gilbert, J.E. and Foster, E. (2013a), "Toward culturally responsive computing education", *Communications of the ACM*, Vol. 56 No. 7, pp. 33-36.

Eglash, R., Gilbert, J.E., Taylor, V. and Geier, S.R. (2013b), "Culturally responsive computing in urban, after-school contexts: two approaches", *Urban Education*, Vol. 48 No. 5, pp. 629-656.

Emdin, C. (2010), "Affiliation and alienation: hip-hop, rap, and urban science education", *Journal of Curriculum Studies*, Vol. 42 No. 1, pp. 1-25.

Emdin, C. (2016), *For White Folks Who Teach in the Hood... and the Rest of Y'all Too: Reality Pedagogy and Urban Education*, Beacon Press, Boston, MA.

Evans, J. (2020), "Connecting black youth to critical media literacy through hip hop making in the music classroom", *Journal of Popular Music Education*, doi: 10.1386/jpme_00020_1.

Gorson, J., Patel, N., Beheshti, E., Magerko, B. and Horn, M. (2017), "Tune pad: computational thinking through sound composition", *Proceedings of 2017 Conference on Interaction Design and Children in Stanford, CA*.

Graneheim, U.H. and Lundman, B. (2004), "Qualitative content analysis in nursing research: concepts, procedures, and measures to achieve trustworthiness", *Nurse Education Today*, Vol. 24 No. 2, pp. 105-112.

Griffin, K., Gibbs, K.D., Bennett, J., Staples, C. and Robinson, T. (2015), "'Respect me for my science': a Bourdeieuian analysis of women scientists' interactions with faculty and socialization into science", *Journal of Women and Minorities in Science and Engineering*, Vol. 21 No. 2, pp. 159-179.

Gutiérrez, K.D. (2016), "2011 AERA presidential address: designing resilient ecologies: social design experiments and a new social imagination", *Educational Researcher*, Vol. 45 No. 3, pp. 187-196.

Gutiérrez, K.D. and Rogoff, B. (2003), "Cultural ways of learning: individual traits or repertoires of practice", *Educational Researcher*, Vol. 32 No. 5, pp. 19-25.

Hot 97 (2016), "Grandmaster flash talks 'the theory' of being a hiphop DJ and the beginnings of hip-hop!! [video]", YouTube, available at: www.youtube.com/watch?v=m3YXyK-gWvc (accessed 11 April 2020).

Humphreys, P. (2004), *Extending Ourselves: Computational Science, Empiricism, and Scientific Method*, Oxford University Press, Oxford.

Jenkins, H. (2009), *Confronting the Challenges of Participatory Culture: Media Education for the 21st Century*, The MIT Press, p. 145.

Kelly, L.L. (2020), *Listening Differently: youth Self-Actualization through Critical Hip Hop Literacies*, English Teaching: Practice and Critique.

Kim, J. and Pulido, I. (2015), "Examining hip-hop as culturally relevant pedagogy", *Journal of Curriculum and Pedagogy*, Vol. 12 No. 1, pp. 17-35.

Knight, T. and Stiny, G. (2015), "Making grammars: from computing with shapes to computing things", *Design Studies*, Vol. 41, pp. 8-28.

Knight, T. (2018), "Craft, performance, and grammars", in Lee, J.-H. (Ed.), *Computational Studies on Cultural Variation and Heredity*, Springer, Singapore, pp. 205-224.

Kuttner, P.J. (2016), "Hip-hop citizens: arts-based, culturally sustaining civic engagement pedagogy", *Harvard Educational Review*, Vol. 86 No. 4, pp. 527-555.

Ladson-Billings, G. (2019), *Culturally Sustaining Pedagogies: Teaching and Learning for Justice in a Changing World*, Paris, D. and Alim, S. (Eds), Teachers College Press, New York, NY.

Lee, C.D. (2008), "The centrality of culture to the scientific study of learning and development: how an ecological framework in education research facilitates civic responsibility", *Educational Researcher*, Vol. 37 No. 5, pp. 267-279.

Lee, C.D. (2017), "An ecological framework for enacting culturally sustaining pedagogy", in Paris, D. and Alim, S. (Eds), *Culturally Sustaining Pedagogies: Teaching and Learning for Justice in a Changing World*, Teachers College Press, New York, NY, pp. 261-273.

Lieblich, A., Tuval-Maschiach, R. and Zilber, T. (1998), *Narrative Research: Reading, Analysis, and Interpretation*, Sage Publications, Thousand Oaks, CA.

Love, B.L. (2014), "Urban storytelling: how storyboarding, moviemaking, and hip-hop based education can promote students' critical voice", *The English Journal*, Vol. 103 No. 5, pp. 53-58.

McGee, E.O. and Bentley, L. (2017), "The troubled success of black women in STEM", *Cognition and Instruction*, Vol. 35 No. 4, pp. 265-289, doi: 10.1080/07370008.2017.1355211.

Magerko, B., Freeman, J., Mcklin, T., Reilly, M., Livingston, E., Mccoid, S. and Crews-Brown, A. (2016), "EarSketch: a STEAM-based approach for underrepresented populations in high school computer science education", *ACM Transactions on Computing Education (TOCE)*, Vol. 16 No. 4, pp. 1-25.

Marsh, C. (2012), "Hip-hop as methodology: ways of knowing", *Canadian Journal of Communication*, Vol. 37 No. 1, pp. 193-203.

Mass Appeal (2015), "Rhythm roulette: 9th wonder. [video]", YouTube, available at: www.youtube.com/watch?v=Ce8r9RfK1wk

Medin, D. and Bang, M. (2014), *Who's Asking? Native Science, Western Science, and Science Education*, The MIT Press, Cambridge, MA.

Miles, M.B., Huberman, A.M. and Saldaña, J. (2014), *Qualitative Data Analysis: A Methods Sourcebook*, 3rd ed., Sage, London.

Nasir, N.S., Rosebery, A.S., Warren, N. and Lee, C.D. (2006), "Learning as a cultural process: achieving equity through diversity", in Sawyer, R. (Ed.), *The Cambridge Handbook of the Learning Sciences*, Cambridge University Press, Cambridge, MA, pp. 686-706.

Paris, D. (2012), "Culturally sustaining pedagogy: a needed change in stance, terminology, and practice", *Educational Researcher*, Vol. 41 No. 3, pp. 93-97.

Paris, D. and Alim, H.S. (2014), "What are we seeking to sustain through culturally sustaining pedagogy? A loving critique forward", *Harvard Educational Review*, Vol. 84 No. 1, pp. 85-100.

Paris, D. and Alim, H.S. (Eds) (2017), *Culturally Sustaining Pedagogies: Teaching and Learning for Justice in a Changing World*, Teachers College Press, New York, NY.

Patton, M.Q. (1999), "Enhancing the quality and credibility of qualitative analysis", *Health Services Research*, Vol. 34, p. 1189.

Paul, D. (2000), "Rap and orality: critical media literacy, pedagogy, and cultural synchronization", *Journal of Adolescent and Adult Literacy*, Vol. 44 No. 2, pp. 246-252.

Petchauer, E. (2012), "Sampling memories: using hip-hop aesthetics to learn from urban schooling experiences", *Educational Studies*, Vol. 48 No. 2, pp. 137-155.

Pinkard, N. (2001), "Rappin' reader and say OH playmate: using children's childhood songs as literacy scaffolds in computer-based learning environments", *Journal of Educational Computing Research*, Vol. 25 No. 1, pp. 17-34.

Pough, G.D. (2015), *Check It While I Wreck It: Black Womanhood, Hip-Hop Culture, and the Public Sphere*, Northeastern University Press.

Power 106 Los Angeles (2014), "Busta rhymes explains the full music making process of calm down w/Eminem. [online]", available at: www.youtube.com/watch?v=WBopunZM1SU (accessed 1 June 2020).

Rogoff, B. (2003), *The Cultural Nature of Human Development*, Oxford University Press, Oxford.

Rosebery, A.S., Warren, B. and Tucker-Raymond, E. (2016), "Developing interpretive power in science teaching", *Journal of Research in Science Teaching*, Vol. 53 No. 10, pp. 1571-1600, doi: 10.1002/tea.21267/full.

Sammel, A. (2009), "Turning the focus from 'other' to science education: exploring the invisibility of whiteness", *Cultural Studies of Science Education*, Vol. 4 No. 3, pp. 649-656.

Shute, V.J., Sun, C. and Asbell-Clarke, J. (2017), "Demystifying computational thinking", *Educational Research Review*, Vol. 22, pp. 142-158.

Schwandt, T.A. (2000), "Three epistemological stances for qualitative inquiry: interpretivism, hermeneutics, and social constructionism", in Lincoln, Y.S. and Denzin, N.K. (Eds), *Handbook of Qualitative Research*, Sage Publications, Thousand Oaks, CA, pp. 189-213.

Warren, B. and Rosebery, A.S. (2011), "Navigating interculturality: African American male students and the science classroom", *Journal of African American Males in Education*, Vol. 2 No. 1, pp. 98-115.

Wilkerson, M.H., D'Angelo, C.M. and Litts, B.K. (2020), "Stories from the field: locating and cultivating computational thinking in spaces of learning".

Wing, J.M. (2006), "Computational thinking", *Communications of the ACM*, Vol. 49 No. 3, pp. 33-35.

Yosso, T.J. (2005), "Whose culture has capital? A critical race theory discussion of community cultural wealth", *Race, Ethnicity, and Education*, Vol. 8 No. 1, pp. 69-91.3.

## Further reading

Barton, A.C. and Tan, E. (2019), "Designing for rightful presence in STEM: the role of making present practices", *Journal of the Learning Sciences*, Vol. 28 Nos 4/5, pp. 616-658.

Hill, M.L. (2009), *Beats, Rhymes, and Classroom Life: Hip-Hop Pedagogy and the Politics of Identity*, Teachers College Press, New York, NY.

Sijbrandij, S. (2015), "The remote manifesto. [online]", available at: https://about.gitlab.com/blog/2015/04/08/the-remote-manifesto/ (accessed 1 June 2020).

Sijbrandij, S. (2020), "Is gitlab? [online]", available at: https://about.gitlab.com (accessed 24 June 2020).

Thorpe, A. (2016), "Cultural learning ecology: a significant shift in thinking", available at: www.anewdirection.org.uk/blog/a-fresh-approach-to-cultural-education

Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A. and Hudicourt-Barnes, J. (2001), "Rethinking diversity in learning science: the logic of everyday sense-making", *Journal of Research in Science Teaching*, Vol. 38 No. 5, pp. 529-552.

**Author affiliations**

Dionne N. Champion, College of the Arts, University of Florida, Gainesville, Florida, USA

Eli Tucker-Raymond, Department of Language and Literacy, Boston University, Boston, Massachusetts, USA

Amon Millner, Department of Engineering, Franklin W. Olin College of Engineering, Needham, Massachusetts, USA

Brian Gravel, Department of Education, Tufts University, Medford, Massachusetts, USA

Christopher G. Wright, Department of Teaching, Learning and Curriculum, Drexel University, Philadelphia, Pennsylvania, USA

Rasheda Likely, Bagwell College of Education, Kennesaw State University, Kennesaw, Georgia

Ayana Allen-Handy, Department of Policy, Organization and Leadership, Drexel University, Philadelphia, Pennsylvania, USA, and

Tikyna M. Dandridge, School of Engineering Education, Purdue University, West Lafayette, Indiana, USA

**Corresponding author**

Dionne N. Champion can be contacted at: dchampion@arts.ufl.edu