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LEARNING

"But the science we do here matters": Youth-authored cases of consequential learning

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Abstract

In this paper, we use the concept of *consequential learning* to frame our exploration of what makes learning and doing science matter for youth from nondominant communities, as well as the barriers these youth must confront in working toward consequential ends. Data are derived from multimodal cases authored by four females from nondominant communities that present an account of "science that matters" from their work during their middle school years. We argue that consequential learning in science for these girls involves engaging science with a *commitment to their community*. This form of engagement required the girls to develop bridging practices that allowed them to transform existing relationships among science and community for themselves and others despite normative barriers experienced in science. Our study expands upon current understandings of consequential learning through highlighting the vital role of sociohistorically constructed understandings of community in determining when, how, and why science learning and doing matters for youth. This view opens up new ways to understand how youth can and do contribute to the changing contexts in which science takes place, and toward the ways in which youth contributions alter what gets counted as learning, as being expert, and as meaningful participation.

KEYWORDS

consequential learning, Community science, youth participatory action research, Equity, Hope

Green Club[1] *(informal science club) is different from school science because you don't sit in your seat and listen. You listen, then start letting your community hear you. Get your point across to the world. You are saving the world and it's power. Think about it. I am a 12-year-old sixth grade girl saving the world and its people. – Maya*

1 | INTRODUCTION

Despite multiple national reform efforts in the United States, achievement and interest gaps continue to persist in school science, disproportionately impacting youth from nondominant communities. A growing body of research

suggests that many youth, both girls and boys, from nondominant communities who have not traditionally fared well or been interested in school science are excelling in *informal* learning settings in both knowledge gains and increasing interest in science (Deschenes & Malone, 2010). Yet, little is known about how school science teachers might build upon these out of school successes. In other words, How do youth make sense of their out-of-school science experiences, and how do they want this to matter in their classrooms, if at all?

The opening quote speaks to these questions directly. The quote is part of a story Maya, a sixth-grade African American female, wrote when asked to describe an experience when science mattered to her. Her writing emphasizes a vision of doing science as dynamic, and an avenue to take action in, for and beyond her community. Learning science holds personal and social transformative power for Maya by extending beyond knowledge acquisition into action taking to "sav(e) the world and its people". Her quote reveals an empowered sense of self in science, filled with hope and urgency—a contrast to western stereotypical views of young minority females in science (Carlone, 2004).

Maya's story is not an isolated case among the youth with whom we work. Many of these youth have told powerful stories about when, where, how, and why science matters to them. Their stories collectively reveal a vision of science learning that is consequential and situated-in-action across local contexts and developed over time. By *consequential learning*, we mean learning opportunities where youth alter traditional patterns of participation in science (i.e., white male dominated) to expand upon who and what areas of expertise are recognized and valued within and across "dynamic networks of practice" (Jurow & Shea, 2015).

We are primarily interested in how youth from nondominant communities with whom we have worked, primarily in informal learning spaces, over 6 years, engage in consequential learning—or as these youth would say, "science that matters". The term "science that matters" refers to learning experiences where youth use their developing understandings and practices in science, as well as other areas of expertise, to take action based on their commitments to their community. For this paper, we use the context of in-depth multimodal cases authored by four of these youth (all girls) over the course of a 4-month period, and which present an account of "science that matters" from their work during their middle school years (ages 11–14). The cases, which we describe in detail later, included personal stories of experiences doing science, youth-authored messages to science teachers, and science artifacts they developed over the course of their middle school years. These cases were the brainchild of the youth, who sought to find new ways to present their experiences and expertise to their school teachers. In choosing teachers as their audience, the girls identified people they felt did not value who they were or what they knew/could do, but nonetheless could learn from them and held the power to alter the ways participating with science happens in school. Thus, by constructing their cases and choosing science teachers as their intended audience, the girls' expressed *hope* that school science learning opportunities could be consequential, as well as communicated a need for *urgency* in transforming science learning experiences in classrooms for themselves and their peers. The following questions guide our investigation:

1. What do the multimodal cases authored by the four girls from nondominant communities reveal about consequential learning in science, including how it takes shape over time and space, and why it matters?
2. What practices support the girls in enacting consequential learning? And how do these practices help them to break down the unequal power relationships across the spaces of their lives, as they seek to alter local and broader narratives regarding participating with science?

In what follows, we first situate the concept of science that matters within sociocultural views of learning and participation with/in science. In particular, we expand upon the concept of consequential learning to highlight the importance of community, including the dimensions of social context and action, as a vital aspect of the learning process.

2 | FRAMING SCIENCE THAT MATTERS

"Science that matters" is a phrase used by the girls in this study to contrast learning science because you "need to pass" with learning and doing science to "make a difference" in their lives, and among their peers, family, and community.

The phrase has sociohistorical significance for these four as it emerged the year before this study was conducted when these girls, along with their peers, attempted to explain the difficulty they encountered responding to a seemingly simple question—what do you like about science? After all, these youth chose to spend over 6 hours a week in an after school science club. During this conversation, the youth agreed that school science matters in going to "college and getting a good job," but that by itself was not satisfactory. The youth rallied around the point made by Maya, who said that science afterschool mattered "because it matters to our community and to our Earth… When we save the Earth from all of the disastrous stuff that is going to happen to us, they are going to be like, oh I should have!"

Maya's conceptions of participating with science that matters center on a discourse of "making a difference" and being an "expert" in both science and community. This sentiment where science, community, and action were intertwined was routinely expressed by these youth and their peers, and propelled them to articulate future spaces in which their work was needed, as we later show in their cases (Barton & Tan, 2010; Birmingham & Barton, 2014). Understanding what constitutes "science that matters" for these girls and others is imperative in light of persistent achievement and interest gaps in science for students from nondominant communities (NCES, 2012). Even when students are academically successful, many still see science as disconnected from their lives and pursuits (Tan, Barton, Turner, & Gutierrez, 2012; Thompson, 2014). This trend persists from middle school into the professions, where women and minorities remain underrepresented in the physical sciences and engineering.

Responses to the on-going achievement and interest gaps in science among youth from nondominant communities involve a renewed call for connected and meaningful engagement in science ideas and practices (NGSS, 2013). These responses suggest that to develop "a sustained attraction to science and for them (students) to appreciate the many ways in which it is pertinent to their daily lives, classroom learning experiences in science need to connect with their own interests and experiences" (NRC, 2012, p. 28). This stance frames meaningful as a way to inspire engagement in science, rather than an epistemological resource needed to build knowledge and take action.

In contrast, for the girls in our study, learning and doing science that matters is not about teachers or curriculum "communicat[ing] the relevance and salience" of scientific ideas and practices (NRC, 2012, p. 28). Instead, learning and doing science that matters "desettles expectations" regarding the very "forms of knowledge, experience, and meaning-making" with which students participate in science (Bang, Warren, Rosebery, & Medin, 2013, p. 304). Science is one form of expertise (among many) in which youth may leverage, co-opt, or move across spaces in pursuit of personally defined interests (Barron, 2015; Bell, Tzou, Bricker, & Baines, 2012). However, as we will see, youths' desire to learn and engage with "science that matters" is more than interest driven. Interest matters, but so do the ways in such interests are forged within sociopolitical histories where issues of power, privilege, and location deeply shape opportunities to learn and become (Haan, Leander, Unlusoy, & Prinsen, 2014).

Thus, we turn to consequential learning to frame our study. Drawing from a synthesis of research on sociocultural views of learning and its expansive outcomes, consequential learning essentially calls attention to what counts as valued learning. Questions around *who* is learning and how are they located in sociohistorical context? *Why* do they learn and what makes them make the effort? *What* do they learn, and what are the outcomes of learning? And *How* do they learn, and what are the key actions of learning? (Engestrom, 2001, p. 133) become central to framing the ideal of consequential.

From studies in sociocultural views of learning, we take as the starting point that to understand what counts as valued learning for a young person, we have to understand how learning and engagement in science is rooted in the history and geographies of young people's lives in ways that support rigorous engagement with and connections among science, community, and broader social issues in pursuit of transformative outcomes at the individual and social level. We know from sociocultural studies that learning and doing science are always situated within—indeed a part of—local practice, a result of the complex interactions between "agent, activity and the world" (Lave & Wenger, 1991, p. 33). However, Jurow and Shea (2015) note the inherent challenges in understanding learning from this perspective. What counts as valued learning historically has been understood against a stable, normative background context. However, learning is always on going, happening across time and space. As people learn, their activity reshapes the social contexts in which they participate, just as the social contexts contribute to what they learn. Their dynamic interactions among the individual and the context are a part of the processes and outcomes of learning, and what makes learning

consequential (Leander, Phillips, & Taylor, 2010, p. 330). For example, an individual's identity work, an important outcome of learning, is both an artifact of their developing knowledge and practice as well as how they are recognized by others for what they know and can do. Determining who can do science, where science matters or how, however, can be an ongoing struggle for individuals as they negotiate relationships between personal and historical narratives regarding participation with science (Holland & Lave, 2001).

To understand consequential learning requires one to also pay attention to the power dynamics that shape how youth are recognized for what they know and can do. Holland and Lave (2001) argue, "in practice, material and symbolic resources are distributed disproportionally across socially identified groups and generate different social relations and perspectives among participants in such groups" (p. 5). The unequal distribution of power impacts whether one sees oneself as capable and welcomed in science (Carlone, Huan-Frank, & Webb, 2011), often resulting in youth from nondominant communities losing interest in learning science in middle and high school (Barmby, Kind, & Jones, 2008).

Interrogating power dynamics as a part of consequential learning over space and time is an important equity-minded project. Young people's experiences in science take place in what Collins (2000) calls a "matrix of oppression," the structure that operates with race, class, gender, and other forms of oppression. They are often positioned as "outsiders" to science based on where they live, what they look like, or a perceived lack of capabilities (or interest) in making contributions to science investigations. The girls in our study, all of whom are from lower income backgrounds, and three of whom are African American (one of whom is White), encounter intersecting power structures and systems of oppression across race, class, and gender that shape and reshape their experiences in science over time and across spaces (Collins, 2000). Normative discourses and practices (of those in power—in science/western society—mainly white, male, and middle class) position girls in real and symbolic hierarchies, leaving actors to confront contrary narratives in their experiences. This often plays out in the struggle between the ways in which school positions and values certain ways of knowing and doing science and the cultural meaning making practices youth from nondominant communities bring with them from personal and sociohistorical experiences (Rosebery, Ogonowski, DiSchino, & Warren, 2010). These intersections impact conceptions of what it means to be scientific, who can participate in science and how (or if) science is consequential.

In our study, we are interested in exploring what makes learning and doing science consequential for youth from nondominant communities, as well as the barriers that must be confronted in working toward consequential ends across space and time. The idea that learning ought to be consequential through how it draws upon but also responds to everyday knowledge and practices in expansive ways is not new (Gutierréz & Rogoff, 2003; Barron, 2015). However, attention has yet to be paid to how youths' existing and developing commitments to their community that constitute *the dynamic social contexts* they engage with over time are integral to forming conceptions of consequential learning. Such a view of consequential learning opens up new ways to understand how youth can and do contribute to the changing contexts in which science takes place with both a sense of hope and urgency, and toward the ways in which youth contributions alter what gets counted as learning, as being expert, and as meaningful participation.

3 | METHOD

The study was carried out as youth participatory action research. Our work was participant-centered in how the problems were defined, how we collaboratively sought action to address those problems, and the focus on transformation of local contexts toward empowering ends (Cammarota & Fine, 2008). The project grew out of the girls' request to author and communicate messages about their science learning outside of school that they hoped we could use to educate others. Through conversation groups with the youth, we settled on the idea of co-constructing multimodal cases that could engage and educate teachers about their experiences. While the cases ultimately became a part of a larger design-based implementation research project (see Birmingham, 2013), the case co-construction represented youth taking action on issues they cared about and wanted to coinvestigate. In particular, while the girls' artifacts included

in the cases represent evidence of their action taking over time (i.e., videos shared with peers, at school and in the community), the action taken in connection to this study was the development of and eventual use of cases in a professional development opportunity for science teachers, which is described elsewhere (Birmingham, 2013; Birmingham & Calabrese Barton, in progress). As such, the girls participated in designing the study and taking action on local issues by proposing the idea of developing cases for their teachers; by the critical ways they questioned what science is across the contexts of school, home, and community; and by naming the audience to whom they desired to communicate their experiences. The critical nature of participatory design work was important to us, given that a central goal of this work was to communicate the stories of girls, who are positioned in particular ways due to being young, female students (mostly of color) from predominately low SES backgrounds. This methodology also meant the traditional researcher/researched lines were blurred as all participants assumed multiple roles (researcher, collaborator, participant) throughout the project.

3.1 | Context

The study is situated in Great Lakes City, MI, an urban area hit hard by economic recessions and subsequent population decline experienced across the state (U.S. Census, 2010, Bureau of Labor Statistics, 2011). While poverty and loss of industry often frame conversations about Great Lakes City, the youth we work with are quick to point out that Great Lakes City is a "close knit community" with "fun things to do and places to go." One of the central places in the lives of these youth is the Boys and Girls Club (BGC).

3.1.1 | A site of afterschool learning

The BGC of Great Lakes City opens its doors to over 2,400 youth annually between the ages of 5 and 17 from predominately low-income and minority backgrounds. One of the programs offered to members of the club is an informal science learning program called Green Club, the program in which the girls involved draw upon for many of the artifacts included in their cases. Green Club is open to youth ages 10 through 15 with anywhere between 15 and 20 weekly participants.

Green Club provides youth with sustained opportunities to engage in green energy issues in ways that are locally relevant and of global importance, supporting them in developing deep understandings of science while leveraging their expertise of their community to take action. Each Tuesday and Thursday during the school year, Green Club meets at the BGC. In these sessions, youth and adults work together to leverage energy-related science understandings to enact change in the local and global communities. The change might come in the form of participating in a community forum regarding the proposed building of a new power plant, creating digital public service announcements for television or YouTube, or bringing what they know to peers in their schools with the goal of inspiring action. The program also offers a 2-week summer intensive experience providing opportunities for youth to engage with other energy-related science experts in their community and state (see http://getcity.org).

Our participation in the Green Club comes in the form of both informal educators and researchers. In assuming both of these roles, our goal is to provide powerful learning opportunities for youth to develop deep understandings of energy-related ideas and practices and assist them in building connections to their communities and lives. Our work may include designing and implementing learning experiences (e.g., studying energy transformations in the electrical production system, or collecting and analyzing data on the relationship between incandescent and CFL lightbulb usage and energy expenditures, carbon emissions, and economic costs), providing opportunities for youth to expand their social networks through interaction with other local or national experts (e.g., taking field trips to their local power company, e-mailing, or skyping with area experts), and leading discussion groups that foreground youth voice and guiding youth as they prepare to take action in their community (e.g., youth-led workshops for other youth at their club or at their churches). Our approach to our roles as teachers and researchers was youth-centered, and through the use of weekly conversation groups supported the youth in providing the directions they wanted to take their investigations and the actions that mattered to them. Thus, while we had curricular goals connected to the

science understandings needed to take action, we were committed to co-constructing investigations (and the intended outcomes of those investigations) with youth, as well as providing a space to legitimize their expertise and lived experiences.

3.2 | Participants

The four girls who participated in this study chose to be involved based on a desire to communicate "science that matters" to science teachers. All four were regular participants for 2 or more years in Green Club and the weekly conversation groups (see data sources). The girls also represent diversity in life experiences, academic achievements, and interests. Finally, these four expressed a desire over time to be part of the study and share narratives of their science experiences with schoolteachers. Other youth who had participated in Green Club regularly were invited to be part of the study, but declined for various reasons such as schedule conflicts or inability to commit the in-depth time to build multimodal digital cases.

Below, we present brief biographical introductions to all four participants with the acknowledgment that these introductions do not capture the complexity of these girls' lives or how they position themselves within broad categories with respect to race, gender, class, and age. Instead, these introductions are meant to provide contextual information that will be expanded upon/desettled through detailed presentation of their cases.

3.2.1 | Nicole

Nicole is an African American female who is a highly successful student by traditional measures (grades, standardized test scores) and routinely finds herself on the honor roll at her school. She is a bright, creative, and talented young woman, in the sixth grade, who has shown, through her participation in Green Club, a desire to seek out and act upon opportunities to make a difference in her community. She lives most of the time with her mother, but spends weekends with her father, who also lives in the Great Lakes City area.

3.2.2 | Hannah

Hannah is a Caucasian female who is not considered a successful student by traditional measures. Earlier in her academic career, she was held back resulting in her being 1 year older than most of the students in her class, including her younger brother who was also a sixth grader. Hannah lives with her mother and father, brother, and an older sister. Her family life is marked with severe poverty. Hannah is kind, caring, outgoing when part of a group, committed to her friends and family, and brave enough to take intellectual and social risks.

3.2.3 | Caitlyn

Caitlyn is an African American female who is an honor roll student, winning first place in a statewide competition for a public service announcement she created and finishing third in the district essay contest for a paper she wrote on Dr. Martin Luther King Jr. Caitlyn was a seventh grader who had been a regular contributor in Green Club since the fifth grade when she created her case. She is seen as a leader in Green Club by both adults and other youth due to the work she put in to educate her community as well as the history she has in the program. Caitlyn lives with her mother, and her older sister who, at one point, was part of Green Club.

3.2.4 | Maya

Maya is a highly successful African American female who attends a local charter school in Great Lakes City. She was in sixth grade and 12 years' old when she created her case. Although academically successful, at the time of this case, Maya was not enjoying school and often talked about her plans to switch to a different school the following year. During Green Club discussions, Maya was often the first one to share an answer, idea, or question. She is creative leader who has shown how hard she will work to make a difference in her community.

3.3 | Digital science learning cases

To communicate experiences where science mattered, digital cases of the girls' participation with science over time and across contexts were codeveloped by the participants and researchers. By cases, we mean a collection of youth-authored messages and artifacts that were published into a digital Wiki page. In developing these cases, the girls drew from science learning experiences across their time in Green Club (between 2 and 3.5 years of work) that represented the multiple places within and beyond their community in which this work took place. These cases reflect the culmination of 3 years of science-related activities outside of school that the girls purposefully assembled to teach others about their engagement in science. Spending 4 months to assemble these cases, the girls carefully decided which artifacts and ideas best reflected their experiences doing science that matters.

Each case was organized in three sections. The first section was titled "Getting to know …" and included a self-description written by each girl and a Website introducing themselves. The second section of the cases was titled "Explicit messages to science teachers" and included quotes from each girl regarding ideas they wanted science teachers to think about. The third, and largest section was titled "Conversations and artifacts." This section included artifacts that the youth produced over time, and used in different ways and across different communities. This section included public service videos and digital shorts the girls made, stories they wrote, video diaries they filmed, and transcripts of conversations in which they participated.

3.3.1. | Co-constructing cases

In building these cases, we hoped they would reveal the experiences of the participants in as close to an unedited form as possible. In an attempt to stay true to their stories, the study was designed so that the cases were co-constructed with the girls. The idea was that the girls would take the lead on creating their cases with assistance from us. It should be noted all artifacts and messages included in the case were chosen by the girls.

We met with all four girls together to explicitly talk about this project three times as the cases were created with each meeting lasting between 45 minutes and 2 hours. The first two meetings occurred early in the process and focused on developing an overview of the project and collectively brainstorming ideas for sharing experiences with teachers. The researcher(s) started these conversations with open-ended questions, but the girls ultimately determined the direction and content of the discussion. The third meeting, which occurred after the cases had been developed, focused on positionality and was initiated by the researcher(s). In particular, we asked these girls to reflect upon the impact of our role as researchers in helping to develop the cases with specific attention to differences in gender, race, age, privilege, and power.

In addition to the whole group meetings, we met with each girl individually four times to co-construct the cases. These meetings usually lasted between 30–60 minutes each. During the first two meetings, we (researcher and one participant) brainstormed artifacts they wanted to include and what they wanted science teachers to know about their informal science experiences. After each meeting, the researcher would insert written messages and chosen artifacts into the wiki page so that they could be reviewed at the following meeting. The third and fourth individual meetings were spent critically examining and revising the cases. During these final individual meetings, we discussed what was missing and what they hoped teachers would take away from the cases. At the end of the fourth individual meeting, all four girls decided the cases were ready to share with teachers.

3.3.2 | Positionality

While the design of the study put some of our fears to rest regarding staying true to the girls' stories, we also knew that we had a history with these girls. We worked with all four girls in Green Club for at least 2 years. We felt this history brought with it both positives and potential issues. The relationships built established trust, which opened spaces for the girls to share their stories and take authority of constructing their cases in ways that would not have happened devoid of this trust.

However, as an adult white male and an adult white female, we also understood our life experiences were very different from theirs. The girls are all young, female, mostly of color (three of four are African American), youth who are growing up in very different conditions than what we experienced at their age or continue to experience. Particularly, we worried about how these girls saw the power dynamics playing out in this study. These ideas are what we tried to "get at" in our third group conversation. I (Danny) asked what they thought about differences in race, gender, age, and SES in terms of my participation as well as the teachers who would eventually view the cases. In the end, the girls were not sure how these factors mattered to the teachers because they did not know these teachers. However, they believed they understood our (Danny and Angie) position relative to these categories. As Caitlyn, one of the girls involved in the study, said, "We wouldn't have talked to you if we didn't trust you." This statement speaks to an understanding that there are power dynamics at play. They trusted that we would represent their stories and their emerging identities, but they also recognized that our position affords the power to share these stories with others in ways that are not available to them due to their age, race, gender, class, or position in schools.

3.4 | Data sources

The digital science learning cases described above resulted from the girls' work over the course of their middle school years across contexts of home, community, and school. Each of these data sources are described below.

3.4.1 | Youth conversation groups

We conducted conversations with a subset of Green Club youth (four to six youth per meeting) each Wednesday during the 2009–2010 and 2010–2011 school years. The four girls in this study were regular contributors to these discussions. These data provided information about how science matters to them, whether they see science as part of their place, what issues they believe are facing their community, and what actions they want to take in response to these issues. Additionally, two of the girls (Maya and Nicole) chose to use transcripts from these conversations in their cases to communicate the ways in which science, community, and the bridging of these two worlds mattered to them. After each conversation, field notes were written and audio recording were transcribed.

3.4.2 | Girls' artifacts

Throughout the course of their time in Green Club, the girls created artifacts that were shared in various spaces in and beyond their community. Examples include public service announcement videos, informational videos about building a "green" teen center for the board of directors at the BGC, web pages about themselves and their interest in science, and drawings of their high and low points with science. Additionally, as we co-constructed these cases, the girls were asked to write a story of when science mattered to them and also were given a video camera to shoot a video diary about science in Great Lakes City. The artifacts the girls chose to include in their cases provide data regarding the ways in which they conceptualize and enact science that matters.

3.4.3 | Case creation conversations

As noted above, we conducted four one-on-one conversations with each of the girls and three group conversations as we co-constructed their cases. These conversations were not only central to the process of creating the cases, they also provided data regarding the girls' beliefs about science, their desire to work with teachers, and their hope for reforming science classroom practices. After each conversation, field notes were written and audio recording were transcribed.

3.5 | Data analysis

Our analysis was guided by social practice theory (SPT) (Holland & Lave, 2009), which provided a lens to examine the ongoing struggle between personal and historical narratives influencing the girls' participation with science. Thus, SPT assisted us in identifying the tensions the girls experienced in connection to the racialized practices and other barriers

to STEM participation across contexts. Additionally, SPT guided our analysis in understanding the girls meaning making process as they confronted personal and historical narratives in local practice (Holland & Lave, 2009). Specifically, this analysis provided insight into the meaning the girls made and experiences leveraged around what counts as science, who is capable of science, and the places science occurs. Finally, the framework helped in thinking about what other types of expertise and identities were allowed to be brought to these investigations and how this facilitates meaningful learning.

The first stage of analysis involved transcribing all conversation and interview data, which revealed initial themes and patterns in and across participant talk. Upon completion of each transcription, we wrote analytic memos regarding these themes and patterns as well as questions that initial analysis of data brought up. These analytic memos became a starting point in our later development of a coding scheme.

Next, we began to make sense of the multiple data sources collected. To investigate the stated research questions and data sources, we analyzed data using constant comparative analysis (Glaser & Strauss, 1967). We analyzed all data sources and identified themes among participant responses. This work was guided by what Miles and Huberman (1994) refer to as data reduction and display. As data sources were transcribed, we worked to organize the large amount of information collected to focus on stated research questions and themes identified in participant talk/artifacts. This work further contributed to our coding scheme. This scheme was informed by relevant literature, analytic memos, and themes that emerged in participant responses during this first pass of the data.

During the next stage, we organized participant responses with regard to themes across data sources using a linkage chart so they could be further analyzed across contexts. We then moved from themes to claims regarding the stories of youth participation with science that matters.

4 | FINDINGS

In this section, we argue that the girls' cases—a reflection of their engagement in science across the middle grades—authored narratives about what consequential learning is and why it matters. These narratives are evident in the specific artifacts and messages they produced for the cases, as well as in their broader stories about their artifacts told over time. Specifically, we make three main claims:

1. Consequential learning for these girls involves engaging science with a commitment to their community.
2. To engage science with a commitment to community, the girls developed and implemented practices that bridged science and place in ways that allowed them to transform existing relationships and knowledge structures among science and community for themselves and others.
3. The girls encountered normative barriers in science connected to race, gender, class, and age, which further shaped how and why they took up bridging practices toward their commitment to community.

These claims point toward a dynamic and relational view of consequential learning that accounts for how such learning occurs in/across space and time. In what follows, we first present the girls' cases in detail to highlight the vital role of girls' commitment to community to their conceptions of consequential learning. Next, we refer back to the descriptions of their cases as evidence of the second and third claim.

4.1 | Engaging science with a commitment to community

Across their cases, the girls in our study argue for a vision of learning science that reflects some of the core ideals at the heart of current reform initiatives in the United States (NGSS, 2013). They want opportunities to develop deeper understandings of scientific knowledge and practice to do science in more sophisticated ways. They also want to engage in sustained scientific inquiry on authentic problems of personal interest. However, the cases authored by the girls suggest that their desires to learn and do more with science cannot be separated from who they are, who and what

they care about, and the impacts they hope to have toward making a positive difference. The science experiences the girls chose to communicate to teachers were ones in which they authentically engaged with science in ways that are grounded in their commitments to their community.

For these girls, engaging science with a commitment to community is framed around three ideas. First, understandings of science content and practices are necessary for solving important problems, and these understandings ought to be contextualized, accessible for others, and lead to action. Second, authentic scientific inquiry in the community happens at the "powered boundaries" of race, class, and gender, suggesting that issues of power and privilege are deeply entrenched in how one experiences science learning/doing (Warren & Rosebery, 2011). Third, engaging science with a commitment to community reflects both the urgent in-the-moment nature of community science work as well as the long-term efforts to develop the necessary understandings, practices, and expertise over time and across spaces.

We explain and develop these aspects of engaging science with a commitment to community through an analysis of the four cases below.

4.1.1 | Maya "Science that matters"

Maya joined Green Club to accomplish the goals of building better understandings of science as well as of the places that matter to her. Her case opens with a message to "tell my teachers that in Green Club we learn, and we learn a lot of knowledge but we enjoy it, and we do stuff that can make a change in our Earth. And do things that really matters in our Earth." For Maya, what she learns cannot be separated from how she uses what she learns to make a difference in her community. We see threads of this commitment strongly in all of the artifacts she shared, whether they were collected from home, school, or the club.

For example, after her written message to her teachers shared above, the first artifact Maya includes in her case is a transcript of the "matter's conversation," briefly described in the introduction of this paper. Recall that Maya argued that her experiences in school science do not matter as much as out of school science because school science is not tied to action in her community. In this transcript from a youth conversation group, she depicts school science as a place of "zazoom science"—a place of seeing but not doing:

Maya: Science in school we just sit there and read a book and that is not doing anything. All we do is sit there and read a book about doing something. And when we do something, it is like an experiment maybe that doesn't really matter.
Male S1: And the teacher does it!
Maya: Yeah, and the teacher just shows you. Then he said, "well you guys are going to get to do this, no – never mind, I can just show you." So all we did was make water drip into a bucket through a straw. When we are in Green Club, we actually do something. We don't just sit there and read a textbook and watch our teacher drip water through a straw.
Hannah: Is watching a straw and water drip through it even science? That is not even science…
Maya: I think when you have a tube and make water come out of it, that it doesn't matter much. It doesn't matter as much as what we are doing… I call it the "zazoom" science, the stuff where you mix the chemicals and all that stuff.

Maya values school science and performs well there. However, she enthusiastically prepared her case because she wanted to see school science transformed so that it might matter *more*. Transformation of school science for Maya (and Hannah) requires a critical examination of what is/should be considered science in terms of the content, context, and learners' opportunities to participate. While "zazoom" science may bring with it initial wonder, it lacks the substance, connections to local issues, and opportunities to take action that Maya has experienced through participation in informal science learning.

Maya's view of taking action is premised on knowing science. Her case artifacts portray her using her developing science expertise to teach others, take on technological and behavioral changes at home and school, and lead new initiatives to expand science experiences in her school.

For example, Maya included in her case an artifact where she and two friends (Hannah and Nicole, also participants in this study) discuss a water efficiency audit of her school that they conducted. This audit was part of a year-long investigation into energy efficient building design and its implications for their school, home, and community. Through this

investigation, Maya learned about the importance of water for herself and local ecosystems, how water cycles through our environment, how water usage equates to energy usage, how water supply compares to population growth, and how human behavior impacts the availability of water. The video was taken inside the girls' bathroom next to the cafeteria. In this segment of the video, Maya and her friends explain what data they were collecting about the water in the bathroom sinks, what these data tells them about which bathroom sinks are most efficient, and why this information is important in connection with the above science understandings. After the adult mentor with the group suggests that they take photos of various sinks, Maya interrupts the conversation to add another layer to their audit, challenging the simple narrative that efficient technologies by themselves are better. She suggests that only collecting data on water flow is not sufficient because it does not account for how people use the sinks.

Maya: Can I add something? Also I was saying that we could find stuff and write if they are being efficient. Let us just say that all of the middle schoolers eat lunch, and then after lunch they all have to come in and use the bathroom. We were talking about how we say the things, and one [faucet] flows slower than the other ones, and that means that it saves more [water]. But how about if a bunch of people use it? Is it really saving?

In this artifact, Maya is making direct connections to the impact of human behavior on the water supply that has implications connected to other key understandings about water efficiency. Later in this same video from the bathroom Maya turns her attention to discuss her personal commitments to the work she is doing in the bathroom and elsewhere:

> *I know this is kind of lame, but I went on this web site where you could pledge to do stuff like keep the amount of energy and water you use low. It is about green stuff. I pledged to do a couple of things. Like turning the water off while I am brushing my teeth because that is wasting water by the minute. And if your water bill is really high, if you are using water your bill is going to be high, so I pledge to do that kind of stuff.*

Despite social stigmas she experiences in connection to being involved in science, as evidenced by qualifying her statement as "kind of lame," Maya wants teachers to know that she cares and wants to make a difference in her community and beyond with the science she knows. The video reveals that her care and concern for the economic and environmental ramifications of water use extends to her personal decisions outside of structured learning experiences. This is important because Maya has also talked about how her family lives on a budget, and saving both energy and money is important to them. It is also an example of Maya contextualizing and taking action based on her science understandings.

Maya notes in another short audio clip, also included in her case, that making and sharing videos was an important way to make science ideas *accessible* to a wide range of others—to teach and to inspire action regarding their own behaviors. Maya said "When we make our videos, we make them really interesting so people like to watch them. Videos attract people, so if more people watch our videos, the more people hear our message." She goes on to name some of the people she thinks about when making videos, such as leaders at the BGC, community leaders, and teachers, because, "people in charge in our community have a higher advantage to tell more people." She also targets, "people in the community who have high electricity bills and are using incandescent bulbs"; people who are likely to benefit from actions grounded in deeper understandings—saving money and the environment—made accessible through the types of videos Maya and her peers create.

Lastly, Maya shares a story she wrote entitled "Science: From a Different Point of View." In this story, Maya wrote about her "highest moment" in science. She describes a moment when she was reasoning aloud about why coal consumption was harmful for the environment.

> *THEN IT CLICKED!!! By clicked I mean that it all came together, and I realized that I can make a change if I just apply myself and use my brain and I don't have to worry about being wrong as long as I think my answers through and have fun doing that because all that matters is that I try. Green Club isn't boring you just have to apply yourself… I started to enjoy Green Club. Next thing you know I'm making videos with my friends and getting great opportunities to apply myself and have fun doing it. Next thing you know we are having carnivals and going to MSU [to teach others]…*

Maya's story embodies how she engages science with a commitment to her community. The moment when everything "clicked" – indicates her growing ability to link what she knows, what she can do with what she knows, and why it matters to her community and her world. For Maya, in order for science understandings to be leveraged to solve important problems it must also be contextualized, accessible, and hold the potential for action.

4.1.2 | Nicole: "helping out"

"My mom is a single parent. She is doing whatever she can to take care of me and her, and I just want to give back to the community to show my appreciation for my mom."

Like Maya, Nicole views engaging science as deeply tied to a commitment to her community. For Nicole, this commitment involves having a deep awareness of the immediate challenges faced by those around her, and helping others to address those challenges. In her written message to teachers, which opens her case, she writes, "We try to help the community out… It is important because we are a whole team, and no one wants to die over too much CO_2. So we help the community and they need to help us too."

Nicole's case draws attention to the intersection of economic and environmental challenges faced by people in her community, such as difficulty paying electricity bills and lost jobs. These experiences are what she says have been her primary inspiration to becoming involved with science.

She also felt it was important for teachers to hear about these stories because they needed to know what challenges their students might face. The first artifact she presented in her case was a written description of what it was like to grow up in her city that she produced during a youth conversation group when she was in the sixth grade. The following excerpt highlights the specific economic challenges that we see later threaded across her case:

> *It is normal to have problems in a state but you can't keep having those problems. You need someone to come and fix them so we can have a better city and actually people would say hey that is a good city and we should go there to live there. Even though we have little of jobs, we are still working on that… I already have two friends that have left Great Lakes City just because of jobs and stuff.*

Nicole is protective of her city, despite the fact that it has faced severe economic challenges, which have impacted her personally. She refers to the importance of helping out with what she knows as an integral part of rebuilding her city. Nicole included several video artifacts that illustrated how she used her energy-related science expertise to address economic challenges faced by her family and community head on. In one video focused on why her work with science is important to her shot while she was in seventh grade, Nicole spoke about her efforts to help her mother deal with economic hardships through using water resources more efficiently.

> *She listened to me on that one (reducing water uses through efficient technology), because she has a really high bill and stuff. So she needed to know a way to bring her bill down so now that we are living in an apartment they put energy efficient stuff in. Like the showerheads, it has one of those energy efficient things in it and it is really cool too because we are saving water.*

Nicole's desires to help her community, as we see in this video artifact, are not simply about acquiring and revoicing narratives about environmentalism. Nicole's efforts to save money through employing new energy technologies and behavioral changes are deeply tied to her growing contextualized understanding of energy systems and green design. Threaded throughout her work, we also see a critical stance toward the use of energy efficient technologies. If we return to the video she made with Maya (discussed in Maya's case), she and her friends developed a nuanced audit of water efficient technologies in their school bathrooms to ground their claims about efficiency not only in the technology itself, but also in data they generated about how they are used by the people at their school.

Nicole also cared about teaching others as a part of helping them. In the video artifact we describe next, we see Nicole attending to both teach others as well as take on the twin challenges of economic and environmental concerns raised by the electrical production and consumption system in her city. Drawing attention to her school, and the recent budget cuts faced by the school district, she further explores how her school could save money.

FIGURE 1 Energy efficiency video [Color figure can be viewed at wileyonlinelibrary.com]

The 3-minute and 44-second video she made during sixth grade begins with a picture of coal and a coal-fired power plant, with Michael Jackson singing in the background, "What have we done to the world? Look what we've done." The next scene presents a picture of a power strip with several appliances plugged in, and the text "How much energy are you using?" Nicole and her friend Maya (previous case) then pose a set of questions tied to energy practices at their school: "Do you turn off the lights when you leave the room? Do you turn off the computer when you are not using it?" They share interview snippets with teachers, which focus on their energy practices, and using video footage and pictures, illustrate how they conducted an audit of their school's energy practices. They situate their school's energy challenges within a national context ("US schools spend close to $6 billion a year in energy") and challenge the viewer to consider "how much" they could "save" if they took up different practices (see Figure 1). In the background Selena Gomez is singing,

> *"Everybody tells me that it's so hard to make it/It's so hard to break yeah/There's no way to fake it [cut] Tell me tell me tell me tell me something I don't know."*

Nicole and Maya then offer two solutions: switching to CFL light bulbs and monitoring personal energy behaviors. Nicole takes the lead explaining CFL technology including sharing a story of her grandmother who switched to CFL bulbs upon her urging and was surprised to discover her energy usage went down, along with her bill. Nicole ends by saying, "Now she can use the money for the things she needs" (see Figure 1).

The multiple layers of messaging in the video—the music selection, the text, the images and spoken word all add depth to what Nicole and Maya seek to share with others in ways that are accessible to them. Through music, they implicate themselves in the broader problem (look what "we" have done to the world), and indicate that "there is no way to fake it" through solutions. They use a lesser known song from a popular cultural icon (Michael Jackson), to speak, in part, to cultural insiders who will know his music well. They use text boxes to pose questions, share data, and state claims in engaging and easy to access ways, as we see in the figure above. Pictures and video clips provide further details that are not spoken (e.g., reminding the viewer that Great Lake City's electricity comes from coal that many teachers at their school are unaware of their energy practices, etc.). And their voice intonation and gestures invoke a strong sense of *urgency* tempered with *hope*—that if only we learned more about what was going on, we could take educated action toward making a difference.

In addition to sharing this video on her case, Nicole shared it at community events, such as the Green Carnival[2], where youth sought to engage hundreds of members of their community in dialog and practices of green energy. She also brought it to school to be viewed by her classmates to experience with her how they can take action in their community.

Nicole's last artifact—a tour of her apartment—further reveals how important it is to Nicole that science learning and doing always happens at the powered boundaries of race, class, and gender that are a part of the wider economic,

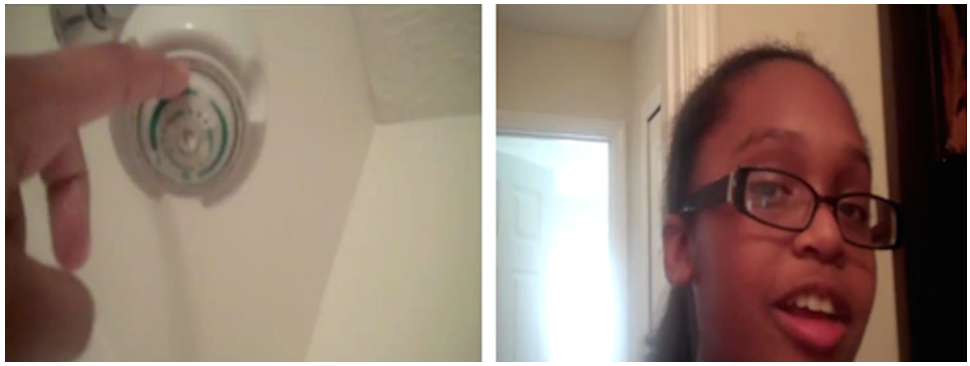

FIGURE 2 Nicole's apartment tour [Color figure can be viewed at wileyonlinelibrary.com]

social, and political concerns of her community. In this "crib style"[3] video apartment tour that Nicole specifically made for her teachers while she was in seventh grade, she provides a glimpse of her home life as she describes the "an energy efficiency make over" that her apartment received (see Figure 2).

The video itself foregrounds the energy efficient technologies that Nicole carefully describes to the viewer. For example, in one scene, Nicole is in the bathroom showing a water-efficient faucet. The camera zooms in on the faucet and you hear Nicole talking about how the technology limits the amount of water used. Next you hear Nicole say, "Does anybody know why? Hmm, you don't know, do you? Alright, I am going to tell you why." Nicole then describes how the faucet has a smaller opening, restricting the amount of water coming out resulting in less water usage, while still retaining the same amount of pressure as a regular faucet. The movie, at the same time, shared a narrative of why and how these issues matter in her life. As she walks us through her small apartment she shares with her mom, she describes the importance of saving money, and provides advice on where to buy these technologies affordably. This video artifact pushes her teachers to think about how their classrooms, and the science they teach, are part of the community in which they are located.

4.1.3 | Caitlyn: "how it matters here"

Caitlyn uses her case to argue for the vital role of community, including her existing and developing commitments to her community, in learning and doing. In one of her explicit messages to science teachers, Caitlyn wrote, "we talk about a lot of stuff (in school) but never consider *how it matters here*" (emphasis added). She uses her case to highlight that the complexity and excitement of this work does not lie in simply gaining scientific understandings, but instead in contextualizing those understandings and making them accessible to multiple audiences to empower them to take action. Her views implicate the importance of young people knowing and doing, in the here and now.

Caitlyn's artifacts span 3.5 years of work, from fifth through seventh grade. Looking across the artifacts, one can see her understandings and abilities in science developing over time—from her explanation of how green roofs work and why they are important to a discussion of the impact of the current electrical production system on carbon emissions. At the same time, one can see her growing efforts to contextualize her understandings in ways that make them accessible to others and deeply ground them in her community-based concerns. She threads economic, political, and ecological narratives into youth-centered videos that draw attention through her use of pop culture.

For example, Caitlyn shared a video she made in the fifth grade on climate change. It begins with her stating her reason for making the video, which is to "make people aware of climate change. If people aren't aware about climate change, the world will never change." The video them immediately positions the viewer and the author as central to the problem and solution. With a picture of hands holding the Earth, and the climate change rap playing in the background[4], Caitlyn both states and scrolls the text,

TABLE 1 Climate change video

Scrolling and Spoken Text	Images
Climate change will occur	Graph of carbon emissions in the northern and southern hemispheres, by year
Glaciers will melt because of the heat differences in the atmosphere	Melting glaciers
Floods will happen all over the world	Flooding, Hurricane Katrina
Penguins will go hungry because the oceans will be polluted by careless people	Penguins
CO_2 will also contribute to climate change	Great Lakes City power plant
How can we prevent climate change?	Pollution billows
The future is wrapped in one light bulb	CFL
And some people don't even know it	Person walking in green field unaware of the tornado behind them
So lets get people to know	Black screen
The future is now	Earth embedded in a lightbulb

The earth is in our *hands*

so take care of it.

How come we *have to*

Take care of the earth?

The video then presents a textual and pictorial narrative regarding how carbon emissions, produced in part from their city's power plant, will lead to local and global environmental problems, including poor air quality in their city, flooding from hurricanes, and melting glaciers. Table 1 provides an overview of the video.

In the video, Caitlyn situates the problem of climate change in local practice by focusing on the local power plant that relies exclusively on coal. She implicates both local and global issues (air quality, flooding, penguins) with specific attention to the specialized problems that poorer communities might face, such as the impact that flooding had on the communities in New Orleans during Hurricane Katrina. She identifies a lack of awareness as a roadblock to understanding before reminding her audience that there is an *urgency* to her message and that "the future is now." She ends with a call for her peers to change their behaviors and to "take aim at climate change."

Caitlyn's messages become more deeply entwined with her commitments to community and the centrality of youth as her understandings of energy, the environment, and her community develop over time. Her second video artifact, "Make a Change" focuses on taking action on issues related to the economic hardships felt throughout Great Lakes City. Upon hearing of a budget crisis set to impact their local school district, which was already resource-strapped, Caitlyn and two other youth designed and conducted an energy audit of their school. Specifically, in the video made during their sixth-grade year, Caitlyn and her peers investigate the types of light bulbs used in classrooms, bathrooms, and other school spaces. The video is serious and yet playful, as Caitlyn and her peers incorporate dance, music, and youth talk into an urgent and deliberative call to understand the interrelationships among energy, the environment, and the economy. The video ends with calculations based on the data collected during the audit of pounds of CO_2 and dollars that would be saved if the school switched all incandescent bulbs to energy-efficient ones (see Figure 3).

The video is directed at various audiences such as her peers, parents, city leaders, and school personnel. After her video was shown at her school, her principal pledged to change all of the lights, and eventually did. When the local energy company had learned of the video, they further donated 1,000 CFL bulbs for Green Club youth to distribute to their families and community members. Caitlyn and her peers distributed these bulbs at the BGC and their churches, but not before they asked family and community members to participate in a short hands-on workshop they created to communicate understandings about energy efficiency. As Caitlyn later reflected on this video, "I think it was important

FIGURE 3 Caitlyn's energy audit video [Color figure can be viewed at wileyonlinelibrary.com]

for teachers to see that we, three African American girls, … used our investigation to make a real difference for our school… We actually saved them money." Here, she challenges racialized and gendered narratives of who does science and the differences they can make.

Caitlyn's third artifact focused on a place that was a centerpiece in her life—the local BGC—where she has spent countless hours since she was a toddler. In the seventh grade, Caitlyn made a video with the goal of convincing others that the BCG needed a "new green leadership in energy and environmental design (LEED)-certified Teen Center." She and her peers investigated green building design using the LEED framework to guide their work. The investigation was set up around the idea of building a new teen center at the BGC, a need identified by the youth as well as several adult leaders at the club. Caitlyn and her peers felt that the BCG could be a leader in the community, showing others how to build in economically and environmentally sustainable ways, while also making the space attractive to the teens who no longer attended the club.

In the video, Caitlyn and her group members leverage what they have learned about LEED certification by highlighting various green construction features and offering recommendations for making the new LEED-certified teen center. To help her audience visualize these proposed features, Caitlyn created a detailed sketch of the new teen center using Google Sketchup that incorporated LEED recommendations gathered through their investigations in a three-dimensional drawing presented as a "fly through" tour (see Figure 4).

As with her school audit project, this video was designed to attract a range of viewers and open conversations about green building technologies in their community. It was shown at several community events where Caitlyn and her group members opened spaces for conversations with their peers and adult community members to ensure it was built to attract a greater number of teens to the club, be environmentally friendly and economically viable. The video was also presented to the board members at the BGC as they considered the idea of building a new teen center.

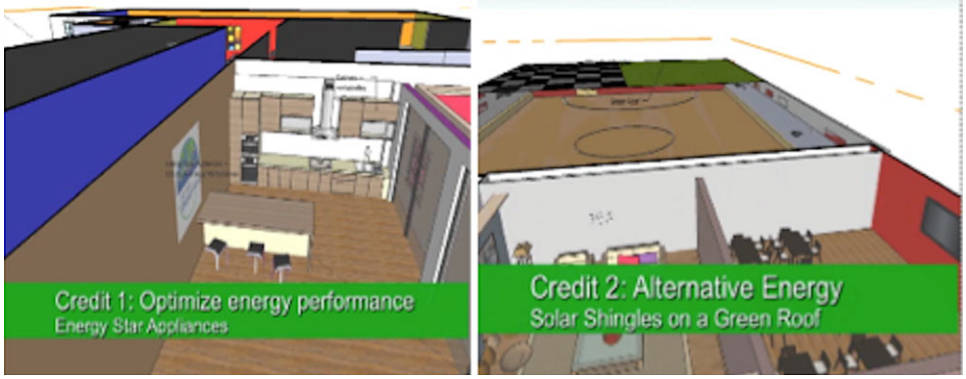

FIGURE 4 LEED teen center sketch up [Color figure can be viewed at wileyonlinelibrary.com]

These three examples, representing Caitlyn's work over the course of 3 years, highlight her ability to contextualize her understandings of science to make messages accessible and inspire action within her community. Through her messages and artifacts, she wanted science teachers to understand that in addition to developing understandings of science content/practices, linking science and community requires understanding wider economic, ecological, and political concerns of her community, especially with respect to the experiences that young African American girls in lower income communities might have. In this way, her artifacts are intended to help science teachers think about how engaging science with a commitment to community opens space to "consider how this matters here."

4.1.4 | Hannah: "it was good"

Hannah's case reveals the experiences of a youth who has traditionally been unsuccessful in school and with science. She uses her case to show science teachers that she is capable and dedicated to engaging science with a commitment to her community. For Hannah, this means that her case reveals success impacting her community with science within the backdrop of her own sociohistorical positioning as a female from a low-income family who has never enjoyed the label of the "smart science student." Her awareness of her positioning is evident through her messages to science teachers in reference to video artifacts found in her case. Hannah wanted to make sure teachers knew that "we worked hard and the video is good," that she was able "to get it done," and that "she got known with it."

These statements reveal a desire to let science teachers know that she is capable of learning science, taking action upon her understandings, and that she has been recognized for these abilities despite the history she carries forward as a student. Her artifact section begins by addressing her own history in the space she most often feels alienated from science – school. Hannah's video, personally designated as her "high moment" with science, was of her collaboratively teaching a lesson while in fifth grade on energy efficiency with her Green Club peers to younger students in her school. The experience was important to Hannah "because I got to go into other classes and show people what I know about science."

The lesson begins by surveying students about what types of light bulbs they use at home before asking them to predict the efficiency of three different kinds of light bulbs presented (incandescent, CFL, LED). The video shows Hannah coteaching this section and leading the class into an experiment of the amount of energy each bulb uses. Hannah says, "Let's compare light bulbs to see if CFL light bulbs and LED light bulbs can save energy. Like, this is the CFL and that is the incandescent." After her partner lets the students know that they will be measuring energy using a watt meter, Hannah asks for volunteers to predict how many watts each bulb will use. Every student that can be seen in the video has his or her hand up to make a prediction. Hannah calls on students as another Green Club youth makes note of their predictions by repeating each students' guess. After many predictions are elicited, Hannah focuses the class on collecting data by saying, "OK, let's measure how much energy each light bulb uses." Next she calls on a student to come to the front of the room and helps them read the watt meter, which she then repeats for the other two bulbs. Hannah then asks, "What did you notice about the amount of energy used between a CFL, LED and incandescent light bulb?" The 5-minute 42-second video clip (a selected portion of the entire lesson) ends with students discussing what they noticed and what that means for the amount of energy they use at home.

To plan this experience, Hannah and her group members reflected upon the knowledge and practices they had developed over time about energy efficiency and how to best connect those ideas to younger students. Hannah drew upon her experiences learning and doing science across contexts in Great Lakes City to foreground student experiences at home and at school to make science concepts accessible and important to a younger audience. She also leveraged and communicated her understandings of efficiency, energy transfer, and wasted energy to help others see how this knowledge was vital to addressing issues of energy use in their community.

Based upon her own history as a learner, Hannah's case includes other examples of ways in which to make science content accessible for others in her community with a specific focus on her peers. She includes two videos that point toward accessibility as an avenue toward action.

The first video, discussed in Nicole's case, was a project where Hannah, Nicole, and Maya engaged in an investigation of water-efficient technologies in connection with a LEED certification exploration. The video begins with a song

TABLE 2 Hannah's water efficiency video

Scrolling or Spoken Text	Images
Eco-friendly faucets are faucets where less water comes out than a regular faucet but the pressure is the same	Image of the Earth coming out of a faucet
It does this because the opening letting less water out	Image of an eco-friendly faucet
Are you wondering how much less water? Well I can tell you. An eco-friendly faucet uses 1.4 gallons per minute and a regular faucet uses 4 or 5 gallons per minute	Image of an eco-friendly faucet will water usage statistics scrolling across the screen
And that is saving a lot of water with eco-friendly faucets	Image of a faucet with the slogan "every drop counts"

mimicking the theme song from Bill Nye the Science guy and accompanying dance that Hannah wrote and choreographed. The girls danced as they sang:

Water efficiency … water, water, water

Water efficiency … water, water, water

Water rules!

Hannah leveraged her talents as an artist and musician to open the video in a way she believed would attract audiences of her peers. Next, the video shifts into a discussion of water efficiency where we hear Hannah defines the term as "the long-term ethic of saving water resources through the employment of water saving technologies and technologies." Next, she talks specifically about the benefits of low flow faucets, a technology she believed would impact environmental and economic narratives both at home and in her school (see Table 2).

Hannah highlights her ability to leverage areas of expertise not traditionally valued as part of science, but that are part of who Hannah is and what she cares about. The videos also underscore that she is willing to work hard to learn and communicate science understandings when engaged with a commitment to her community.

The final video Hannah chose to include stems from a conversation during her sixth-grade year where many of the Green Club youth, despite being involved in an afterschool science program, were having trouble coming up with anything they liked about science (see Maya's case). This distinction between the ways in which they experienced science in different contexts led the youth to create a new word, fcience (pronounced fy-ence), to describe the type of science they participate with outside of school. Hannah was a driving force in coming up with the word, defining it and later appearing in a short video describing the term that was included in here case (see Figure 5).

Female Youth: Our word of the day is …

Hannah: Fcience

Female Youth: Fcience is what describes Green Club, its science that's fun

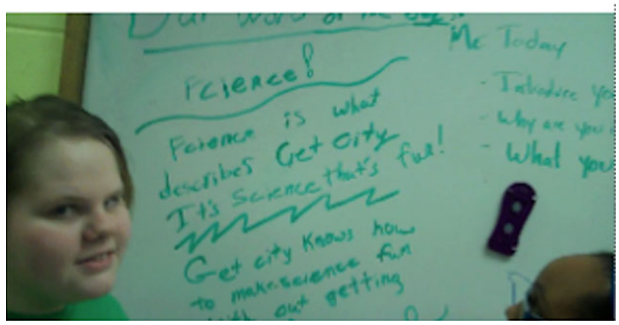

FIGURE 5 Fscience video [Color figure can be viewed at wileyonlinelibrary.com]

Hannah: Green Club knows how to make science fun without getting bored

Both: Instead of a bored face, you will have a happy face

The term "fcience" challenges how we think about the accessibility of science for Hannah and others like her in school settings. It points toward Hannah's insistence that she is capable and interested in developing expertise in science, but those understandings cannot be separated from who she is, what she cares about, and the types of impact she would like to make on her community. The artifacts in Hannah's case underscores that fcience is not simply a desire to have fun devoid of learning. Instead, science is something these youth want to engage with when it is made accessible, contextualized, and geared toward action that aligns with their commitments to community.

4.2 | Bridging and reorganizing science and community

Science and community, generally, have been viewed as producing different and sometimes contradictory practices that are in tension with one another. In this section, we develop our second claim regarding the creative and dynamic ways in which the girls bridge these worlds that embody a dialectical relationship between the scientific and community. Particularly, we further unpack the girls' cases to illustrate how they bridge various forms of expertise (science, community, cultures, each other's strengths, popular culture, technological savviness) to communicate understandings across the boundaries of science and community, and to build the capacity to engage in this work.

4.2.1 | Communicating across boundaries

The girls, through their artifacts, renegotiated epistemological and power boundaries between scientific and nonscientific, repositioning science expertise as involving insider knowledge/practice. For example, one of the key practices featured across the girls' cases was the ability to communicate their science knowledge with those closest to them. We see this practice taking several forms, including:

- integrating place-based arguments in relation to local experiences and expertise,
- linking environmental and economic narratives,
- using multiple forms of representation, which include popular culture and youth-centered talk,
- positioning youth as or more capable than adults.

These practices represent the various ways in which these girls are responsive to their commitments to their community. Through employing these practices, they are addressing local issues, positioning themselves as experts, working to make science accessible for community members and drawing upon personal experiences and hardships with family and friends to not only take action themselves, but also empower others to act. The girls show how they leveraged these practices in their cases by exhibiting how they are able to negotiate and move ideas across existing barriers between science and community with their parents, other significant adults, and peers, opening up new and legitimate forms of participation for themselves and others in their household and/or community.

For example, in Caitlyn's Climate Change video, we see her situating the global problem of climate change in local practices with local impacts. Her use of video, music, images, and text provide her peer audience with multiple ways to interact with the video, helping them to link their own energy practices with broader global issues (see Figure 6).

The picture on the right is of the local power plant that represents the backdrop to many of the experiences her peers have on a daily basis. On the left is a global image with a message reflecting the idea of a collective responsibility for the health of our planet. The video connects use of electricity at home and school to CO_2 emissions at their local power plant and finally to the overall health of the planet. Caitlyn uses multiple forms of media and local knowledge to communicate understandings to her peers and other community members about the causes and potential ramifications of climate change by moving the idea across the contexts of their lives. The video highlights Caitlyn's belief that collective action is needed across her community to make a difference and underscores the importance of leveraging practices aimed at empowering others.

FIGURE 6 Caitlyn's local and global implications of climate change [Color figure can be viewed at wileyonlinelibrary.com]

In her LEED video, we see her continue to use a wide range of representations that might convince a more adult audience. By juxtaposing the local need for better space for teens with economic (cost), environmental (better for the environment), social (increasing teen attendance), and political (we can be leaders) messages, she reorganizes doing science to explicitly involve a commitment to community from multiple perspectives.

At other times, it was necessary for the girls to repurpose ideas to move them across community and social boundaries when communicating science understandings. The act of repurposing and moving of ideas and resources was a critical practice in helping the girls redefine what it means to be an expert, and to bridging science and community in powerful and accessible ways. For example, in school, Hannah has not often found success and is rarely recognized as a "good student." Yet, in her case, she argues that not only is she willing to work hard, but she enjoys participating with fcience. In her repurposing of science, fun is not the antithesis of or distraction from learning as it is often framed. Instead, fun comes through actively working together to learn and use science in and for her community. She provides evidence in her case through sharing a vision of fcience learning in one of her artifacts, a video on LEED certification she created with Maya and Nicole. The video is both playful and embedded with rich science content designed to teach others by defining water efficiency, why it is important and detailing technologies (W.E. faucets, rain barrels, low-flow showerheads) that could be used at home. Hannah's repurposing of what learning and doing science can look like allowed her to communicate energy related understandings in ways that engage peers and other community members and connect those understandings to their lives in schools, at home, and in other community spaces.

In their cases, the girls communicated artifacts that either described or were created to facilitate real opportunities in community spaces for peers/community members to observe, participate in, and become fluent with energy-related understandings to impact local economic and environmental conditions. Each of the girls shared artifacts that focused on communicating messages of bridging science and their places to various groups based on experiences across settings and over time. Maya and Nicole, in particular, wove in economic narratives to create engagement points into science. Nicole even mentioned that her mother did not start to listen to her until she incorporated economic narratives. Hannah foregrounded her ability to get it done by helping younger students see how energy efficiency can matter in their homes/schools. These practices positioned the youth as experts, who knew some things about both the science at hand *and* the needs of the community to make the messages resonate with community members and teachers in ways that mattered to them. The girls' artifacts reveal that vital to consequential learning involved breaking down the science/community binaries in ways that positioned themselves, their families, and communities as having power and agency.

4.2.2 | Capacity building

To shift the outcomes of science toward their commitments to community, the four girls recognized a need to build capacity toward these goals. This involved the girls developing practices for expanding their networks of activity across

people, places, and expertise. For instance, Maya wanted to make sure that teachers understood that "we work with a group of people who want to be there and want to cooperate with each other. We actually enjoy it and it is something that we love to do." Nicole wrote to teachers, "We work in groups so it works even better. All of us have different types of knowledge and different levels of knowledge, so if someone doesn't know something, someone in your group will help you."

The collective and collaborative approach valued by the girls expands their networks of activity by broadening the diversity of expertise considered when taking on local and global issues. These expanding networks are also dialogic—sharing their ideas/actions and learning more from others' cultural practices and strengths they bring to conversations and investigations. The community events they highlight in their artifacts (e.g., LEED video used for the green carnival or the energy audit video used with school leadership) reveals the value of on-going energy conversations in their community and their roles in them. As we saw in the water efficiency video, the school energy video, and the Maya's story, the girls present evidence of experience working alongside "experts" from around their state and around the country in working on energy problems in their community. This was all part of the collaborative process of building their capacity to contribute to ongoing local economic and environmental narratives, necessary for their goal of making the world a better place.

If we look closely at the video Hannah, Nicole, and Maya created together on water efficiency, we can see how each of the girls played a unique role in making this video a useful resource to others and in how they drew upon their individual expertise and interests. Hannah leveraged artistic skills to write and choreograph a song/dance about water efficiency to appeal to their peers existing interests. Nicole leveraged her understanding of economic hardships experienced by her family and community members while Maya brought a commitment to the environmental ramifications of overusing water. These girls learned from each other, and leaned on each other to build understanding of water efficiency and communicate it to multiple audiences.

However, the video was also a result of engaging with LEED experts at Michigan State University and around the state of Michigan, as well as groups of community experts made up of local politicians, BGC board members, family members, and their peers. Through listening and engaging in conversation with this diverse group of people, places, and expertise, the girls were able to better understand the complexity of economic and environmental concerns across contexts.

The girls' cases reveal their desire and ability to bridge science and their community through their developing bridging practices. Specifically, the girls reveal developing practices necessary to communicate science understanding with various members of their community as well as recognition this work requires building capacity through broadening their networks of activity. Through efforts to bridge science and community in schools, homes, and the club, their varied and growing expertise was recognized and valued by different groups within and outside of their community, inspiring them to continue to alter their modes of participation with science, feeding their desire to make a difference in/for their community.

4.3 | Bridging practices toward breaking down barriers

In this section, we call attention to how the girls consistently and powerfully engaged in bridging practices toward breaking down barriers they confronted about their participation in science. Indeed, the girls encountered normative barriers in science connected to race, gender, class, and age that they call attention to in their cases. They acknowledge their youth and make a plea for others to see the impact that they can have as young people (e.g., "Think about it—I am a 12-year-old sixth grade girl saving the world and its people."). Their families' and friends' economic struggles are front and center to their narratives. Their messages act as strong responses to the "racialized practices" they have experienced in science (Martin & Shah, in press). In particular, the girls communicate and challenge the deficit-oriented ways in which they believe others see their neighborhoods as well as their individual/collective abilities. Through invoking these narratives, the girls remind us that all experiences are filtered through the lens of race. Finally, that they work hard, care about science and their communities, are smart and capable, and live with families who also work hard are points they needed to make strongly and centrally in their cases.

By leveraging practices described throughout this paper and being recognized for doing science in their community, the girls altered their modes of participation with/in science in ways that challenged normative views of how girls and nondominant youth can and do engage with science. Examples of the girls challenging normative views about who does science and where it is important can be seen across all four cases in terms of how they position themselves as experts and communicate that expertise with others. This is evident in Caitlyn's video proposing a new LEED-certified teen center to the board of directors at the BGC, Nicole's bridging science and community to impact conditions at home, and Hannah's placing community at the center of learning science in her school for younger children. These examples reveal young women who do science routinely but in nonroutine ways. They work hard at it and take action upon issues facing their community despite how others perceive their abilities as well as the ability and desire for members of their community to participate with science.

If we look closer at Maya's case, as one example, we can further see how the ability and desire to challenge normative views required the girls to simultaneously engage the contexts in which they learn science, the discourses, and other forms of representation, and the tools and artifacts by which ideas move and become reified over time (Leander et al., 2010). In many ways, Maya served as the original inspiration for this study by critically questioning the degree to which science matters in school ("to get into college and get a job") and outside of school ("to make a difference for our Earth"). One of the artifacts that exhibits her desire to challenge normative views and ability to realize the significance of challenging these views is found in her story, "Science from a different point of view." In the story, Maya writes about an experience where it clicked for her that she could make valuable contributions to science investigations despite her inclusion in intersecting categories that often position her and her community as outsiders to science. She ends the story by reminding us that she is a "12-year-old sixth grade girl saving the world and its people."

As a young, African American female, Maya rejects notions that she is not smart enough, interested enough, or from the right neighborhood to be considered someone who can do science. In her story and supporting artifacts, she challenges traditional Western explicit and implicit racialized narratives about who participates in science and to which communities this participation matters. By naming the story, "Science from a different point of view," she recognizes and then desettles the normative views of science learning and doing that she must challenge to alter the ways in which she (and her peers) participates with science. She also points to how being recognized for bridging science and community and taking action based on her expertise empowers her to continue working to "sav(e) the world and its people."

That an ethics of care—care for community and all of its complexities—was central to the girls' practices is worth noting (Noddings, 1992), despite not being recognized as a valued way of being in the more positivistic world of science (Harding, 2008). However, the young women who authored these cases attend to the injustices their families and communities have experienced, both material and environmental, and make that central to their argument. They deeply and passionately engage new ideas and new people to understand these injustices and to respond to them productively. By doing so, they challenge not only the question of whether they belong in science, but they call into question the dominant conceptions and practices of knowledge structures and action.

5 | DISCUSSION

The girls' cases represent a more expansive view of *consequential learning* by foregrounding the importance of social context, empowerment, and action in the learning process. The experiences they communicated reveal their commitments to community when participating with/in science. The girls reveal that consequential learning is not simply about learning relevant science or seeing the impact of science learning. Instead, for the girls in this study, it is about both in connection to who they are and who/where they care about. Thus, consequential learning for these girls occurs in experiences where they act as empowered agents of change who develop and leverage understandings of science and their community as they work toward transforming local conditions.

Across the cases, "science that matters" for the girls involves participating and contributing to science learning environments that account for the social, cultural, political, and institutional "demands and contradictions" they negotiate as they "move in and across the ecologies" that constitute their everyday lives (Ito et al., 2013, p. 6). These layered social

contexts of their communities matter to how and why these girls participate with science, and the types of knowledge and practices they draw upon to communicate their understandings to others as we have highlighted above.

Engaging science with a commitment to community calls attention to the importance of the dynamic nature of their relationships to both science and community. Throughout their cases, the girls made strong statements about what they knew and could do that spoke to the importance of having opportunities to develop scientific knowledge and practice. However, their talk and actions indicated that such knowledge and practice was necessary to have an actual impact on local environmental and economic conditions. One way to think about this is that for science learning to be consequential, it must aim to solve problems in and for community. Each one of the girls in their cases invoked the importance of scientific understanding. And each of the girls positioned themselves, through their selected artifacts, as scientific experts who knew how to leverage their understandings to solve problems that matter in their community. Even more, they positioned themselves equally as strongly as science learners, as people who were willing to work hard enough to figure out what they needed to know so that their science-related actions would make a difference.

The girls' cases reveal how relationships between science and community form—and the learning opportunities they provide—are much more than interest driven. They are shaped by one's own historical geographies, suggesting that issues of power and privilege are deeply entrenched in how one experiences connected learning (Haan et al., 2014). As individuals move through space and time, their activity is enabled and constrained by the layered social contexts of their community(s), shaping what it means to engage and be seen as a legitimate participant in science with a commitment to community. The places where girls engage science, as highlighted in their cases, are not just physical places—the home, the club, or the classroom. They are sociocultural and political spaces with histories and trajectories of activity and relationships, further grounded by past and future cultural narratives and understandings of what it means to be and learn in that space.

However, if we look more closely at the ways in which youth authored consequential learning through their cases, we begin to see an emerging narrative. At the interplay of space and time for these girls, as they seek out science that matters, is the embodiment of *hope* and *urgency*. The youth express a sense of urgency in their desire to engage others in ever-expanding consequential learning in the here-and-now, and a sincere hope that the designed spaces in which they, and others, are assigned to learn can be transformed in the process. These almost visceral dimensions of hope and urgency are not simply affectively charged dimensions of learning; they are integral to how and why and where youth narrate science that matters. We discuss each point below.

5.1 | Expressing hope for school science

> *Hopelessness is a form of silence, of denying the world and fleeing from it… Hope, however, does not consist of crossing one's arms and waiting. As long as I fight, I am moved by hope: and if I fight with hope, then I can't wait (Freire, 1970, p. 72–73).*

Through their participation in this study and desire to work with science teachers, the girls expressed hope for what school science could become. Despite their prior experiences in science classrooms where they passively collect knowledge or experiences confronting narratives regarding their abilities or interests with science, these four girls still hold hope. Through their cases, these girls exhibit a realization that an education is about more than disembodied learning. It is the transformative power (Freire, 1970) of knowing and doing that matters. These girls' cases are filled with stories of moving and repurposing ideas and resources in ways that both break down science and community binaries, and that make a difference. Their hope rests on transformation and on the belief that change is possible.

In his writings on hope, Heidegger (1927/2006) states "To say that hope brings alleviation from depressing misgivings, means merely that even hope, as a state of mind, is still related to our burdens, and related in the mode of Being-as-having-been" (p. 396). Heidegger highlights the temporal aspects of hope as both related to what is to come as well as a result of what has already been. Hope is a response to an identified experience or set of experiences that an individual or group desires to alter.

These four girls worked tirelessly to put these cases together. However, their hope originates with past experiences—being recognized as an expert and seeing work make a difference propels the girls to think about future spaces in which their work is needed. Their hope also emerges alongside the social connections they build across space and time. These girls focus their hope on micro- and macrolevel change in how science is taught in classrooms, in their relationships with their teachers, and their (and their peers' and community's) future opportunities for participation in science. Their hope, in many ways, "desettles expectations," problematizing "entrenched, usually hidden, boundaries that tend to control the borders of acceptable meanings and meaning-making practices" (Bang & Medin, 2010, p. 303), relationships, and places.

However, hope is not infinite. We further argue that without hope that things can change, or that their work as community scientists makes a difference, there is no consequential learning. Even if science is connected to place and youth enjoy engaging with it, if they/we do not see how actions impact those around them or hold the potential to, then they become just another learning experience (O'Connor & Allen, 2010). It does not alter the epistemic or power narratives that the youth in our study sought so hard to shift.

5.2 | Embodied urgency of their messages

The girls' work challenges how we think about consequential learning by disrupting spatial/temporal notions of classrooms and learning. In addition to being hopeful, the girls stressed a sense of urgency in the need for change. We felt part of this urgency was connected to the girls' understanding of the gravity of the environmental and economic concerns they cared about and the need for action now. However, the urgency also extended to their own and their peers' futures as science learners and potential aspirations as science professionals. They shared experiences where they are physically present in their science classrooms, but not participating with science in ways that matter beyond completion of a course. For the most part, they are "achieving" in terms of grades and test scores, but are seeing little value in what they are doing. They are youth who refused to be disembodied. They desire to have their very selves acknowledged "as a tool for mediating relations with the world" (Nespor cited Leander et al., 2010, p. 338).

Research supports these girls' urgency in terms of a lack of STEM participation among females as well as African American and Hispanic students (National Science Foundation, 2014). Just as they presented hope for change that would impact themselves and their peers, their call for urgency went beyond concern for their own learning. They express fear that their peers are not sharing in the opportunities they have found to participate with science in ways that matter, serving to perpetuate narratives about who can do science and where it matters; further cementing modes of participation with science among youth from nondominant communities.

And yet the youths' conceptions of hope and urgency are both absent in the Next Generation Science Standards. Instead, youth participation in civic–science dialog is positioned as a future endeavor once they learn the intended content and practices required for high school graduation. Clearly, this is not what the girls hope for, and what we must take action on. The girls' stories point toward the multitude of ways in which science education must provide opportunities for young people, while still in school, to bridge science and community. Teaching practices that link these worlds is not only important for young people to see a reason to engage in science, but critical to our planet's future.

6 | IMPLICATIONS

As we worked with the girls to co-construct these cases, we often found ourselves wondering how the girls' conceptions of consequential learning could impact learning and participation in formal school contexts. We believe it is significant that these girls chose teachers and schools as the people and places in which to share their experiences and conceptions of consequential learning. Once again, it reveals a belief that teachers hold the power to alter experiences in schools for themselves and others, yet are unsure of how or why these changes are important. In response, the girls' cases are constructed so that science teachers might realize the importance of altering patterns of participation and expanding who and what is recognized as valuable within and across "dynamic networks of practice" (Jurow & Shea, 2015).

We believe the girls' conception of consequential learning presented throughout this paper present powerful narratives to help science educators understand how youth can and do contribute toward altering what gets counted as learning, as being expert, and as meaningful participation across the contexts of their lives. These narratives hold promise to bridge the informal/formal learning divide in ways that reveal the possibilities for altering participation in STEM for youth from marginalized communities. In particular, the girls reveal elements of the learning process that leads to science that matters such as legitimizing multiple sources of expertise, providing opportunities to take action and bridging science concepts and skills with community concerns.

To move forward in addressing the informal/formal divide through the inclusion of consequential learning in K-12 schools, greater attention is needed in several areas. First, the girls reveal the importance of their commitment to community and their dynamic social networks in learning and taking action with/in science. However, school science is often decontextualized from the lived experiences of youth, especially youth from marginalized communities. Greater attention needs to be given to the ways in which the incorporation of the assets and needs of local communities into school science creates tensions with existing institutional narratives that drive practice in school settings. Second, consequential learning requires teachers to consider how youth can be empowered both in connection with the learning process and the intended outcomes of participating with science. Greater attention needs to be given to the aspects of teacher learning and practice that allow for power to be distributed in classrooms in ways that allow youths' expertise and experiences to be legitimized. There is an important body of work that has examined how teachers can support identity development as a part of science learning in classrooms. However, more research needs to be conducted that examine other ways in which distributed expertise can be recognized and distributed in classrooms. We have begun this work with teachers by providing professional learning opportunities that foreground youths' experiences with consequential learning as well as studying how to support teacher noticing and responding to youths' ideas of "science that matters" (Birmingham, 2013; Birmingham & Calabrese Barton, in progress).

7 | CONCLUSION

To both recognize and design for consequential learning, the youth in our study remind us that we need to pay attention to the ways in which their commitment to their community matters to the how they engage with science. The girls remind educators how learning takes shape across spaces and time, in ways that desettle expectations for what it means to know, do, and have expertise. They further remind that this desettling is at the heart of a more expansive view of consequential learning. The girls' practices were meant to not only alter their own participation in science/community but to make possible new forms of engagement for others. Their practices sought to transform the outcomes of learning, inclusive of the knowledge products, actions, relationships, and ways of being legitimized for themselves and for others. At the same time, their cases further remind us that such a project is deeply political, for how youths' mobilities of learning expand is tied to institutional, sociohistorical, and in-the-moment power dynamics.

For the youth in our study, engaging science with a commitment to community broke down power and epistemological boundaries, allowing them to be seen by powerful members of their communities as experts and as people who make things happen. However, it left some boundaries untouched, such as that between everything-but-school and school. It was this boundary that these girls identified as a barrier preventing their peers from seeing science as consequential in their own lives, and to larger narratives about achievement and interest gaps in science among youth from nondominant communities[5]. By leveraging a sense of hope and urgency, the girls worked toward breaking down this boundary.

Yet, there is much work to do. The girls' participation in this project, their visions of learning/doing science that is consequential, and their identification of teachers and schools as the people and places in which to situate their work is a significant statement about the importance of understanding how dynamic social contexts influence learning and doing science for youth from nondominant communities, and the need to uncover the possibilities for school science experiences to reflect these practices, expertise, and expanded outcomes.

ENDNOTES

[1] Pseudonyms are used for people, places, and informal science group throughout this paper.

[2] Community event organized by Green Club Youth. For more, see Birmingham and Calabrese Barton (2014).

[3] Based off MTV Cribs program where celebrities show viewers around their homes.

[4] Take Aim at Climate Change: www.passporttoknowledge.com/polar-palooza.

[5] The work of understanding how science teachers make sense of these girls' cases and what it means for the divide between school science and all that is experienced outside of school is ongoing (Birmingham, 2013, Birmingham& Calabrese Barton, in progress).

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