Cognition and Instruction

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/hcgi20

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To cite this article: Edna Tan, Angela Calabrese Barton & Christina Restrepo Nazar (2022): Youth Enacting Social-Spatial Justice in Middle School STEM: Advancing Justice Work in Hyperlocal and Interscalar Ways, Cognition and Instruction, DOI: 10.1080/07370008.2022.2081692

To link to this article: https://doi.org/10.1080/07370008.2022.2081692

Published online: 07 Jun 2022.

COGNITION AND INSTRUCTION
https://doi.org/10.1080/07370008.2022.2081692

Youth Enacting Social-Spatial Justice in Middle School STEM: Advancing Justice Work in Hyperlocal and Interscalar Ways

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ABSTRACT

While issues of (in)justice in K12 STEM learning have garnered increasing attention, limited research has attended to learning as *social-spatial transformation*. We draw upon a justice-oriented framework of equitably consequential learning to call attention to how learning and engagement in K12 STEM is rooted in the history and geographies of young people's lives. Without attention to the ways in which learning is an historicized and sociopolitical activity, efforts to address seemingly intractable equity challenges in K12 STEM education across the intersections of racial and class inequality will remain elusive. Using data from middle school classroom studies focused on engineering for sustainable communities, where community ethnography is central to engineering design, we investigate the social-spatial relationalities that minoritized youth bring to engineering design, and how relationalities may support youth in transforming oppressive knowledge and power structures toward equitably consequential learning. Findings reveal that organizing learning engineering design around youths' rich everyday experiences and community wisdom through community ethnography, addressed hyperlocal, sociopolitical community challenges. As a result, the social-spatial terrain upon which subject-object relations are enacted shifted, expanding the discourses, practices and outcomes of middle school engineering design that were legitimized. Making present this power-mediated terrain makes visible the often hidden, but ever present, unjust school-based relationalities, enabling them to be re-mediated in justice-oriented ways. Paying attention to social-spatial relationalities reveal (1) the multiple scales of activity, (2) interscalar mobilities and interactions, and (3) possible resultant impacts of such interactions that further affect activity at each scale. We discuss implications for how theories of equitably consequential learning can be advanced through the frame of social-spatial justice.

While issues of (in)justice in K12 STEM learning have garnered increasing attention in the past several years, limited research has attended to learning as *social-spatial transformation*. We are concerned with how and why K12 STEM[1] science learning matters to youth and their communities. We hold the stance that fundamental to addressing justice-oriented challenges in science education is understanding the consequentiality of learning. We draw upon a justice-oriented framework of equitably consequential learning to call attention to how learning and engagement in science is rooted in the history and geographies of young people's lives. Supporting youths' rigorous engagement with STEM must include investigation into community and into the broader systemic injustices that play out in everyday living that inadvertently intersect with youths' learning. Without attention to the ways in which learning is an historicized and sociopolitical activity,

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[1]We use STEM in the context of K12 integrated science, where learning core ideas of engineering and technology are given equal status to learning the natural sciences (NGSS front matter, pp. 4–5). Additionally, one middle school represented here officially refers to K12 integrated science classes as "STEM" class. We do not mean STEM as an acronym for "Science, Technology, Engineering, Mathematics."

efforts to address seemingly intractable equity challenges in science education across the intersections of racial and class inequality will remain elusive (Calabrese Barton & Tan, 2018). We suggest that the soliciting for social-spatial justice in science learning through incorporating community ethnography as central to engineering design, is a productive way forward. By social-spatial justice, we refer to the ways in which injustice is produced and reproduced through the dialectical relationship between space and social interaction (Soja, 2010).

Consider the following vignette that took place in a K-6 school, where the sixth graders in Ms. L's class built innovations meant to address their school community's concerns, elicited through surveys and interviews by the sixth graders, as a part of an "engineering for sustainable communities" unit. In this school, orderliness in how students behave and comport themselves in common spaces such as hallways, was very important.

The students in Ms. L's sixth grade classroom worried that children in their K-6 school were unhappy. School had "too much drama" (data from community survey), and classroom activity was sometimes "boring." After interviewing parents and students in other classrooms and observing and interviewing the children walking through their hallway at different times of the school day, Mrs. L's sixth-graders concluded that being unhappy was a problem students needed to solve. Using a classroom engineering design challenge focused on sustainable communities, a group of four youth decided to build the "Helping Hands" mood-supporting interactive poster. The interactive poster was beautifully decorated, filled with pictures of happy animals, hearts, and diamonds, with a set of "helping hands" reaching out. The board had the words "Shine Bright," in reference to the R&B hit recorded by Rihanna, "Shine Bright Like a Diamond" (Furler, 2012). The Helping Hands board lights-up when an attached hand-crank generator is turned. The instructions read: "Use the board when you are feeling down (have a time out) and want to be picked up."

Louise, one of the project designers, explained, "we want the kindergarteners who walk down our hall know that we, sixth graders, care about them … They will see these "helping hands" and know (as she pointed to the poster)." She noted that "their eyes will pop too when the hands light-up, and they will know that they can do this kind of STEM work when they are in sixth grade, too." Groupmate, Elisha, noted that the design was easy for little kids to use. They designed it so that the handcrank would be easy to reach and turn, and even for kids who "can't read" they can see the "pretty pictures." Louise' group had two goals: To cheer up their peers, and signal to kindergarteners that STEM learning could be fun in the sixth grade.

The process of working toward this functioning light-up board took several iterations. Teacher, Ms. L, encouraged her students to interview and survey students and adults all around their school and community (not just their classroom) to collect as wide a range of data relating to challenges their school community currently faced. Later, when the students were analyzing their data and looking for patterns (e.g., "75% of the students we surveyed said low morale was an issue" because "school had too much negative drama" and "too many kids get in trouble"), Ms. L further encouraged her students to consider concrete examples of such patterns, as well as specific and practical solutions to those problems.

When Louise's group wanted to find a way to "pick up" the morale of the student body, Ms. L asked the group to consider how their design might help both kids and teachers. With feedback from visitors from their local community (e.g., parents, grandparents, local engineers), they refined their design to reach as many school community members as possible, including changing the placement of their poster (so that the shorter kindergarteners could reach the board and hand-crank), and adding additional encouraging images and phrases, addressing the literacy levels of younger students. Ms. L allowed students extra STEM days to work so that the prototypes would function as intended. When the project was completed and placed in the hallway, Ms. L encouraged her students to notice when it was used, and to remain observant so that if it needed repairs, they could fix it in a timely fashion.

In her interview at the end of the year Louise explained how much their poster helped with the school morale: “I was kinda surprised, like really, for how much people liked our poster. Like the little kindergarteners learned how to crank the lights on, and they were smiling. They were happy.”

She further explained that she felt happy every time she walked down the hall and saw her group’s poster displayed for all to use. Louise was pleased that the project was fun and playful and helped other children be happy, while also tackling a serious school problem.

In this vignette, the students were engaged in two engineering practices as defined by the Next Generation Science Standards (2013)—defining problems and designing solutions—as they sought to iteratively prototype the Helping Hands project. They deepened their knowledge of energy transformations and energy demands of loads, as they sought to figure out how to power four lights on their board with a 6v generator. Simultaneously, the youth situated this learning in efforts to more fully understand and engage the experiences of their school community members, and used classroom, recess and lunch time to work with each other, their teacher and visiting community members until they had a project that worked as they intended. Louise and her peers’ learning during this engineering unit was equitably consequential because it mattered to them in the here-and-now and yielded both socially transformational learning artifacts and new relationalities that promoted new social futures for themselves and their schoolmates, as the Helping Hands board was used by youth, teachers, staff and parents alike.

This vignette situates our focus with issues of social-spatial justice as manifested in the learning that relationalities engendered, and the transformation of these relationalities as integral to equitably consequential learning—which examines what matters to people in the here-and-now and toward imagined, just social futures. What is being learned, by whom, where, when and how, all matter to connect the present to the past and imagined future in social-spatial ways. Our research questions are:

1. What are the social-spatial relationalities that students bring into the STEM classroom when engaging in a sustainable engineering unit?
2. How does attending to social-spatial relationalities support minoritized students in challenging traditional knowledge and power structures toward consequential STEM learning?

This manuscript takes up these concerns by examining youth learning and engagement in sixth-grade STEM class during a unit focused on engineering for sustainable communities. We investigate how youth efforts to enact what they have termed “engineering that matters” opened up opportunities to recognize relationalities previously unsanctioned in the classroom and other school spaces, in ways that impacted their agency toward what, how, why and for whom, they engineer.

Engineering education and issues of justice

Justice-related issues in engineering education are chiefly concerned with (1) the enterprise of engineering itself, and (2) the underrepresentation of women and people of Color in engineering. The first critiques the norms and practices of engineering that have come to reflect the neoliberal agendas of governments and corporations for whom engineers work (Riley et al., 2014). Epistemologies of engineering—what counts as engineering, by whom and what engineering values—have thus been called into question. Specifically, Cech (2013) highlighted the problematic twin ideologies of traditional engineering education—depoliticization and meritocracy—that frame engineering as an apolitical and benign enterprise, where “issues of inequality and justices [are] irrelevant to engineering practice” (p. 68). Cech further argued that the ideology of meritocracy, with its focus on individual talent and ability as the sole determinant for achievement and success, acts to solidify the depoliticization ideology. Thus framed, political and social issues are simply not the purview of engineering or engineering education, leading to a "misframing [of] social justice issues" (Cech, 2013, p. 75). Hynes and Swenson (2013) likewise suggest that an equity agenda in engineering education should focus on attention on how engineering is done *for people, with people, and as people*. This view calls attention to how engineering education should focus not only on the knowledge and practice of the discipline but also on the needs of people who will be impacted by design solutions, as well as how people work together across different backgrounds, expertise and stakes in a project. However, few studies investigate how the social aspects of engineering by, and with, people contribute to disrupting and transforming the social-spatial relationalities in and of engineering.

This apolitical and individualistic culture of engineering is related to the lack of representation of women and professionals of Color in the field (National Center for Science and Engineering Statistics, 2016). Beyond gender and race, Cech and Waidzunas (2011) found that LGBTQ + engineering students felt isolated and performed as heteronormative, masculine and white as a shared coping mechanism to succeed. In sum, white masculinity as the prevailing culture in engineering reflects the voices of those who determined what engineering is and could be, with direct consequences to the content valued and legitimized in the discipline (Pawley, 2012).

The "service learning" pedagogical approach in engineering education also problematically reproduces injustices (Strand et al, 2003). *Whose* problem is important, *who* are the expert engineers deemed capable of addressing issues and if these engineers are outsiders or from the community, are crucial justice-oriented questions to consider in engineering education (Riley et al., 2014). Normalized power differentials between the "privileged server" and the "underprivileged served" (Henry, 2005) is in need of critique in engineering education (Nieusma & Riley, 2010).

Conceptual framework

Equitably consequential learning as a justice-oriented project

Our study is grounded in the research on equitably consequential learning, which we operationalize as what matters to people in the here-and-now and toward their imagined, just social futures. Consequential learning attends to the fluid, historically contingent, and potentially expansive temporal and spatial dimensions of learning, through socially-negotiated interactions involving people, technologies and tools (Hall & Jurow, 2015). What concepts are valued and by whom, are nested within social networks and situated in nature. In considering equitable consequentiality, we focus on the "changing scales of participation in time, space and social relations" (Hall & Jurow, 2015, p. 177) that support minoritized students "to become recognizable as competent participants in situated practice" (Jurow & Shea, 2015, p. 289). In the context of K12 STEM learning, we further operationalize "equitable" as related to the opportunities that youth have to deepen their STEM knowledge and practices as an integral part of their cultural knowledge and practices; and "consequentiality" as the direct results of youth leveraging such equitable STEM learning opportunities toward transformative outcomes in both their STEM learning and in perturbing everyday injustices that matter to them.

We hold the stance that equitable consequentiality in and of learning is a justice-oriented project in at least three ways. First, equitably consequential learning involves opportunities to author meaningful forms of engagement, rooted in both community knowledge, practice and wisdom, while deepening disciplinary engagement (Calabrese Barton & Tan, 2018). Some authors describe such meaningful acts as ones of hybridity, fostering third spaces for learning and becoming. For example, Gutiérrez et al. (2017) describe how youth from minoritized communities organize learning with ingenuity, in how youth and families engage in "everyday creative responses to constraints and (un)intentional moves to blur boundaries" as they cross and disrupt borders, as they innovate and leverage familial and other everyday knowledge to imagine and enact new practices (Gutiérrez et al., 2017, p. 45). Such hybrid critical literacy practices enabled students to link their past and present to an imagined future and supported students' efforts to reorganize everyday concepts acquired through social interaction into the joint activities of school-based literacies.

Second, equitably consequential learning is concerned with challenging sanctioned modes of participation for individuals and collectives across scales of activity (Jurow & Shea, 2015), where "scale making highlights the work that actors do to create and disrupt flows of ideas, practices and people across spatial and temporal orders" (p. 288). Rubel et al. (2016), drawing upon the work of Soja (2010), describe how (in)justice exists at multiple levels of scale, "from the intimacies of the household to the uneven development of the global economy" (p. 20). In classrooms, we can think about these scales as involving macro-level decisions regarding school funding, zoning, bussing policies, and so forth; meso-level decisions regarding how classrooms are organized social-spatially through curriculum, instruction, behavioral/disciplinary policies; and at the micro-level in terms of how interactions are shaped through the social-spatial context. Designing for equitably consequential learning in community requires new social-spatial arrangements that are more just and productive for people and for communities (Taylor & Hall, 2013).

Third, these multi-scalar dimensions of social-spatial relations and their effects on consequentiality can be remediated through forms of social and political action. To understand equitable consequentiality in learning requires one to pay attention to power dynamics, e.g., how actors are positioned (and by whom) across time and space. For example, when learning about the respiratory system in sixth grade science, students were supported to draw from lived experiences to engage in classroom Discourse, leading to the production of scientifically robust and targeted artifacts (e.g., anti-smoking posters in sixth grade STEM) tailored to specific audiences, posted in specific spaces beyond the classroom, including particular stairwells in the school buildings and outside of the school spaces in students' apartment complex (Tan & Calabrese Barton, 2010).

The importance of centering spatiality in social justice

In working toward equitably consequential learning in K12 STEM education, paying explicit attention to spatiality is essential, since "powerful social forces … purposefully shape spatial form. These geographies, along with their inherent injustices and inequalities, are produced to meet the needs of those promoting the social processes." (Soja, 2010, p. 88). Soja describes space as where human existence literally "takes place," including the social, material, historical, geographical, and political. Space is where social relations happen, informed by the real and imagined, as perceived, conceived, and argued over in a particular context and a particular time. Soja emphasizes the "ontological assertion of the fundamental spatiality of being" (2010, p. 103).

For example, in a study focused on equitable engagement in science museum settings, Dawson et al. (2019, p. 13) show how the design of the "museum space" put visiting girls in a "difficult position for both learning science *and* enacting the identities they were invested in." When museum exhibits aligned with identities girls valued—through the activities they invited, the stories they shared, and the histories they represented—girls engaged with the science exhibits. However, Dawson et al. learned that this was rare at the science center. Most exhibits eschewed the girls' lives, limiting opportunities for their meaningful engagement. From a social-spatial justice perspective, one way to think about this is in how people see themselves while visiting science centers: How materials (e.g., exhibits) are built or organized is shaped through social relations regarding ideals about whose knowledge matters most in these spaces.

Further, we draw on Soja's definition of spatial (in)justice as an "intentional focus on the spatial or geographical aspects of justice and injustice … from the space of the body and the household, through cities and regions and nation states, to the global scale" (Soja, 2009, p. 2). The social and spatial are ineluctably intertwined in *hyper* local ways as people interact in/through space in everyday life in formative and consequential ways. It is in these local interactions that (in)justice can be produced and reproduced. Indeed, "spaces can be produced to control, indoctrinate, colonize, and discipline young bodies/minds just as they can be created to actively support creativity, curiosity, expansive subject positions, and social critique" (Jones et al., 2016, p. 1154).

In our study, the school classroom, lunchroom and hallway are particular spaces organized in particular ways that afford and constrain different kinds of social-spatial relations. How bodies are organized in relation to each other and the physical structures of these spaces shape who youth are and can be in school settings. In Mrs. L and Louise's school, hallways are tidy, orderly places, where signage directs walking patterns, and rules encourage students to walk quietly with metaphorical "bubbles in their mouths." Being a good student in these spaces is in dialectic with spatiality. Disrupting such orderliness with a playful Helping Hands poster potentially re-orients social-spatial relations.

Lastly, social-spatial (in)justice is always enacted relationally. How people and things are in relation to each other—their spatial ordering—both reflects and enacts power and politics (Soja, 2009; 2010). In considering social-spatial relationalities, we mean that spatial and social relationships are dialectically produced while students are learning and doing STEM. As Davis and Schaeffer (2019) remind us, making visible the social-spatial is particularly important for Black students, who systematically experience oppression "by how power and injustices in science manifest in locally-specific ways" (p. 4). Rubel et al. (2016) further expand on this point when they describe how students needed to read within and beyond maps to develop a nuanced understanding of how sociopolitical forces intersect with spaces to precipitate spatial injustices. The researchers highlighted the limitations of some students who were constrained to only reading the physical map (where lottery stores and predatory financial services are located in neighborhoods, as shown on the map) by their lack of ability to appreciate the undergirding political script (associated factors related to race and income-levels).

As governing relationalities in classrooms structure learning opportunities, consideration has to be further given to how the subject and object of learning are always constructed by the social-spatial context. Here, powered dimensions—both visible and invisible—are central to how relationalities are enacted in learning. One way to further think about this in classroom environments is to consider the deployment of national and state standards, which are presented as untethered to space yet enacted in deeply social-spatial ways. National and state standards not only reflect certain political decisions, but also produce new political, social and spatial relationalities such as the adoption of standardized curricula with uniform expectations of success (e.g., one size fits all, assumptions of equal access to resourced learning environments), testing (which in some places is linked to teacher rating and/or pay; or student tracking and/or advancement), curricular materials and tools, sorting/tracking/documenting students' learning/achievement, legitimized embodied activity, and the production of discourses regarding what it means to learn, achieve or be successful. Standards are not just symbolic of power, they themselves exert social and political power by privileging students whose cultural capital mirrors that which is valued.

Relationalities of/in social-spatial justice

Social transformation/social imaginaries

Social-spatial justice centers the role of space in (re)producing (in)justice. Spatiality plays a fundamental role in knowledge production, as "all forms of knowledge production, from epistemology to theory formation, empirical analysis, and practical application are always simultaneously and interactively social, historical and spatial" (Soja, 2010, p, 71). Whether and how the expansive aspects of fully lived lives are elemental to learning depends upon *whose* lives are lived in any given moment in any given space. However, because space is socially produced, it can be socially changed. Opening up opportunities to learn in equitably consequential ways demands new relationalities, often grounded in socio-spatial considerations, that explicitly enable political formation as a part of learning. We seek to learn through this work about how new relationalities may emerge and give rise to discourses and practices that can be used by students to perturb and remediate the science learning system as it is, redressing instances of injustice along with other forms of distributed expertise (Calabrese Barton & Tan, 2010).

A focus on the relationalities of social-spatial justice as critical in working toward equitably consequential learning further allows questions about power relations in the classroom and its intersections with youths' historicized experiences in school settings to be interrogated. We see classrooms and other school spaces as a "relational space of organized striving, competition and co-operation, and can be studied as such" (Desmond, 2014, p. 556). We are interested in how equitably consequential learning unfolds in classroom and school settings, where local practices are shaped by systems of privilege and oppression (Nasir & Vakil, 2017), including social-spatial relationality as students traverse between common spaces (e.g., hallways, lunchroom, whole-school assembly areas) and discipline-specific spaces, such as the Science classroom.

Focusing on spatiality, "spatial justice as such is not a substitute or alternative to social, economic or other forms of justice, but rather a way of looking at justice from a critical spatial perspective" (Soja, 2009, p. 2). Historically, youth from lower-income communities of Color disproportionately experience the space of classrooms as "outsiders" as a consequence of how cultural systems (which maintain historicized injustices) position them. Understanding and achieving justice requires a close analysis of particular social settings and how oppression and privilege unfold and interact (Balibar et al., 2012). This work requires on-going interrogation of pedagogical and curricular structures, processes and discourses which align with overt and hidden outcomes, anchored in overt and hidden social-spatial relationalities.

Methods

A participatory critical ethnographic approach

We engaged in participatory critical ethnography across the classroom sites of curriculum implementation time. Critical ethnography (Madison, 2011) as a methodology is rooted in the belief that exposing, critiquing, and transforming inequalities associated with social structures and labeling devices are consequential and fundamental dimensions of research and analysis. Teachers and student partners significantly contribute to the design and enactment of our research together. As expert insiders, their insights critically challenge how we make sense of social-spatial (in)justice and its enactments in the relationalities of classroom and school life.

School communities

We collaborated with teachers and students in sixth grade classrooms at three schools from two different cities (Sage Middle School from Sage City; Liberty & Wilkenson Schools from Great Lakes City). Sage Middle School serves a diverse student population, with students identifying themselves as 43% Black, 38% White, 11% Hispanic, 5% Biracial, 3% Asian, and less than 1% each Native American and Native Hawaiian. 58% of the students come from low-income families. During the time of the study, Sage was led by a dynamic school Principal and won the "Most Improved Middle School" award in the district and the "[Region] Signature School Award," both for most improved test scores.

Liberty School is a prek-6 school with a focus on global studies and Spanish immersion. It is one of the most diverse schools in the city, with 47% Black, 28% white, 18% Latinx, 3% Asian, 3% other, and 1% Native American. Liberty was converted to a magnet school with a focus on global citizenship 5 years prior to this study in an effort to stanch the flow of students into the local charter school system and other districts allowed by state policies. The school has strong community support and connections across the cultural and linguistic groups it serves. Parents post how much they like the teachers and the school on social media. There are many cultural nights and celebrations at the school. Students are constantly encouraged to share their project work with peers, teachers and family members beyond their own classroom.

Student demographics at Wilkenson school include 32% white, 28% Latinx, 8% Asian, 22% Black, 9% two or more races, and 1% Native American, Wilkenson was converted to a "STEM" school 4 years prior to this study for the same reasons as Liberty—to stanch the flow of students leaving the school. By District accountability policies, the school does not have a strong reputation for academic success, with only 11% annually meeting passing levels on state exams (compared with state average of 33%). However, the school community rallies around supporting all of their students, such as hallway displays celebrating the diversity of its student body, strategic partnering of students, hosting culture nights, and teachers encouraging students to "help each other" often.

Design approach: community ethnography as integral to teaching and learning

We have been working with sixth-grade teachers teaching engineering for sustainable community (focusing on engineering practices within disciplinary core ideas of energy transformations) from schools serving diverse demographics. We integrated community ethnography into teaching and learning engineering design, considering relationalities between STEM and community knowledge and practice, as well as everyday, local classroom activities and historicized experiences which shape realities in classrooms and communities. We are interested in the porosity of boundaries between students' everyday lived experiences across classroom and school community spaces.

This work occurred during an integrated science and engineering unit focused on learning engineering design in the context of disciplinary core ideas—energy transformations, sources and systems—while also exploring the practices of engineering design. As a culminating project, students were given the design challenge bounded by the following criteria: Innovate something that would address a classroom sustainability concern. They were required to use a renewable energy source, such as solar panels or hand-crank generators, 10 mm gumdrop LED lights, copper tape, and any materials readily available in their classroom.

We supported teachers in integrating community ethnography in two primary ways. First, we worked with the teachers to incorporate community dialogue throughout the design process, including observations, surveys and informal conversations. For example, youth surveyed members of their community on what concerns they had about the healthiness and happiness of their communities. The goal was to support the students in thinking beyond themselves, the kinds of problems they might solve, and how, through engaging in dialogue with community members. Students interviewed peers at school and around their neighborhoods. Using Survey Monkey, they surveyed parents, peers, school staff and community members on what community problems were important to the school. As students analyzed these data toward identifying and defining solvable problems, they further engaged in systematically observing community practices around the issues and engaged in further conversation around the problems initially identified. We worked with teachers to create opportunities for students to weave in and collectively analyze stories, interactions, and other data they collected, discussing patterns and exploring stand-out ideas.

Second, we worked with teachers to plan multiple feedback cycles with different community constituents and coordinated these feedback sessions at different points in their design cycle. The goal was to support students in gaining access to different types of technical (e.g., science and engineering) and social (e.g. community members and/or peers who provided feedback about the use of designs) input helpful to iterative design work. This sometimes took on a more formal tone as youth presented their projects to various stakeholders (e.g., local engineers, parents, pre-service teacher candidates at the local universities and peers) who provided written or oral feedback, or when youth involved various community members as prototype testers. Informal feedback cycles included various community members (e.g., school teachers and Principals) visiting youth at their workstations and sharing idea-generating conversations.

Positionality

We have spent time weekly in partner spaces over years to build the relationships needed to engage in justice-oriented work across positionalities and perspectives. Our different positionalities afford us some insight into the importance of centering the voices, experiences, and lives of those most silenced by the institutions need to be at the research and development table if such elevation and transformation are to authentically inform a contextualized, equity agenda. The first author is a Southeast Asian immigrant who regularly experiences real and symbolic violence in the academy. Positioned as outsider through "backhanded compliments" (e.g., "Your English is so good!") and experiencing on-going verbal violence as she navigates the geographical terrain of her context ("Chink!"), the social-spatial realities of (in)justice are profoundly embodied, though in different ways from some of the youth (and teachers) in our study.

The second author who is white and female has experienced a vastly different set of social-spatial relationalities than either the coauthors or the youth in our project. As a white female, she literally "blends in" to the power structures of partner schools, where the majority of teachers are also white and female. However, a long-time member of the local community, she has worked to navigate these social-spaces in ways that disrupt her unintended complicity in these powered-dynamics, pushing her to continually question how she may embody the very power structures she hopes to disrupt. She knows many of the participating students and their families at partner schools through her presence at their community center, where community elder, Granny, has informally mentored her in learning with and in the informal networks and epistemologies which sustain community members, and also welcomed her into her family. She also uses her own experiences growing up female in a working-class community to render problematics of what it means to know and become in STEM.

The third author, an Arab-Latinx female has had to overcome historical, political and often hidden socio-spatial barriers in her success. As a bi-cultural individual living as a first generation American, spaces oftentimes determine the values, beliefs and assumptions that are allowable and recognizable. For example, in predominantly Latinx spaces, institutionally, she is recognized for her Latinx identity. Yet she holds a high affinity to her Arab matrilineal heritage. However, with political narratives in the United States shaping views of people of Arab descent, spaces and spatial boundaries have dictated when she can and should uphold that part of her identity. As participation in STEM and STEM education are continuously problematized, questions of identity and agency are deeply rooted in the ways we are recognized and positioned but also how we are raced, classed, gendered and culturally identified within spaces.

Collectively our experiences have helped us to more critically examine how people are positioned as insiders and outsiders to schooling in STEM through both sociocultural and institutional structures and in local practice. They give us an angle to understand what social-spatial justice may mean in working toward equitably consequential learning in STEM.

Date generation and analysis

Data were generated during the enactment of the "How can I make my classroom more sustainable" unit in nine middle school classrooms over the course of about 26 instructional hours during the spring 2017. Each session took about 90–120 minutes per session. Data were generated using a critical ethnographic approach. All participating teachers and students were consented through university-approved IRB processes and identified through pseudonyms.

Detailed field notes of classroom interactions were kept, along with video recordings of select lessons and group interactions. Fieldnotes were kept by more than one researcher for all class sessions to allow for multiple perspectives to inform how we understood the contexts and interactions. Mid-unit and end-of-unit "artifact interviews" with all focal groups were conducted. Here, the "artifacts" are engineering designs youth prototyped, and included their design sketches, actual prototypes and written reflections about their prototypes. Interviews focused on understanding the artifact (what is it, how it works, what problem it solves, etc., materials used and why, etc.), participation and engagement (behind the scenes, including a step-by-step description of the process, and interactions/support youth received from peers, educators, and community members, resources used), knowledge and practices (STEM knowledge and practice needed/learned, and funds of knowledge); and meaning and value (what this project says about oneself, etc.). We also conducted informal weekly conversations with the teachers to make sense of on-going questions, concerns, and feel of the enactments, with a formal interview at the end of the enactment.

Data were analyzed in the grounded theory tradition, using a constant comparative approach (Strauss & Corbin, 1998). The primary analytic grain size was the group project: How students settled on a problem to be addressed, and the solutions they developed, how, for whom, where and why.

The first phase of analysis involved open coding by perusing all generated data to surface critical episodes of engagement in youths' design work (e.g., group activities during lessons that featured salient performances, in talk and actions, by the youth and their dialog with the teacher that were further invoked by the youth subsequently in time/space). Delving deeper into these episodes, we sought to describe: (1) the kinds of community data students solicited, analyzed and found compelling; (2) how students considered community data (what the curriculum termed social specifications of the engineering design) in dialogue with technical know-how (what the curriculum termed technical specifications of the engineering design) in engineering a specific community-problem addressing artifact; (3) what decisions students made in iterating their design based on community feedback; (4) what the above revealed about the kinds of social-spatial relationalities students brought to bear on their engineering and the impact of such on possible modes of equitably consequential learning.

With the help of our theoretical framework, we then worked to make sense of these episodes described above. We sought to make sense of social-spatial justice by examining the impact of social-spatial relationalities –including (1) relationalities that were disrupted, or new relationalities enacted; and (2) the role of materials artifacts, as elements of the spatial that mediated the disruptions/enactments of such relationalities. Across this process, on-going conversations were held among the authors as a way to work toward a more expansive consensus. Any differences in views were debated until new meanings were generated as a result of our differences. This phase of coding led to the major claims presented in our findings.

Findings

Our findings focus on how teaching and learning engineering design for sustainable communities can be organized around young people's rich everyday experiences and community wisdom toward addressing local, sociopolitical community challenges. Such organization shifts the social-spatial terrain upon which subject-object relations are enacted, such as through the kinds of discourses and practices that are legitimized toward particular outcomes. Making present this power-mediated terrain through community ethnography makes visible the often hidden, but ever present, unjust school-based relationalities, enabling such relationalities to be re-mediated in

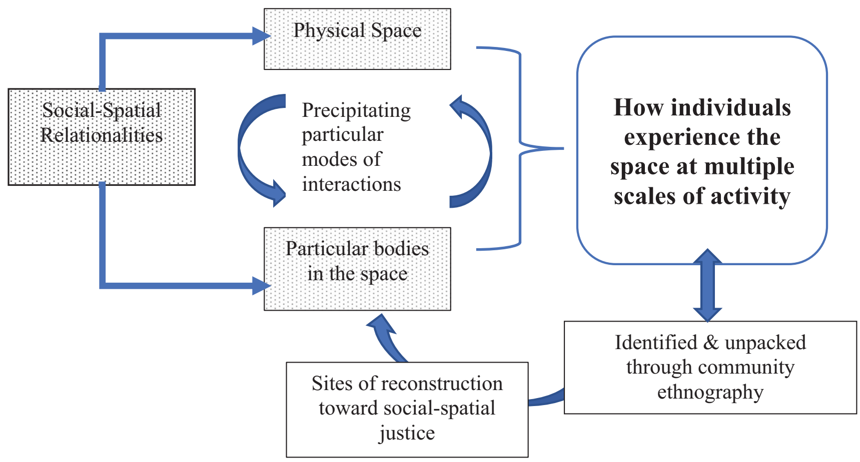


Figure 1. Making visible how social-spatial relationalities produce particular experiences through community ethnography.

justice-oriented ways. Community ethnography as a *social-spatial practice of learning* can reveal both the legitimacy of these relationalities and position students' insider knowledges of these issues as relevant data for informing engineering design. When students engineer in the context of new social-spatial relationalities, they work toward both addressing these issues in spatial *and* social ways in the here-and-now, while agitating for larger transformative changes in school science *and* schooling itself. Paying attention to social-spatial relationalities reveal (1) the multiple scales of activity, (2) inter-scalar mobilities and interactions, and (3) possible resultant impacts of such interactions that further affect activity at each scale (Figure 1).

Community ethnography is an integral part of learning and engaging engineering design in classroom settings where school-based, power-mediated relationalities become visible and potential sites of re-construction. By sites of reconstruction, we refer both *to physical sites* as in specific spatial locales, as well as *metaphorical sites of social relational interactions* targeted for transformation. In what follows, we use two case studies, each to illustrate particular natures of such reconstruction for clarity.

School-based, powered social-spatial relationalities that constrain learning as sites of re-construction

Consider the Butterfly Light-up Lunch Cone ("Butterfly Cone") engineering design, a light-up system used to help the cafeteria staff guide the students to their lunch choices with calmness and efficiency, engineered by Sophia, Manuel, and Clarissa, three students in Ms. B's class. The Butterfly Cone has eight LED lights evenly spaced around a medium-sized poster board decorated with a butterfly. The poster is attached to a post, placed down the center of a soccer cone so that it could be read at a child's height (Figure 2). The design, meant to be both hands-free and good for the environment, is connected to a foot crank to provide human energy to power the lights. Student engineers hoped that the lunchroom staff would use the Butterfly Cone to guide the children toward the specific lunch lines for their selected meal options. The three student engineers felt that the colorful and light up cone would attract younger students' attention and be a fun way to organize lunch lines. This was in contrast to the chaos and yelling they experienced in the lunchroom, and that they felt trickled into their STEM class immediately after lunch. In fact, as Ms. B described and as we observed, both Sophia and Manuel themselves seemed to get into nearly daily shouting or screaming matches at lunch time and "got on each other's nerves" and often carried these disagreements into STEM class.

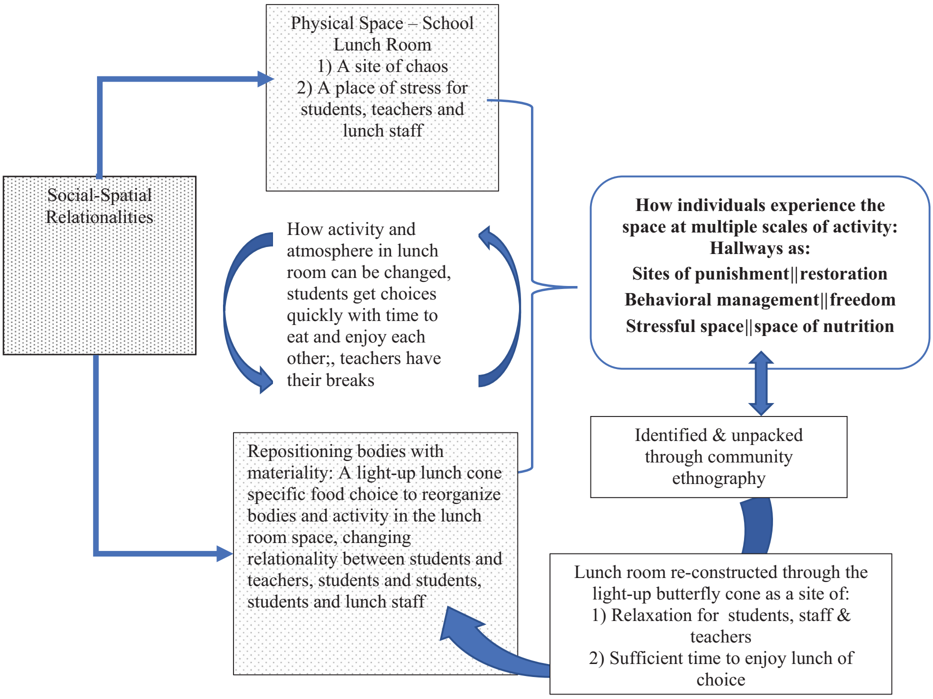


Figure 2. Seeding new spatial-social relationalities with the lunch room light-up Butterfly Cone.
Note: We use || to denote tension as well as social-spatial borders.

In what follows we first introduce the three student engineers. Then we turn to why and how they created the Butterfly Light-up Cone, and how the students worked on the project, and how its later use disrupted and reconstructed the powered social-spatial relationalities of both STEM learning and lunch time.

Butterfly light-up cone student engineers

Sophia was one of a few white students in her classroom who was recognized for her artistry by peers and teachers. She did not particularly like science or engineering and said that engineering "took a long time to understand." A vocal student, Sophia used her voice to defend others, often standing up vocally for the quieter girls of Color in her class when they were unkindly teased, such as her groupmate, Clarissa.

Clarissa was an Asian youth who was very quiet and oftentimes relegated to do more of the "scribe" work others did not want to do. We observed her putting her tasks aside to help Sophia and Manuel with some of the more complex technical elements of design, including designing and assembling complex parallel circuits or converting a hand-crank generator to a foot-crank generator. She wanted to be a cosmetologist and she tried to bring that perspectives to the group's design work. Sophia often sought feedback from Clarissa on her artwork as a way to center the importance of the contribution of her art to the engineering design process.

Manuel was a Chicano youth who loved soccer. He was the child and nephew of construction workers and loved to build. Manuel and Sophia had a somewhat contentious history. We observed them getting into arguments that spilled over from lunch and in the class prior to the group formations for the engineering design projects.

Why students engineered the butterfly cone. The three students designed their light-up system because they were concerned that the lunch period was stressful for students, teachers and staff alike due to lunch line confusion. Instead of being an enjoyable break from the academic day, students were frustrated by lunch line chaos that limited their time to eat and socialize. Sophia stated, "When you stand in line, you can't talk to your friends that are in different classes" but if you "try to talk to friends in other lines you get in trouble." Sophia explained that the cafeteria workers blamed students talking with friends for the lunch line confusion, when in fact, the problem was that students did not know which line went to which lunch option. Manuel elaborated: "In my class they get outta order … Then they won't get the lunch order that they ordered, and the lunch aides'll get mad 'cause they're all outta order … it slows the line down." He then stated:

> Manuel: We're going to combine all of the classes instead of keep them separate so the kids can see their friends. Then when the lunch aids come and instead of yelling at the kids to be quiet [to explain which line to go in] they can use the cone and making the lines for the kids.
>
> Interviewer: And you said that the lunch aides are supposed to use the foot crank on your design to turn the lights on and the students are supposed to line up once they see the lights.
>
> Manuel: When they yell at us we have less time to eat … We get busted.

Manuel, who was an avid soccer player, further stated that he never had enough energy to play due to hunger. He described his concerns with lunch as his motivation to change lunch time experiences for the younger children of the school.

The three students were also frustrated that cafeteria staff and teachers yelled at students throughout lunch time, for reasons they felt were out of their control, such as students being confused on how to select the right lunch. Sophia noted that the yelling made students, like herself, upset and want to yell at her peers. Given that we observed Sophia and Manuel yelling at each other coming back from lunch, this concern was highly salient to her experiences in STEM class, which occurred right after lunch.

The teachers and cafeteria staff were also frustrated. Staff had too many responsibilities with preparing and serving food while managing lunch lines and behaviors. Staff often called in teachers for help, which teachers did, but it meant giving up the only time during the school day that teachers had downtime. Ms. B., their teacher explained that it was "frustrating" and "tiring" for her to have to help out at lunch time. She had "no prep periods," and lunch was the only time she had to "think."

Sophia, Manuel and Clarissa documented this challenge in their cafeteria and their school communities' experiences and feelings about it through observation, surveys and interviews. The students described their project as such:

> In our school, we noticed [through observations] that lunch aides were having trouble taking food orders for kids during lunch. Not only did this affect the lunch aides with problems with respect, but it also took time away from our lunch hour. This started to affect us, because the less time we have to eat, the less we eat and that can affect our schoolwork (group's written description of the problem).

The team carefully documented, through observation and surveys, that not all students had the same amount of time to eat lunch in a pleasant way, with some groups of students not having adequate time to eat their entire lunch. They documented, for example, that "71.43% of the surveys" indicated that school needed to be "more fun." Sophia explained that "school was boring" and lunch, the "only fun part of the day" was "not fun" when students could not "talk with our friends." They also that "42.86% of all kids" thought that they should engineer something that would "make a difference" (Figures 3 and 4).

Sophia noted that lunch time was particularly not fun even when it was supposed to be the "only time" that kids were able to hang out with their friends in other classrooms.

The students worried about how the lunch line confusion impacted their younger schoolmates. Clarissa explained that the "younger students often made one long line regardless of menu options, slowing down the menu selection process, or randomly created lines that did not lead to

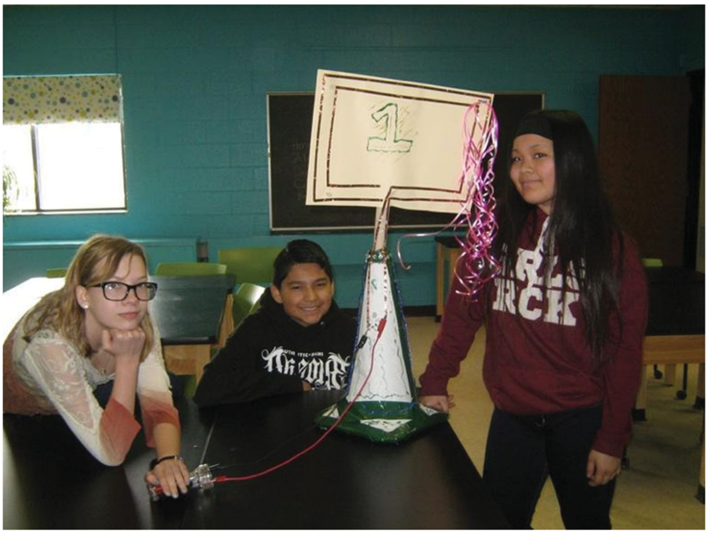


Figure 3. Sophia, Manuel and Clarissa with the butterfly Light-up cone.

their lunch option." As a result, children often were told to eat whatever food was at the end of their line, in as little as five minutes. Manuel stated simply, "It's not fair." The sixth graders felt that a disorganized lunch period negatively impacted students, lunch staff and teachers. They wanted to change this, especially for the younger students at Wilkerson.

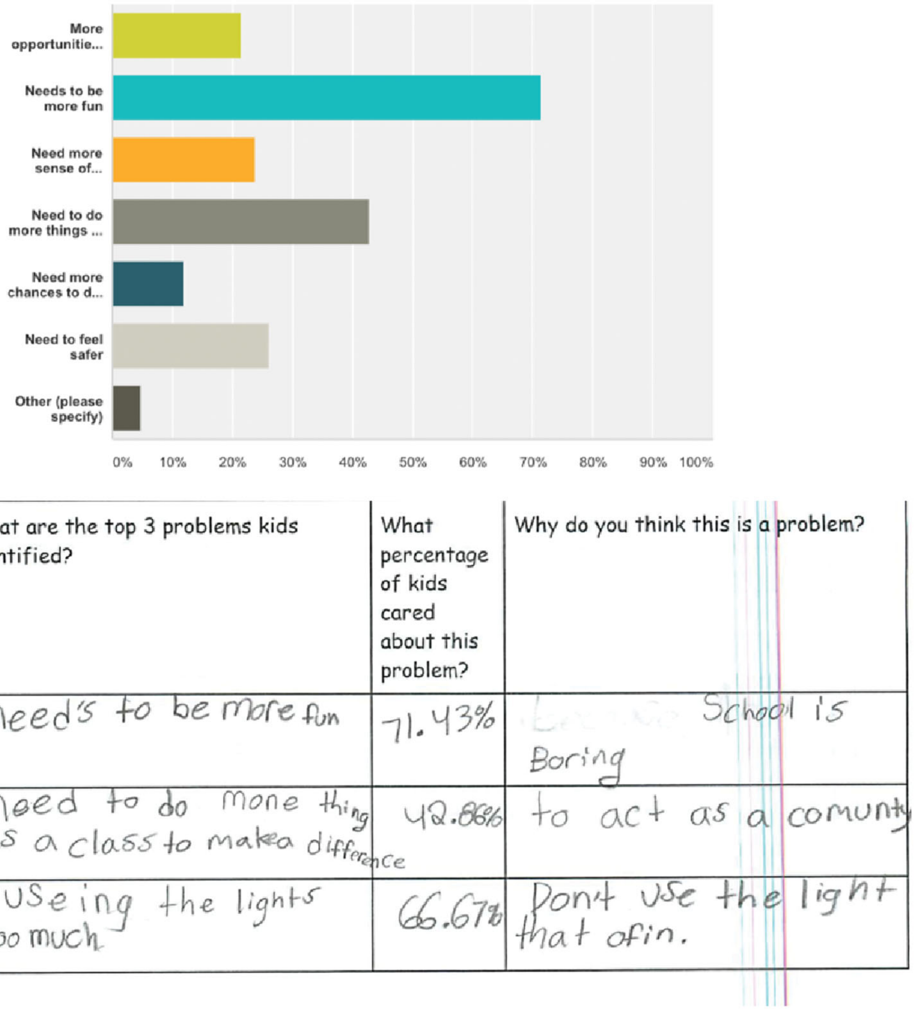
Re-constructing the atmosphere of a necessary space (lunch room) through surfacing social-spatial connections

Making visible discourses of social-spatiality. The youth noted, and Ms. B. confirmed, that lunchroom challenges were addressed as behavioral problems. As Ms. B explained, "They were trying to change it so that kids could know where to go. They thought this would reduce the friction we all feel in the lunchroom." She further elaborated during a teacher reflective conversation group:

> *Ms.* B: One of the ones that was really cool that I thought, as an adult, we have lunch choices, the three, two, ones, and so they made a butterfly cone. It was supposed to be a light-up cone of where threes were, where twos were, and where ones were in the line to go to lunch. That way, they didn't have to be handed a card because it's always a cluster[deleted] every single day with the lunch assistant.
>
> Ms. H: It is.
>
> Ms. B: That was something that the kids came up. It was like, "Hey, maybe we can alleviate the problems with them yelling at us by [laughter] standing at these cones that are supposed to light up."

She, too, wished for lunch to be a relaxing time for the students in the classroom, where they could socialize at tables with their peers over their desired food choices. Ms. B. felt optimistic that the prototyped light-up cone could disrupt this practice.

From the perspectives of school staff, the fault often rested on the children, when in reality they knew and had little recourse to counter-narrate the structural and school-community issues that were arising as a result of their lunch problem. Talk about these concerns was limited to nonacademic spaces, during recess or in other spaces where students could vent with each other about not being able to eat in time, or not being able to eat at all. Ms. B acknowledged that she "always yells" at the students in the lunchroom, and that at times this "yelling" transgressed into her classroom space. Furthermore, Sophia, Clarissa and Manuel's experiences in the school



What are the top 3 problems kids identified?	What percentage of kids cared about this problem?	Why do you think this is a problem?
need's to be more fun	71.43%	School is Boring
need to do mone thing as a class to makea difference	42.86%	to act as a comunity
useing the lights too much	66.67%	Don't use the light that ofin.

Figure 4. Group Graph of Overall Survey Data & Open ended data analysis.

lunchroom had previously been made to feel irrelevant to their science classroom discourse and practice, e.g., "let's talk about lunch time at lunch time, not now during STEM class."

It is not possible to consider how relationalities take shape without considering how they are sustained by the sociopolitical and institutional *spaces* of schooling, including the school systems and educators' politics, policies, and practices (Wilson et al., 2014) that shape what is possible or not in either the lunchroom or the science classroom. As the youth documented their investigation into sustainable community concerns, lunch time chaos was grounded in school-based, social-spatial relationalities that reinforced disempowering hierarchies: adult/child; well-behaved/chaos; controlling bodies/enjoying social company and food in the lunchroom space—experienced daily by youth, teachers and staff. The youths' ethnographic investigation made visible these embodied binaries, surfacing the metanarratives around lunchtime practices and how children and adults were configured in that space. Their data illustrate youth frustration as they wasted time standing in lines that often did not lead to their chosen food options while being reprimanded and also how teachers and lunchroom staff felt unable to grasp *control* over the situation or the children's bodies, exacerbating the tension.

Making explicit connections between science classroom space and lunchroom space through legitimizing expanding discourses. When the students had opportunities to engage in community ethnography to document the school sustainability concerns of community members, new and legitimate discourse threads about lunch time chaos emerged in their science classroom. Through documenting their data in tables and maps, the students were then able to consider how the space of the lunchroom could be re-configured socio-politically and institutionally. Legitimizing these discourses expansively opened up the subject-object relation in the spatial relationalities of engineering design in *inter-scalar* ways: How children, parents (serving as lunch-volunteers) and teachers felt and interacted led to creating and enacting hybrid forms of expertise toward designing solutions that impacted how people and/or bodies moved through space. We refer to this as inter-scalar because we see that the *on-going movement* of people, bodies and ideas across scales as central to the learning.

As Sophia, Manuel and Clarissa delved into their survey data, they began to see these data as *directionally orienting* how and why they engaged in specific dimensions of engineering knowledge. In working to address lunch time chaos, they developed the idea to engineer a "Butterfly Light-up Cone." As they wrote,

> To solve this problem, we decided to make a butterfly light-up cone that can be used by the lunch aides to signal the number of the order that the kids want to eat that day, and also for the kids to follow the signal so that they be quiet and stay in line waiting for their lunch.

They also felt that this would help to remove some of the tension they felt existed between the staff and students and allow teachers to enjoy their break uninterrupted. In short, the students sought to remediate existing social-spatial relationalities currently at play in the lunchroom with their innovation.

During a community feedback session, where community members visited to learn more about provide input on designs, conversation turned to how to optimize the design. At the session, youth shared large sketch-ups of their projects and developed questions they wished to ask their visitors. The butterfly cone group developed the following questions:

Feedback Questions:
Technical:

1. Do you think the lights will light up well enough to alert people to form the line?
2. Do you like the foot crank?

Social:

1. Does the Lunchroom Stand satisfy your lunch needs?
2. Does the Lunchroom Stand make you feel connected to your friends?
3. Do you like the butterfly drawn on our Lunchroom Stand?

One community member, Brian, a maintenance technician that works with electricity and HVAC (heating, ventilation and air conditioning) validated the importance of the design, for both directly addressing the problem the youth identified, but with possibilities for reaching other contexts, further legitimizing these discourses in *inter-scalar* ways the youth had not considered.

> When I was in school, we didn't have all these gadgets and I remember between people coming together and getting yelled at, no one was served their food on time. Then we had to rush in eating and then we wouldn't be able to eat everything. I think this design is not only necessary but it will help us in being more organized at school and give us more time to eat. It can be used in other places too, like in churches for people to stand up and get communion, or even like in stadiums for people to know where they are sitting at.

Brian further offered a consideration for modifying the design by asking about who might be designated to run the foot crank:

> I love the idea of the foot crank. I don't know if the lunch ladies should be the only ones using it, but maybe there can be designated students that have been student of the week or something and for that day or week they can use the foot crank.

In responding to Brian's ideas, the students began to develop guidelines for how students might be in charge of the Butterfly Cone, potentially shifting the powered relationalities in the lunchroom more. Sophia noted that the sixth graders (oldest students in the school) could be in charge instead of adults, pointing out how much the younger students looked up to the sixth-graders and how much "more," compared to adults, that sixth graders appreciated the importance of lunch time social needs of children.

Expansive discourse grounded in epistemic knowledge and practices. All three youth indicated that getting the electrical system to power the seven LED lights was the most difficult challenge of all. Clarissa "who knew the most about circuits" according to Manuel, provided leadership in this part of the task. However, as both she and Manuel explain, each team member played an important role in getting the lights to light-up. As they wrote in their final project description:

> In order to make our butterfly cone, we did several tests. The first was that we made sure all the LED lights were working before we put it on a circuit. The circuit worked the first time that we put it together, but we noticed the hand crank was having problems. The solution was to get another hand crank that we had available. A second test that we did was that all the lights were burning out. We used batteries from our electric art cards to test the circuit, and we noticed it worked, but with the hand cranks it was having issues so we knew the circuit was OK but the hand crank was not strong enough for all the lights.

Manuel further explained that the group did not want the lighting to be "too dull" and had to figure out how to re-create their design with a parallel circuit to increase the brightness. Sophia noted that "figuring this out was not easy for the group," and caused some tension, but that "everyday" she "sees people" in her school community who were not happy at lunch. She said she understood why teachers and staff yelled at the students, but that did not make it "right" nor did it help with low student morale that resulted from teacher yelling.

All three youth indicated they learned not only how to make circuits, but also to figure out how different circuit ideas they had demanded different power requirements, which were science and engineering expertise applicable to other situations. Manuel captured this point well, when he described how this project mattered beyond the lunchroom. He said, "I can turn things from being ugly into being nice and useful. I'm now a circuit expert. I can help around [at home] to build things we need."

The powered relationalities of who is an expert were disrupted. Manuel explained that the experience was challenging but fun because it gave him a chance to make something "on my own." He contrasted this with other STEM class experiences, such as building robots, where "we have to create it from instructions and stuff."

Expansive discourse integrates youth histories and talents. As community perspectives became integrated into the youth's work, they also began to co-implicate each other into the project in new and powerful ways by building on their hopes for the project through their individual strengths. For example, as Manuel noted, the three youth participated in the project in different ways at different times, as different needs and strengths arose. The process of designing and building the Butterfly Cone was not trouble-free for any of the youth. There were many histories and tensions between students in Ms. B's class, especially as this class period was the one right after lunch.

Consider what happened after a visiting adult community member, Hector, an engineer, offered the group feedback on their design, calling attention specifically to the height and visibility of the design:

> And I think that you really need to consider the height of your product because you want to call people's attention. So, you need for the light to be really bright. And you need to test that and to make sure that it's going to be powerful enough to attract people people's attention and to be a good guide that people know where to go. But you also need for it to be high enough so that people can see it. So, you need to be very careful with your design … another light on the butterfly was a nice addition to your design.

Hector's insight on the height and visibility led the group to reconsider how their butterfly poster was mounted, creating some tension within the group. At one point, Manuel was very upset because Sophia and Clarissa wanted to use cardstock as a material to holdup the posterboard paper where the LED lights would be. He insisted that cardstock was not sturdy or tall enough. We observed him physically taking up space with his body and using his authority as an expert builder—"my dad does construction!"—to convince his groupmates of his ideas.

Manuel proposed using one of the soccer cones that were available at recess time. His intention was two-fold: both as an engineering solution for the problem of making the design sturdy enough to see, but also as a pointed critique to the experiences of students not being able to play soccer during recess, as a result of a lack of energy from having no time to eat. Manuel was an avid soccer player and recognized by his peers for his soccer-playing-abilities. As we wrote in one of our fieldnotes,

> Manuel explained to me today how he was very upset that he could not play soccer at recess very much, in part because recess time was getting taken away because of the lunchroom problems. He said he came up with the idea of using the soccer cone he and his friends used at recess in their design as way to keep his love of soccer a central part of the design. He also thought other kids who liked soccer might see the soccer cone and feel excited by having it a part of the lunch line design. This fits with how I have come to know Manuel this year. He always seems to the first one rushing out to recess to get his soccer time in. He always seems so disappointed when the weather prevents the kids from being able to go out to recess (fieldnotes).

Through further testing, the youth figured out that the soccer cone was sturdy enough to host the poster affixed to a meter stick.

Sophia was an excellent artist and suggested that her signature butterflies that she was known for drawing would help attract younger children to the light-up system. Sophia described the butterfly design as "fun," "creative" and "attentive," meaning that it helped to "grab people's attention" and "you can see its purpose"—a most useful point when the younger children in her school may not be able to read the words.

Clarissa– oftentimes recognized for her ability to center the group toward its task—provided most of the design direction and mediated the discussions between Manuel and Sophia. Clarissa was the one who introduced the idea of putting the butterfly decoration on the cone, as both a compromise and a way to reach many students. At one point, Manuel and Sophia noticed that Clarissa's perspectives were not being included in the design, and so they asked her to contribute something to the project that showcased her talents. She included the "pink stringy" as a way to showcase the femininity of the Butterfly Cone, especially because she wanted to be a cosmetologist. She explained that this was similar to "how a unicorn has a rainbow hair at the end" with the lunch time cone thus decorated. The group ended up building three cones to direct the three line options in the lunch room, with one that was lit up as they continued to iterate on the circuitry and foot crank usage.

These power-mediated relationalities became visible and sites of re-construction toward the design of the Butterfly Light-up Cone (Figure 2). The Butterfly Cone illustrates the potential of *new social-spatial relationalities* in deepening how, why and for whom students in middle school engage in and learn engineering, and how they come into engineering. We suggest that these new social-spatial relationalities in school settings are possible when youth have the opportunity to

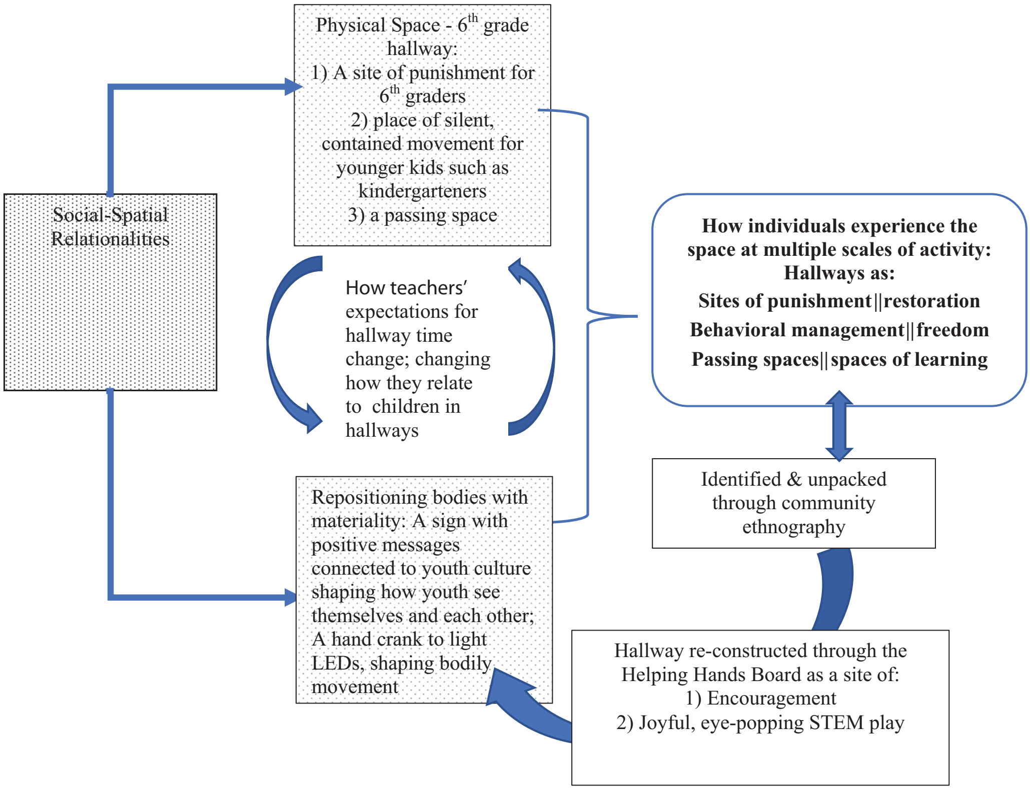


Figure 5. Seeding new spatial-social relationalities with the Helping Hands Interactive Poster.

engage in engineering design grounded in their lives—their funds of knowledge and community wisdom from their lives lived (Tuck, 2009), and in the materiality of the spaces they embody. In the case above, we see the youth having particular insights not only on the challenges created by the long and troublesome lunch line for students, but also on the resultant tensions among students, teachers and lunch staff (who tend to be parent volunteers). Despite brick and mortar walls separating school spaces, spatiality reveals the porosity of spaces. In particular, new relationalities, grounded in subject-object relations support multi- and inter-scalar activities relating to people, bodies and mobilities between spaces within school and community. Attending to socio-spatial relationalities in these ways worked to transform disciplinary engagement for the youth innovators.

How new social-spatial relationalities support equitable consequentiality in learning

Activity—and learning—in classrooms are not only shaped by social-spatial inequalities but also play a role in (re)producing them. Only when the social-spatiality of learning and activity in classrooms and in school is made *legitimately* visible, can students engage in social and political forms of actions toward remediating the resultant inequalities. If we return to the case of the Helping Hands, we see how what it meant to have "time out" in the hallway was re-configured as a space of care, support and encouragement by peers, rather than a punitive space (Figures 5 and 6). For example, we observed students sitting in the hallway playing with the handcrank. While we do not know if the encouraging messaging was helpful to them, we do know that their time in the hallway was disrupted by legitimized play with the lighting system. Of the design, the teacher Ms. L stated that the design itself gave her an awareness of her students' desire for fun.

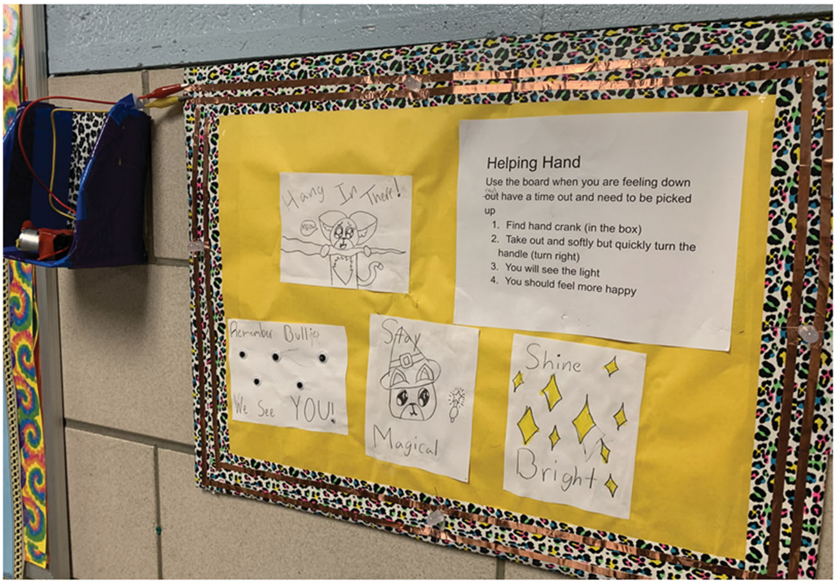


Figure 6. Almost-finished Helping Hands Poster.

We also observed how the sixth-grade hallway that kindergarteners pass through daily to get to the lunch room, mediated by the Helping Hands poster, became a playful place of welcome. For example, kindergarten teachers encouraged students to play with the board, shifting what it meant to be a kindergartener walking through the sixth-grade hallway. Moments of quiet lines with imaginary bubbles in mouths ("walk with a bubble in your mouth!"—a bodily practice intended to promote silence among the children) gave way to movement, giggles and commentary. In each of these social-spatial reconfigurations, peer-to-peer relationalities worked to push back against the real and imagined geographies of school hallways as "hierarchically organized spaces of colonial occupation and the processes that produce them" (Soja, 2010, p. 37).

In this next section, through an in-depth look at the Light-up Bingo Cage for fair participation case (Bingo Cage), we examine how, when previously unacknowledged social-spatial relationalities gain legitimacy, systemic oppressive practices become salient to why, how and what students engineer, toward challenging systemic oppression in material ways. When newly-visible school-based relationalities were taken up and interrogated as an integral part of classroom engineering discourse and practices, they supported the development of new, *justice-oriented* relationalities to replace unequally-powered ones. Such justice-oriented relationalities nurtured new, multi-directional networks connecting students, teachers, classroom and larger school communities to engineering disciplinary content and practices in conjunction with taking concrete, justice-oriented action through classroom engineering. sixth graders Paul and Kaison described their innovation as such: "Our innovation is a light-up Bingo cage to give everyone a chance to participate. We used a Bingo cage, then got everyone's names on balls, so that when we use it someone's name will come out. It will help people to not get left out."

Gaining a nuanced understanding on social-spatial relationalities within a Whole-classroom context through community ethnography: mapping particular relationalities to particular classroom spaces

After engaging in community ethnography as part of the engineering unit that included 165 survey responses, the community data Paul and Kaison's group chose to address with their innovation was a perceived inequity in opportunities to participate in class discussions. The students pointed in particular to survey results indicating that 56.4% of respondents felt that "school needed to be more fun," and that 43% of respondents felt that "school needed to be more fair." As their engineering for sustainable communities response, Paul and Kaison's group innovated a light-up Bingo Cage to promote fair participation in their classroom.

Light up bingo cage student engineers

Paul is an Indian-American student who comes across as serious and focused. He told us that his older brother, whom he admired, is going to college and majoring in engineering, although he could not say exactly what engineering is. However, Paul said that he might be interested in "studying the same field." In the first design challenge of the unit where students made an electric art card for someone they loved, Paul made a card for his brother to take with him to college.

Kaison is a White girl who is studious and whom Ms. D describes as "very responsible." She was also excited about the engineering unit because she told us that her father is an electrician, and that she had previously attended a STEM academy in elementary school. We observed Kaison demonstrating epistemic knowledge such as explaining to a classmate why green energy sources are "clean energy, because they don't put out stuff to pollute the environment like coal." Kaison was also the group member who helped and reminded Ms. D throughout the process of getting the homeroom class list printed, as we describe further below.

Why engineer a light-up bingo cage for fair participation. This data was related to a larger issue of "unfairness in school" that had come up in the community survey. In further defining their problem, Paul explained that "teachers often have their favorites they call on all the time" and that "it's hard to get the teacher's attention if you're sitting in a corner." Paul further described this issue as linked to grades, as class participation is worth 10% of his grade, and this, for him, gave added importance to the issue. Kaison opined that for some students who were quieter but had something they wanted to share, yet who failed to "be crazy enough" to get the teacher's attention positively, those students "don't have opportunities and that is not fair." The group talked about students who were "in trouble" and made to sit "in the corners" which resulted in them having decreased chances of getting the attention of the teacher if they wanted to answer a question from being sat at classroom corners.

Kaison and Paul displayed dexterity in how they identified entangled threads inherent in the school community data on "unfairness in school." Perusing data from open-ended responses, the students noted particular ways in which students experienced unfairness. They pointed in particular to three, open ended responses from the community survey that informed their reason to prototype the Bingo Cage. One was the "lack of opportunities to participate in class," another was "need equal opportunities for participation for everyone" and the third, "HAVING FUN AND MAKING IT FAIR!!!!!!" Paul and Kaison corroborated these data points with their own embodied experiences in their science classroom, where the same few students were constantly called on by the teacher. They also mapped particular relationalities (e.g., well-behaved students with whom teacher is pleased) with particular physical spaces in the classroom (such students are seated within easy view of the teacher), structurally supporting a positive feedback loop of guaranteed participation for such students, since the teacher can clearly see their raised hands without them having "to be crazy enough." Ironically, the students out of the teacher's peripheral vision, in trying to garner her attention to answer questions or give an opinion in classroom discussions, had to "act crazy" as Kaison described, often standing up and waving dramatically, making huge arcs with entire arms and torsos. These "crazy" attention grabbing gestures work to further displease the teacher, fixing these students continuously in their less obvious classroom corners. In one classroom space, students, by dint of relationalities with the teacher, are sorted to occupy different kinds of spaces which then precipitated different kinds of interactions and unequal participation patterns.

Upon brainstorming in their group how they could engineer something to address the lack of equal opportunities for class participation, Paul volunteered his family's bingo ball game as something that they could make into an unbiased student-selection device, with each bingo ball showing a classmate's name. Getting a printed list took repeated requests by Kaison, hovering near Ms. D, as Ms. D was understandably busy with six other groups in the room. When there was no paper for printing to be found in the classroom, Kaison volunteered to go to the Media center for printing paper. Once paper was procured, Ms. D had to eliminate information like allergies from her class list before printing it, and the process took up valuable time the first day of prototype construction. However, this was the way Paul and Kaison wanted the names to appear—typed and taped to the balls –as the light-up spinning bingo cage would allow them to promote fair class participation. Ms. D was supportive throughout the process even as it took time, telling Kaison several times as she was waiting and helping to get the names printed, "you guys need a list of names? I gotcha" and "I'm going to go print it out, give me a second." Ms. D. also asked Kaison how many copies she wanted and printed three copies in case they made mistakes in the cutting and pasting process. The individual names were then cut out and carefully stuck onto individual white bingo balls.

When the bingo cage handle is turned, whichever ball falls out bearing whichever student's name guarantees that student's participation. To draw attention to the bingo cage and make it celebratory and fun, the students constructed a mat for the cage to stand on, with LED lights on a parallel circuit that is powered by a hand crank. The inclusion of students' names personalized the game, recognizing their peers as participants who matter. Paul explained that, "The main purpose of it [the Bingo Cage] is to help students participate in class." However, it was equally important to, in Kaison's words, "make the bingo cage fun so people would *want* [emphasis in Kaison's articulation] to participate." During the building process, their peers gave them feedback and one classmate, Sydney, exclaimed "Oh I am soooooo excited about your project!" The group received positive feedback from their peers, the school principal (who visited the classroom during the prototyping lessons) and Ms. D. Their innovation was praised as "cool," "very creative," and "really helpful for the classroom."

The focus on creating a celebratory vibe when selecting a participant was informed by survey data and suggested that Kaison and Paul recognized and wanted to alleviate the reluctance of some peers when mandatory participation is required, even when the larger goal is to address unequal participation opportunities. Ms. D put the bingo cage to use, often calling Kaison and Paul to "work the Bingo" to choose a participant. Ms. D described how this created "a fun game show atmosphere for a student to answer a teacher's question."

However, a problem soon became apparent to Paul and Kaison. As they related, two student volunteers were needed each time a student was to be fairly selected by the Bingo cage—one to turn the bingo cage handle itself, another to turn the handcrank that powered up the light-up mat on which the bingo cage set. Paul and Kaison both felt that having two student volunteers each time could be deemed disruptive to the class, which might in turn discourage Ms. D from wanting to use the bingo cage more often. Paul and Kaison remained concerned at how often, and for how long Ms. D. would support the use of the Bingo Cage, and if she would allow for more of its use if only one person was needed to operate the device. Here, both students showed a nuanced understanding of classroom norms and how Ms. D preferred bodies to be composed in her classroom space. They set about to redesign the Bingo cage so only one person need operate it.

Soliciting and supporting social-spatial relationalities across school and home spaces. The Bingo Cage project went through multiple well-investigated iterations. Paul and Kaison continued to improve upon the design in order to work toward an even more efficient prototype that they had in mind, even after the engineering unit was over. They stayed after school and enlisted our help in their iterations. Their goal was to improve the design of the Bingo Cage so that Ms. D would keep on using it in the classroom, to continue to promote equal participation. They wanted to figure out a way to connect the handcrank directly onto the axle of the bingo cage so that only one person is needed to work the bingo device, and light-up the mat.

To have more room to work, Ms. D allowed Kaison and Paul to move their Bingo Cage and other materials to the school media center, where large tables were available. In the media center, the students continued refining their design. For example, they had learned from the engineering curriculum that the motor in the handcrank converted mechanical energy into electricity and decided to try attaching a motor onto the turning axle of the bingo cage. They first tried a smaller motor connected directly to the parallel circuit on the mat, but that did not produce enough energy to light the LED lights. Paul and Kaison reasoned that since the handcrank produced enough energy to power the lights, then the motor inside the handcrank must be powerful enough. Kaison offered to take the handcrank home and ask her electrician father's help to dissect the handcrank to remove the motor.

Kaison came back the next day with the part of the handcrank she was successful in partially taking apart, with her father's help. She could not disconnect the light bulb from the motor but was able to disconnect one gear. Kaison thought to put this handcrank gear on the axle of the bingo cage, then use it to connect to the axle of the motor from the handcrank; this would power the lights when they spin the cage axle. However, after hot-gluing the parts together, they could only get the lights to flicker momentarily because of poor connection of the parts.

The next afternoon when Kaison and Paul were working in the media center again, a seventh grader, named June, who had experienced the same sustainable engineering curriculum when she was in sixth came by the media center and decided to help Kaison and Paul. After Kaison and Paul explained to June what they were trying to do, June suggested that they use the handcrank handle as a connecting piece to attach the handcrank to the turning axle of the bingo cage. All three worked together. Kaison unscrewed the handle piece and they hot glued it in place to the axle. They were delighted when the pieces fit perfectly and worked according to plan. Paul and Kaison were very pleased that the hand crank could both power the lights and spin the cage and that only one person is needed to operate it. They were confident that with this design update, Ms. D would allow the Bingo Cage to be used more often (Figures 7 and 8).

There were critical mobilities between spaces and relationalities at play that impacted Kaison and Paul's continued iterative engineering process. A key part of the innovation was brought home to Kaison's father so he could give some advice. Moving the project into the school media center allowed June access to the sixth graders and their project, allowing June to share her expertise and support for Kaison and Paul's work. We see how new social-spatial relationalities were seeded and supported in the nature of both home and school-based interactions (Figure 9). Ms. D continued to use the Bingo Cage for the rest of the school year with the class. She also sought Paul and Kaison's permission to keep the Bingo Cage as an example of engineering for sustainable communities in sixth grade. This prototype caused Ms. D to reflect on her own pedagogical practices:

> I am guilty of calling upon the same students often. It's easy to get into the habit of calling on the same students who normally want to participate. What the students brought to my attention was that I was calling on the same students. The students who normally did not participate most definitely were more engaged with the bingo cage. I think this is due to the excitement from their peers. Teachers not always directing the flow of instruction is also exciting for the kids. Meaning, I also allowed the kids an opportunity to crank up the bingo cage and call upon their peers instead of myself.

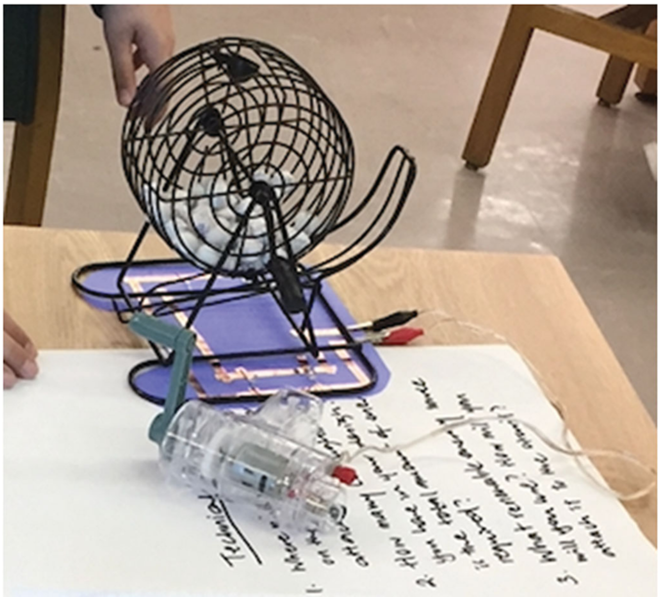


Figure 7. The light-up bingo cage with hand crank version 1.

Figure 8. Light-up bingo cage version 2: Gluing the hand crank to the Bingo Cage.

Discussion

Centering students' every day, hyperlocal experiences as epistemic resources is one way to reorganize the social-spatial terrain related to subject-object relations in STEM teaching and learning. Such reorganization can reveal the often hidden, but ever present, unjust school-based relationalities to be re-mediated in justice-oriented ways. Relatedly, community ethnography, as a *social-spatial practice of learning,* can reveal both the legitimacy of these relationalities while

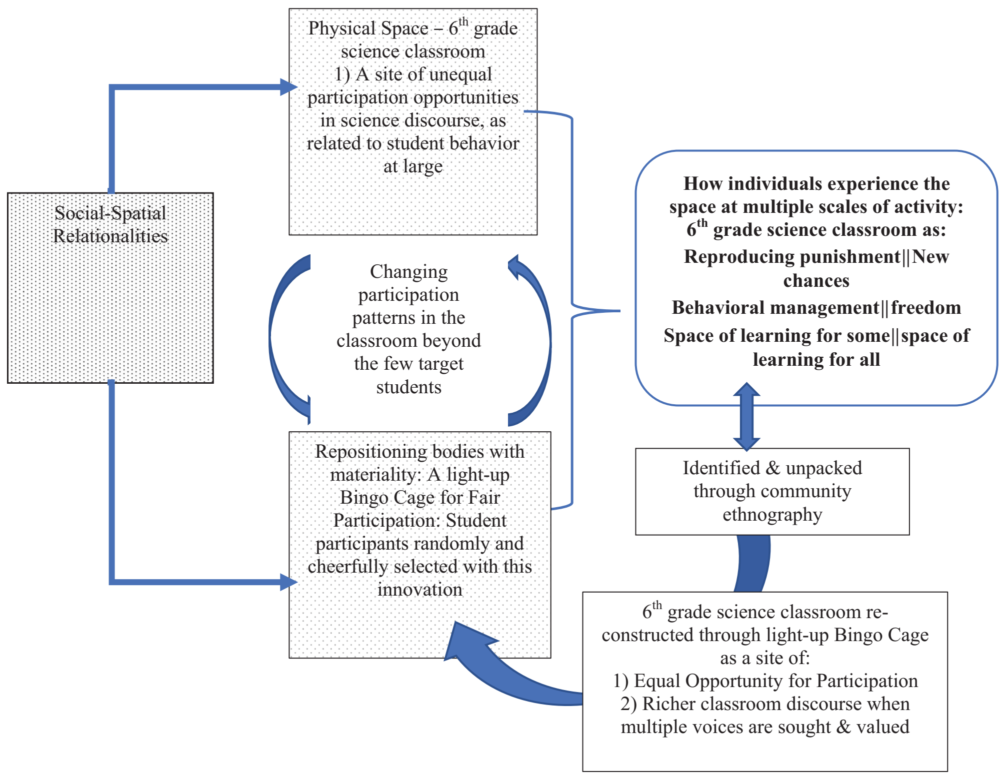


Figure 9. Seeding new spatial-social relationalities with the light-up Bingo Cage for fair participation.

positioning students' insider knowledges of these issues as relevant epistemic data for informing engineering design.

When students engineer in the context of new social-spatial relationalities, they author new enactments of and possible visions for justice-work that should inform the field of the learning sciences. They work toward making visible issues of injustice in both spatial *and* social ways such that they can be acted upon and disrupted in hyperlocal ways in the here-and-now, while agitating for larger transformative changes in school science *and* schooling itself in the desire for more just futures.

We consider three points in relation to youths' enactments and possible visions that should inform the learning sciences. First, justice work is simultaneously hyperlocal and interscalar, and the design of teaching and learning should work to put these in contact. Second, the reorganization of social-spatial relations makes possible social transformation in how it opens up possibilities for new imaginaries to be enacted in practice. Third, youths' actions in engineering for social-spatial justice reflects their desire to reclaim a rightful childhood while schooling. They do so by asking adult allies to recognize the gravity of their concerns, despite their youth.

Justice work is both hyper-local and inter scalar

We put the hyperlocal and interscalar in dialogue in response to how and why the youth engineered for sustainable communities. Historically, schooling practices have been grounded in power differentials entrenched in White supremacist and heteropatriarchal ideologies that take shape in the (re)production of school spaces with specific boundaries and ways of being for particular bodies. The youth documented numerous ways in which these powered relationalities play out, such as kindergarteners walking on lines on the floor in single file with "bubbles in their mouths."

Hyperlocal, first used in the context of media/journalism in response to media production that was information-based and focused on the needs and concerns of a particular population in a well-defined community (Metzgar et al., 2011), speaks to how youths' engineering designs sought to transform the spaces they occupied in the here-and-now, using their experiences and information gleaned from local community members. Youth seeded new modes of interactions between people, their innovations and space. These new modes of interactions reconfigured specific spaces, disrupting not just what space looks like, but the settled upon discourses and identities allowable in particular spaces. The light up butterfly lunch cone served as a child-friendly structural tool to organize children effectively according to preferred lunch choice, rearranging how bodies are composed in the lunchroom, impacting ensuing social interactions. Attention to the hyperlocal is a concrete way of humanizing science learning–this spatial rearrangement of student bodies in space had the potential to not only cut down the time it might take for students to get their lunch options and start eating, social spatial relationalities between lunchroom staff, parent volunteers and students would also be impacted positively to reflect the reduced chaos. It also allowed students to eat lunch with peers from different classrooms. If the cone worked well enough, teachers may not have to give up their sole period of respite during the school day to police the lunchroom.

The youth engineers in this study have demonstrated a keen sense of "strategic spatial consciousness" (Soja, 2010, p. 104). The hyperlocality, both in terms of physical proximity and social immediacy of the injustices they experienced and embodied across school spaces, directly informed how they chose to enact social spatial justice. The youths' agency in working toward social spatial justice through their engineering illustrated how the "taking place of spatial justice is not only shaped from above by the imposition of hierarchical power. It is also configured from below through … endogenous processes of locational decision making and the aggregate distributional effects that arise from them" (Soja, 2010, p. 47). Youth engineers' spatial consciousness is not only strategic but also critical as they understood, through community data and their own embodied experiences, how "the socialized geographies of (in)justice [in school] significantly affect [their] lives, creating lasting structures of unevenly distributed advantage and disadvantage" (Soja, 2010, p. 37) as evidenced in chaotic lunch hours, disproportionately punitive hallway behaviors and unfair classroom participation norms.

However, these projects were more than hyperlocal. In considering the inter-scalarity of activity (Jurow & Shea, 2015), as youth sought to reform social-spatial relations in the here-and-now in their classrooms and schools, they contested the cultural political project of science/schooling (Tsing, 2009). They also made visible and disrupted "microgeographies of power, surveillance, and control" that infuse spaces "with an array of multilayered injustices [that are] subtle and sophisticated in their colonizing effect and spatially organized system of control" (Soja, 2010, p. 41).

The interscalar spatiality of school-based minoritization needs to be better understood and as integrally entrenched in the everyday practice of education, and in need of disruption. Attention should be paid to relationships between supposedly *discrete spaces,* since "social relations do not reside solely within the spatial unit under consideration" (Pulido, 2000, p. 16) but as "stretched out" social relations from one space, reproducing others. The functional roles of spaces designated for supposed functions also designate specific bodies. Investigating these social-spatial connections rests on mapping social-spatial relationalities between bodies, materials, and structures enmeshed within webs of power differentials.

Across the cases presented, we see how youth set to repossess spaces in which they have been systematically sidelined, through their "mark" that resides in their innovations (Philippopoulos-Mihalopoulos, 2014, p. 16). The Helping Hands interactive board legitimized new ways of being when one is in the space of the hallway, for Kindergarteners and sixth graders. Instead of walking single-file quietly while keeping a bubble in their mouth, children could interact with a cheerful poster in playful ways now sanctioned because Helping Hands is a legitimized, engineering innovation created by sixth[t] graders for this very purpose. As a material innovation now occupying space in the hallway, Helping Hands acted as the "mark" of Louise and her friends, and worked to call into question the "classist assertions of good childrearing, and forced compliance that have legitimated institutional claims to children and their physical, spiritual, intellectual, social and emotional development" (Bang, 2020, p. 7).

Kaison and Paul's light-up Bingo cage for fair participation decomposed the assumed uniform classroom space into one that was in fact ordered hierarchically –students who got into trouble were physically sent to the corners of the classroom where they were often out of the teacher's peripheral vision. How spaces are supposed to function, and for whom, were called into question. With the Bingo cage, where students were spatially in the classroom mattered less, when it came to opportunities to participate and earn points in STEM class. As such, social-spatial relationalities were reconfigured with an eye toward greater social-spatial justice.

Re-organizing social spatial relations

Social-spatial relations need to be disrupted/re-organized to make both systemic injustices (such that they can be worked on in hyperlocal ways) *and* youths' imaginaries for a more just world (such that they can be designed for and enacted), visible. Engaging in community ethnography through surveys and interviews allowed new social-spatial discourses legitimacy in the STEM classroom (Gutiérrez, 2008). These new texts, previously unsanctioned, became foundational for students' engineering process. Anchored in storylines of school-community related injustices shared from students' insider perspectives, these texts reflected relationalities new to the STEM classroom. Students' embodied experiences reflected their lives as STEM learners, and as recipients of school-related stressors. These experiences demoralized students, contributing to their struggles in school. Legitimizing these texts of school community injustices overtly supported students' development of a kind of critical agency made possible through new social-spatial relationalities, as they built their engineering experiences on these issues. STEM became the primary vehicle with which students could respond to the everyday injustices they endure across school spaces.

The interactional practices inherent in community ethnography that invited new social-spatial relationalities included: (1) expanding the pool of stakeholders with whom students could converse with about STEM-related issues to include students from other classes; (2) introducing new modes of interactions –through surveys and interviews; (3) shifting traditional classroom hierarchy by positioning the STEM teacher and other adults as co-investigator of community issues rather than the content-authority; and (4) shifting the discourse patterns and student-teacher power dynamics in the classroom when teacher and students unpacked community data. These interactional practices worked in concert and were generative in nature.

With the Bingo Cage, Kaison and Paul drew from their own experiences as quieter students to frame the problem space, in addition to community survey data. 43% of respondents indicating that "school needs to be more fair" was something important to work on. Locating one aspect of this issue of fairness in classroom participation norms and patterns was another relevant scale of unpacking this data. Hearing feedback from peers about how they personally experienced this unfairness when it came to getting selected by the teacher to answer questions was yet another relevant data point, as were their observations of how peers positioned in the corners of the classroom used their bodies to gain the teacher's attention. Getting help from Kaison's father and 7th grader June broadened expertise and stakeholders relevant to sixth grade engineering. Engineering a solution that would support more students having equal voice to counter marginalization in the classroom was what this group of students then chose to focus on. Paul and Kaison explained that the Bingo ball would ensure that the process of selecting student participants was fair "because it is whichever ball with whoever's name comes out from the bingo, not the teacher choosing because someone is super loud and waving their hands." As noted in classroom observations, Kaison and Paul (and the majority of their classmates, except the few who "act crazy") were not "super loud." They raised their hands, but they sat quietly, and tended to be chosen less often.

Youth-centered and youth-defined social-spatial justice

The urgency and hope with which youth seek to enact changes reflects a desire to reclaim childhood (embracing the playfulness and joy they seek to infuse into their work) while asking adult allies to take their justice-work seriously. As discussed above, the prototypes designs were a physical mark that remained in specific school spaces (lunchroom, hallway, classroom) to catalyze new social-spatial relationalities toward justice-oriented social-spatial transformation. Another way in which these prototypes bear the mark of the youth designers is in the form of "signature science artifacts" (Calabrese Barton et al., 2008) where the innovators' identities as youth are abundantly evident. The nature of these prototypes remind us that the designers are children. Not only did the youth designers understand the gravity of injustices students endure via school social-spatial forces, they reclaimed playfulness as integral to justice when applied to children, especially in punitive school cultures. All three prototypes bear whimsical, children-appealing designs as part of their functionality, what the youth described as "fun" juxtaposed with the somber school-based injustices. What is remarkable is the epistemic rigor (science content and engineering practices) and gravity (nuanced parsing of local social-spatial injustices) imbued in the "fun" while not detracting from it –youthful playfulness, an inherent necessity of childhood that is systematically stripped from schooling, is the lynchpin of the three prototypes' functionality.

The youth engineers' innovations were aimed at disrupting their school climate to one that valued inclusivity, promoting justice and healthier and more successful learning for all students. With their innovations, the students imagined a new future (Gutiérrez et al., 2017) where, through being agentic in science and engineering, they could expand their agency toward transforming school culture (Tan et al., 2019). Such new social futures are also spatial imaginaries, "socially held stories, ways of representing and talking about places and spaces" (Watkins, 2015, p. 509). Spatial imaginaries have an advocacy element –they argue for possible social futures through shifting discourse and material practice (Martin & Simon, 2008), undergirding the political nature of working toward social-spatial justice through transforming social-spatial relationalities. From the nature of their prototypes, the spatial imaginaries youth held are just, playful, epistemically rigorous and community-relevant, reflexive of how they want to be in school. With youth-centered, youth-defined, social-spatial justice in schools, playfulness and joy can be anchored in authentic disciplinary work.

Implications and emergent tensions

New social-spatial relationalities provided new social-spatial texts that became salient to school STEM. These new texts worked to impact student positionality and opened up new possibilities to become and to engineer. The kinds of engineering tasks students could investigate in K-12 engineering, how and for whom, have implications for social justice related issues in engineering education. The political and collective nature of these three middle school engineering projects, undergirded in community ethnography, were a marked departure from the individualistic and apolitical characteristics of dominant engineering education projects critiqued by critical scholars (Adams et al., 2011; Cech, 2013).

At the K12 level, engineering standards as outlined in the Next Generation Science Standards "include only practices and ideas about engineering design that are considered necessary for literate citizens" (NGSS Lead states, 2013, Appendix I, p. 3) without attending to the nature of engineering—engineering's epistemic, ontological and axiological underpinnings. Moore et al. (2015) have critiqued the erasure of the nature of engineering from NGSS, specifically pointing out the lack of ethics related to performance expectations in the NGSS engineering standards.

Community ethnography supported the students in compiling and analyzing problem-defining data from community insiders that included themselves and their own embodied experiences. Insider community perspectives allowed for nuanced insights into how social-spatial relationalities mapped onto community-identified issues producing social-spatial injustices.

Undoubtedly, inviting new social-spatial relationalities into STEM classrooms are often fraught with tension (Davis & Schaeffer, 2019). Explicitly investigating spatiality in school inadvertently leads to historical school-space boundaries becoming porous, functionally decomposing the supposed roles of such school spaces. For example, lunchrooms and hallways become sites of engineering investigation and reconstruction, with rippling effects that disrupt settled social-spatial relationalities governing such spaces. Teachers may be put at risk with the school administration when students take on issues that are political and deemed beyond their say, especially when other school spaces are involved. Another tension that teachers have articulated is related to the sustainability of such modes of engagement. The reality of teacher pacing guides, high-stakes testing and other very real social-spatial oppressions rob teachers and students of the time necessary to engage in lessons that invite new relationalities. As one student told his teacher after his class produced six different innovations during the engineering for sustainability unit, "we cannot go back to normal science after this experience" which the student explained as mostly book-based work and copying notes. Yet his teacher is bound by forces larger than both student and teacher to resume at least some "normal" science. Curricular limitations also presented tensions for what students could innovate. The curricular dictates in these three cases included mandatory requirements, tied to standards, that student projects include a complete circuit with LED lights and a renewable energy source that might have hampered the directionality of students' iterative design.

Conclusion

Negotiating social-spatial relationalities in STEM classrooms open up opportunities for students to engage in new forms of equitably consequential learning aimed at addressing social-spatial injustices, positioning students with more expansive ways to engage in more justice-oriented middle school engineering. Student agency is evident in their using different forms of expertise, beyond traditional scientific knowledge, to design solutions to solve problems in their communities. The cases presented in this manuscript show how attention to spatiality in learning and legitimization of new social-spatial relationalities are generative. Students were better positioned to challenge school-based systemic oppression that were unacknowledged but then became salient to a disciplinary, community-related project. Students were recognized as community engineering experts. These new social-spatial relationalities in the classroom afforded students more expansive outcomes for engaging in engineering that attended to issues of import to students and the school communities in the here-and-now, with potential for seeding new spatial imaginaries –imagined futures in school spaces that are more just. Such justice-oriented engineering projects also demand and sustain student engagement in developing robust science and engineering expertise and practices in the process.

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