# Critically engaging engineering in place by localizing counternarratives in engineering design

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## Abstract:

In this manuscript, we use the construct of *critical epistemologies of place* to frame our exploration of how to support engineering design among youth who have historically been marginalized from the domain, and its implications for educational settings. We present an in-depth longitudinal case study of one 12-year-old African American boy to raise questions of what it means for this youth to engage in engineering design in collaboration with the people around in him—experts and knowledgeable others in his community space and how this engagement supports his work in science and engineering. This study suggests that engaging engineering design through a critical epistemology of place involves an iterative and generative process of layering community wisdom and knowledge onto STEM toward (a) how epistemologies of place—and their layers—challenge dominant master narratives, (b) reimagining practices in place, and (c) transforming the dangerous territory of STEM. Our study expands upon current understandings of supporting youth in engaging engineering through highlighting the vital role of sociohistorically constructed understandings of STEM and community in determining when, how, and why engineering takes place.

**Keywords:** case study | engineering | epistemology | equity | learning

## Article:

> "Bullying affects me, my friends, my community and people around me that we do not know. We need to make sure that we help people that are being bullied, and stop the act of bullying when it happens by giving people the tools, such as with my bully app."—Christopher when describing bullying in his community.[1]

[1] Pseudonym

## 1 INTRODUCTION

Christopher, a 13-year old African American 7th-grade student in Great Lakes City describes himself as an "avid technologist and active science learner." He enjoys learning how to create smartphone and computer applications with his adult Big Brother[2] mentor on the weekends. In his Great Lakes City afterschool green energy club, he created the Speak Up Step Up (hereinafter referred to as SUSU) smartphone application. His goal was to stop bullying in his community. Christopher created the SUSU by using Global Positioning System (GPS) and Geographic Information System (GIS) mapping technologies, in combination with community crowdsourcing, to pinpoint common bullying areas in the Great Lakes City area.

While designing the SUSU, Christopher described himself as an "inventor and destroyer." As an *inventor,* he is passionate about using interactive technologies to make the world a better place for himself and his friends. As a *destroyer*, he wants to destroy the act of bullying—including the frustrations and emotions that are harbored by its effects on his local community. He believes technology can be used as an educative tool in support of building healthier communities. As he stated, "Helping is loving someone else in the heart because helping is very important in making the world a better place to live. My app should encourage you to help others not only by supporting our community in preventing bullying but also in taking the time to help others who are being bullied by caring for them and seeking help when needed."

We begin with Christopher's story because it highlights the importance of critically engaging place in engineering design. Engineering design and meaningfully engaging students in the practices of engineering, has become an important goal for K-12 science education. As the Next Generation Science Standards (NGSS) states, engineering design is the "systematic practice for solving problems, and technology as the result of that practice" (Next Generation Science Standards Lead States, 2013, p. 437). As outlined in *The Framework for K-12 Science Education,* engineering design includes three elements: (a) defining and delimiting engineering problems solved through criteria and constraints; (b) designing solutions to engineering problems begin with generating a number of possible solutions and evaluating them using criteria and constraints; and (c) optimizing design solutions involve[ing] a process that is tested, refined and improved by trading off features that are less important for those that are more important in the design (National Research Council, 2010, p. 71).

In this paper, we are concerned with engineering design among youth who have historically been marginalized from the domain, in ways that take up their community knowledge through the practices of identifying problems and designing solutions and its implications for educational settings. Particularly, we draw upon an in-depth longitudinal case study of one 12-year-old African American boy to understand what it means for one youth to engage with engineering design in collaboration with the people around in him—experts and knowledgeable others in his community space—and how this engagement supported his work producing a functioning smartphone app. We ask the following research questions: (a) What is the relationship between Christopher's engineering design and engineering with the community? (b) How do Christopher's

[2] Christopher is part of the Big Brother Big Sisters program, which provides children with strong and enduring one-on-one relationships with an adult in their community. Christopher's Big Brother visits him on Saturdays and is a technology employee at Great Lakes City University

and his community's counternarratives regarding both STEM[3] and bullying *inform* and *transform* his engineering design work?

## 2 DANGEROUS TERRITORIES: BULLYING AND STEM EDUCATION

We frame this paper around two intersecting dangerous territories for Youth of Color: Bullying and achievement in STEM education. We use the term "dangerous territories" because both STEM learning environments and spaces of bullying are/or can be unsafe for Youth of Color. These territories have a history of silencing young people who bring their cultural and community knowledge and repertoires toward engaging STEM.

### 2.1 Bullying

The sense of intimidation, threat, abuse, and fear associated with the multidimensional phenomenon of bullying continues to affect youth, of all ages, in all areas of society, worldwide (Rose, Nickerson, & Stormont, 2015). Defined as "aggressive behavior that is distinguished from fights or arguments between students of equal strength" (Unnever & Cornell, 2003, p. 6), bullying takes many forms. These include physical aggression, verbal abuse, and control of social interactions that humiliate or harm victims (Olweus, 1993). Physical and verbal behaviors associated with bullying are also one of the most widespread types of school violence (Swearer & Cary, 2003).

Nationwide, in 2015, 66.8% of students ages 12–18 have experienced some type of bullying (National Center for Educational Statistics, 2018). Further, more than one-third of middle school students stated that they have underreported incidents of bullying because of fear and a lack of necessary skills needed to report (Garnett et al., 2014). Although a complex phenomenon, "some subgroups of youth are at escalated risk based on individual characteristics, skill deficits, and peer group or societal norms" (Rose et al., 2015, p. 339).

Relevant to our study is the increased risk that Youth of Color experience with bullying, especially in relation to school and STEM attainment (Tynes, Del Toro, & Lozada, 2015). Yet, while bullying's pervasiveness and impact on school culture and academic success of students have been highly researched over decades (Bosworth, Espelage, & Simon, 1999; Haltigan & Vaillancourt, 2014; Unnever & Cornell, 2003), bullying continues to be understudied in Communities of Color (Pritchard, 2013). Major national studies have undersampled Youth of Color, limiting knowledge of how bullying happens across spaces or its differential impact (Pritchard, 2013). What is more, escalating rates of cyberbullying have been tied to increased online racial discrimination and to decreasing adolescents' academic motivation (Tynes et al., 2015), further illuminating the need to understand bullying among Youth of Color.

Youth and adults hold diverse roles in mitigating or propagating bullying behaviors. Some peers have exhibited empathy with the victim and defended them from the bully and their terrorizing behaviors (Nickerson, Aloe, & Werth, 2015). Others participate as bystanders in the process

[3] We use the term STEM to be consistent with how the term is has been appropriated in science education reforms—to refer to *integrated science and engineering experiences*. we do not mean the original term: science, technology, engineering, and mathematics.

because of poor understanding of how bullying takes place or knowledge of how to respond. Teachers and school administrators are often implicated as observers, failing to intervene, thereby empowering or rewarding the bully's behavior (Unnever & Cornell, 2003). Little is known about how these processes are disrupted for Youth of Color. Thus, understanding how the territory of bullying is shaped by the intersectionalities of race and class offers potentially important "unexplored critical possibilities" for disrupting the practices which promote it (Pritchard, 2013, p. 321).

These trends were the reality for Christopher. As we later elaborate, through the process of developing the app, he noted that many bullies in his community quickly moved their aggressive behaviors from outside of school to the inside of the school. This is because teachers and administrators were ill-equipped to address bullying that occurred outside of the physical school space, especially online. Christopher further noted that when teachers did not—or could not—respond to the kinds of out of school bullying that led to in school bullying, they then became "bystanders" contributing to a negative "feedback loop." Christopher's SUSU app was created as a tool to prevent these bullying feedback loops in his school and community.

In our manuscript, we explore how these dominant social narratives around issues of bullying (e.g., sociopolitical and sociohistorical underpinnings of what constitutes bullying spaces within communities) became central to one youth's engagement in engineering design.

2.2 STEM and engineering education

Similar to how bullying harbors a sense of intimidation and fear in physical and online spaces, the territory of STEM has created a "sense of unequal strength" oftentimes hurting and humiliating youth—by stereotyping those students who fail to achieve in STEM education. These territories have had dangerous historical–political and economic effects for youth, and in particular, Communities of Color.

Large gaps in opportunities to advance achievement and interest in engineering and the physical sciences persist for minoritized[4] youth across all levels of educational attainment. In the United States, the percent of bachelor's degrees awarded to African Americans in engineering has hovered around 4% (Yoder, 2012). African Americans, Latinx, and American Indians account for only 6% of the science and engineering labor force, even though they represent over one-fourth of the US population (National Science Board, 2014). Opportunities to advance interest and achievement have changed little in the past two decades (and, in fact, have worsened) despite national science and math reform efforts.

Minoritized students, especially African American males, are more likely to be faced with negative cultural stereotypes and assumptions about their perceived lack of intellectual ability in mathematics and science, as compared to their White peers (Harper, 2010). At the high school level, they are often excluded from gatekeeper courses (e.g., Algebra) required for college

[4] The term minoritized, versus minority, indicates that an individual's minoritized status is a function of how that individual is positioned within a hegemonic society, rather than an inherent descriptor or trait (Gillborn, 2005). The term "minority" is recognized in critical scholarship as a deficit term and an inaccurate reflection of demographics in many communities in the United States where individuals of color represent the majority of the population.

admission (Harper, 2010). Such is the case with academic tracking. In one study, Zuniga, Olson, and Winter (2005) examined the tracking policy of a rural high school with over an 11,000% increase in Latinx student enrollment within 10 years. They found that Latinx students were often placed in lower level science and mathematics courses created for students with disabilities or students requiring special education. Lack of English language programs and support services led to early tracking into low-level science and mathematics programs for these students. These same students were then unlikely and often discouraged to take courses required for college admission, limiting their abilities to pursue and aspire to postsecondary STEM pathways when compared to their non-Latinx White counterparts (Zuniga et al., 2005). More recent studies have indicated that little has changed in these patterns (Umansky, 2016).

Furthermore, schools in minoritized communities do not generally provide access to advanced mathematics and science courses (US Department of Education Office for Civil Rights, 2014). For example, one-fourth of the schools with the highest percentage of Latinx and African American students do not offer Algebra II courses, and of these same schools, one-third do not offer courses in Chemistry.

Even when courses may be offered, many teachers lack access to culturally relevant teaching strategies and resources (Parsons, 2014). Where these resources do exist, teachers still resist embracing and building upon the cultural, ethnic, and racial diversity in US classrooms due to negative perceptions and stereotypes of minoritized students (Gay, 2013).

As the literature above shows, minoritized communities, and Youth of Color, in particular, have been limited access into STEM, while there also exist barriers constructed of historicized stereotyping. These are stereotypes which grow out of dominant narratives of who can do STEM or what STEM learning and success looks like, which unfairly and systematically bully youth out of STEM (Harper, 2010). This particular manifestation of the education debt (Ladson-Billings, 2006) has contributed to the development of STEM as dangerous territory while further limiting the beneficial educative, economic, social, political, and historical aspects of learning STEM. Given science education's focus on engineering design as one way to be “inclusive of students who may have traditionally been marginalized in the science classroom or experienced science as not being relevant to their lives or futures” (Next Generation Science Standards Lead States, 2013, p. 2) we believe that situating Christopher's SUSU app development with community can provide insight for the design of more meaningful and inclusive engineering education in the middle grades for Youth of Color.

## 3 CONCEPTUAL FRAMEWORK: CRITICALLY ENGAGED ENGINEERING IN PLACE

In this section, we bring together intersections of knowledge and practice of engineering and community through epistemologies of place, with Critical Race Theory (CRT)’s stance on counternarratives to build a framework: Critically engaged engineering through epistemologies of place. We view this as an important equity-oriented approach in redressing the ways in which the sociohistorical context of science education has traditionally been raced and cultured in oppressive ways for youth groups from minoritized communities (Nasir & Vakil, 2017).

### 3.1 Epistemologies of place

The importance of "place" in STEM education has increased in focus in the past 15 years (e.g., Lim & Calabrese Barton, 2006; Schindel, 2016). Drawing upon this literature, we view the place as multidimensional, experienced by how one is positioned among the intersections of its historical, cultural, geographical, and political dimensions at any given moment (Gruenewald & Smith, 2008). In classrooms or afterschool programs (such as where this study is situated), place accounts for the nested *physical spaces* of the community (e.g., the particular school or community center within a particular neighborhood), and the historical and sociocultural dimensions of those places and how they shape activity there. For example, in Bang and Medin's (2010) descriptions of their efforts to develop and implement placed-based summer science programs with the Chicago Intertribal Indian Community and the Menominee Community, they needed to attend to both the location of the people and programs, the *scientific* and *community-based* ways of knowing, and the possibilities and challenges young people might face as they navigated those different epistemologies. They show, however, the complexities of place by foregrounding the histories, experiences, practices, and epistemologies of all kinds of community members, including teachers, elders, parents, community experts, researchers, and youth, all of whom experience a place differently, because they are positioned differently within these places. This stance foregrounds the wide range of intellectual resources of people-in-place that "must be mobilized and engaged in meaningful and rigorous ways" to promote STEM learning and the vitality of Indigenous people (p. 2).

One important thread that has emerged from this area of work has been a focus on *epistemologies of place*. Swart (2009) describes epistemologies of place as "embodied knowledge" arising from one's relationship with their environment, always oriented towards their future and that of their survival. Here, we can think about epistemologies of place as a way of understanding a collective community knowledge or wisdom grounded within the various relationships among lived spaces and people (Natarajan, 2017; Tuck, 2009). Epistemologies of place, therefore, foreground the powerful and ongoing knowledge generations *within*, *of*, and *for* communities-in-place (Natarajan, 2017). We purposefully use the phrase communities-in-place in relation to epistemologies of place to foreground a sociospatial perspective of communities, which matter in knowledge generation. As Bang and Medin explain, the day-to-day practices, always grounded in place, "are the sites at which epistemologies and epistemological stances are implicitly brought to life, learned and infused with meaning" (p. 10). This stance stresses how cultural practices of communities reflect and reveal implicit epistemological stances; and in particular the kinds of approaches to understanding the complex and multifaceted interactions needed for the evolutionary trajectories of survival.

Epistemologies of the place is an important equity-oriented consideration in science education. Standard school practices "teach students that their relationship with their place is marginal, uninteresting, and unimportant and the quality of the environment demonstrates this marginalization" (Sanger, 1997, p. 5). Implicit in standard teaching practice is the idea that the "epistemologies that students come to classrooms with are inferior, or less productive, compared with the one(s) that researchers and educators (for our purposes, science education) are trying to assist students in learning" (Bang & Medin, 2010, p. 8). This stance builds on but extends, Cunningham and Kelly's (2017) articulation of the importance of engineering in social contexts

as an important dimension of engineering epistemologies. They argue that “engineering problems, and respective relevant knowledge, emerge out of social needs and are typically resolved and completed through social processes, including evaluation by respective clients” (p. 492). The work of engineering necessarily involves making sense of how problems are defined through the challenges faced in local situations. In this study, engineers need to consider complex design constraints and trade-offs, often drawing upon insights from different epistemological origins. They must also assess the implications of their work in the real world. These aspects of engineering practice are central to engaging engineering in place. We advance this stance to raise the importance of the historicized context in the work of engineering, including how the sociocultural, and political situatedness of design is threaded across the full range of engineering epistemic practices. That is, we believe that marginalizing place removes practice from the cultural—historical realm, reducing culture to a static set of attributes and activity only through subject—object terms.

### 3.2 Counternarratives in challenging dominant narratives and epistemologies of place

For the equity-related reasons described above, we draw explicitly on counternarratives, a tenet of CRT; a theory that seeks to understand the lives and experiences of People of Color (Solórzano & Yosso, 2002; Yosso, 2005). Oftentimes, dominant narratives of place hide or purposefully aim to disenfranchise vulnerable populations by detailing stories of minoritized populations without considering their histories and experiential realities within these spaces. Solórzano and Yosso (2002) argue that counternarratives challenge master narratives and how they oftentimes reproduce White privilege and epistemologies of privilege, undermining the experience of People of Color.

In further situating place and the realities of those that experience place, there are scholars who argue for a more critical view on how people make sense of place. Relph (1993) posits that a person's sense of place—or placelessness—is layered and complex, tied to understanding human experience(s) and human situation(s) regarding events, meanings, and experiences. Through this frame, the place is always experienced differently by different people, shaped by individual's pasts and hopes for their futures as well as the different oppressions one experiences in a world marked by ever-increasing corporatization and inequality. Furthermore, all narratives (including dominant and nondominant narratives) created, for better or for worse, become attributes of the place. In addition, in experiencing the place and/or placelessness, the narratives that are created can come together to create a sense of change based on experiential realities of those who occupy and are part of, that place (Relph, 1976).

In our work with Christopher, we recognize the intersectionalities of how individuals in his community have been historically raced and classed, and whose stories and experiences do not always lead to social change within these places. We recognize that minoritized individuals unfairly may not have the same power, even in the collective, toward change. This study cannot ignore the racial, classist, and minoritizing effects—and intersections among them—that are always at play and may have devastating effects on communities and the narratives told about them. These realities are especially true for youth who live, engage, and experience these communities, and who over time are developing a sense of place or placelessness (Relph, 1976) as they learn, live, and create meaning, including bullying as one example, in their communities.

The parlaying effects of these nondominant narratives of place can have historicizing negative effects for those whose voices continue to remain at the margins of this study. Hence, we take a stance that although the human experience is always inherently part of place, and that narratives created in these spaces are never counter to the other, dominant narratives of people who have the power to change them can reproduce knowledge and practices that are counter to the experiences of minoritized people within communities, thereby creating a sense of placelessness for them. By situating Christopher's work with his community in creating the SUSU app as a counter to the dominant narrative, we highlight the stories of minoritized people whose stories are not often told, like Christopher and his community members, and challenge racial dominance of the dominant narratives that get reproduced.

Collectively, in thinking about how individuals experience a place, and then how those experiences become narratives—dominant or nondominant and the power attributed to them—we center counternarratives as critical to our work with epistemologies of place. They allow for People of Color to localize their counternarratives of place—the cultural, sociohistorical, and sociopolitical understandings they have and how these are connected to broader narratives of racial subordination. This understanding of lived experiences such as those included in storytelling, family histories and biographies allow us to challenge traditional paradigms and theories used to explain geographical experiences of minoritized populations. For example, Solórzano and Yosso (2002) discuss assumptions of negative stereotypes about People of Color in how White middle-class people fall victim to violence. The classic narrative of these negative stereotypes includes: “how can this happen? This is a good neighborhood?” The standard story implies that violent crimes are unheard of in White middle-class neighborhoods where they may be viewed as normal in Communities of Color. This reproduces the narrative that violence happens more in minoritized communities due to their sociocultural and economic marginalization (Solórzano & Yosso, 2002).

These racialized beliefs can often trickle down to affect the epistemologies of what constitutes a good/bad neighborhood and/or community, their population and their schools. While at the same time, communities and individuals take up those racialized and minoritized identities and stereotypes based on these dominant narratives—developing into stereotypes of dangerous territories. Thus, it is our stance that counternarratives are important resources in making sense of the power of epistemologies of place. They help us to understand how epistemologies may be learned and embodied through power-mediated experiences and contribute to how one makes sense of both context and self.

### 3.3 Engineering through critical epistemologies of place

Critical epistemologies of place—epistemologies of place as informed by counternarratives—can serve as powerful resources for individuals learning to engineer solutions to real-world problems. This is particularly important for addressing problems of justice—problems grounded in the accumulated historical, sociopolitical, economic, and moral policies that have been done onto minoritized communities. Solving problems in engineering through critical epistemologies of place foregrounds the interplay between the technology of design (including the problem-solving epistemic practices of envisioning multiple solutions, considering materials and their properties, using systems thinking, and building and learning from prototypes (e.g., Cunningham &

Kelly, 2017), and the needs and collective wisdom of communities. Not only does this approach situate engineering design within local contexts, it also espouses the importance of participatory practices and humanistic action-taking toward the integration of place within the particular epistemic practices and outcomes of engineering.

The critical epistemologies of place framework has great potential to support a more nuanced view of engineering design, as posited by the NGSS. Particularly, the inclusion of engineering design is meant to provide a way for students, especially those minoritized in science, to solve meaningful problems *as a way to identify and take action with STEM* in local contexts. By centering the problems to be solved on the accumulated historical, sociopolitical, economic, and moral policies and practices inflicted onto Communities of Color, we hope to provide a way to decenter and challenge majoritarian narratives of privilege. Rather than one opportunity to engage students in a more meaningful STEM education, we are focusing on ways science can lead toward liberation and survival, where Christopher's story and his community's engagement in creating SUSU can become one pedagogical tool in using engineering design core ideas and practices to engage students and communities in challenging hegemonic and dominant discourses in what counts as engineering design in STEM, and for what purposes it can be used. This stance builds, in part, on the work which has importantly sought to represent the complexity of engineering epistemic practices (e.g., Cunningham & Kelly, 2017), but also to complicate this study in political- and justice-oriented ways (e.g., Hynes & Swenson, 2013).

Engaging engineering through critical epistemologies of place may avoid the kinds of marginalizing epistemologies described by Bang and Medin (2010) by including, as a part of engineering practices, the local sociocultural–historical underpinnings of communities (Gruenewald & Smith, 2008). This critical engagement allows for the diverse meanings of and attachment to place to enrich and diversify sources of knowledge toward engineering design (Semken & Freeman, 2008). Important also is the cultural and sociopolitical dimensions of engineering—that it is a practice grounded in human interactions in place, and thus shaped by ways of knowing, relationships, history, politics, and geography (Hynes & Swenson, 2013).

In this paper, we use this framing to discuss how Christopher engineered the SUSU app dialectically with his community members—as both a response to instances of bullying and counteracting stereotypes of who can do/create/engage with/in STEM—through a collective understanding of a sociospatial critical epistemology of place. We hope to show how Christopher critically engaged engineering in place by localizing counternarratives while engaging in the engineering design practices of identifying problems and designing solutions. Particularly, Christopher's bullying counternarratives and positionality as a STEM learner, who creates computer and smartphone applications, coconstructed knowledge and relationships of place in collaboration *with* his community members.

## 4 METHODS

### 4.1 Context

#### 4.1.1 Green Club at the Great Lakes City Community Center

The study is situated in Great Lakes City, an urban area hit hard by economic recessions and subsequent population decline experienced across the state. While poverty and loss of industry often frame conversations about Great Lakes City, the youth we work with are quick to point out that Great Lakes City is a "close knit community" with "a lot of fun things to do and places to go." One of the central places in the lives of the youth is the local Community Center.

The Great Lakes Community Center opens its doors to over 2,400 youth annually between the ages of 7–17 from predominantly low income and minoritized backgrounds. The Center provides a safe place for youth to engage in many activities, allowing opportunities to play, learn, and have fun. One of the programs offered to members of the club is an informal science and engineering program called Green Club. Christopher, the youth involved in this study, is a member of the Green Club.

Green Club is open to youth ages 10–15 and has anywhere between 15 and 20 weekly participants. Green Club provides youth with sustained opportunities to engage in engineering for sustainable communities (with a green energy focus) in ways that are locally relevant and of global importance (Birmingham et al., 2017). The space supports the youth in developing deep understandings of science while also leveraging community expertise to take action.

Each Tuesday and Thursday during the school year, Green Club meets in a modest space which the youth call the "club room" in the Community Center. On Tuesdays, Green Club youth participate in energy-related investigations that include working to gain understandings of the relevant science and engineering concepts and practices. On Thursdays, Green Club youth work with technology to create artifacts to share with peers and other community members about their energy-related investigations.

#### 4.1.2 Engineering in place: Green Club design challenge

During the 2014–2015 school year, Green Club youth worked on an engineering design challenge focused on safety issues in their communities. In creating these prototypes or inventions, youth leveraged opportunities to merge scientific/engineering practices with community knowledge and experiences. The constant merging of these two—separate but often related concepts—were informed by ongoing lessons about energy, components of circuitry, design optimization, and other engineering disciplinary core ideas important to their engineering design for sustainable communities.

The next set of lessons focused on critical ethnography and learning how to collect data from community stakeholders about safety and energy concerns. Community members gave extensive critical feedback on the initial design and prototypes youth were authoring. There were also opportunities to leverage expertise from STEM experts (e.g., community engineers, faculty members in the College of Engineering at Great Lakes City University). For example, we served as STEM mentors (those with content-area pedagogical expertise in science and engineering who codeveloped the curriculum for the Green Club) to students in the afterschool space, and worked very closely with Christopher to make sense of the community ethnography data and the feedback that would support the development of his SUSU app. Other opportunities to engage with STEM experts included feedback cycle day where youth presented their designs to

engineering experts that gave critical feedback on the green energy and technical specifications of design prototypes. These feedback cycles were important in legitimizing and recognizing youths' engineering work in ways that provide ownership of their STEM expertise when working on the social specifications with communities. Youth also incorporated home/school/community practices they felt were critical to the designs of their solutions.

Youth gathered community ethnographic data to support expertise in engineering design. For example, Ball and Ormerod (2000) discuss that ethnographic methods along with being used for gathering insights into previously unexplored cultures or undocumented social practices should also include gathering data from communities to apply into design behaviors and design productivity outcomes. Therefore, it is important for us to support youth in how to apply ethnographic methods to the critical understandings of what constitutes knowledge/practices of the community into their engineering design practices when identifying problems and iteratively designing solutions.

## 4.2 Research approach

### 4.2.1 Longitudinal case study

Situated in longitudinal single case studies of 12 youth who participated in Green Club between 2014 and 2015, this study focuses on Christopher's case because his engineering design provided a diverse perspective of engineering for and with community members. First, he incorporated his expertise in emerging technologies in his design. Second, he used various tools to gather community ethnographic data that came from his own experiences—and the expanded these gather experiences from community—while working in Green Club; and third, he continuously worked with us to find ways to incorporate these newfound understandings into his app in ways that targeted the different problems he hoped his engineering design would address. Christopher's deep engagement and ethnographic work in developing his design inspired us to focus on his story.

### 4.2.2 Data generation

Data were generated from artifacts, youth conversation groups, and video analysis capturing youth interaction with science/engineering and community experts at various stages in their design process (Table 1). In addition, we had mid-course artifact interviews (December), feedback cycle day with engineering experts (December/February), final artifact interviews (May), and researcher field notes (per session).

**Table 1.** Methods of data generation

| Data forms | Specific data generation strategy |
|---|---|
| Participant observation | • Afterschool STEM program (Green Club): Video recordings of twice-weekly sessions and field notes (48 sessions, 72 hr) |
| | • Green Club community events (feedback cycle day, presentations at the art museum, field trip to local college campus, etc.): Video recordings of events and field notes (3 events, 6 hr) |
| Conversation group | • As a way to debrief what was happening in the club as well as to plan for future activities (18 weeks, 36 hr) |

| Data forms | Specific data generation strategy |
|---|---|
| | • 6-Week segment of the conversation group focused primarily on how and why youth shifted their design, what funds of knowledge or STEM knowledge youth drew upon or leveraged for their design, and how youth positioned themselves in engaging in engineering design process in 2014–2015<br>• 6-Month conversation groups with youth around coconstructed case studies of engineering work over time in 2014–2015 |
| Artifact think aloud | • Allowing youth opportunities to talk about their engineering design work in detail (twice during the year)<br>• Mid-year (December, 2014)—3D Google SketchUp model of design, sketch-up notebook, and initial prototype<br>• End of year (May, 2015)—Final prototype, sketch up notebook, and movie |
| Artifact collection | • Youth's sketch up notebook, 3D Google SketchUp model of design, worksheets, prototype, movie, etc. |

### 4.2.3 Data analysis

We first began by open coding the final artifact interviews of the youths' engineering designs where we asked questions around understanding their perspectives of engaging in the engineering design practices of identifying problems and designing solutions. Specifically, we wanted to understand how their designs iteratively changed over the course of the year, and how/in what ways youth expressed community input, feedback, and issues related to community ethnography in their design and other artifacts. This is not an exhaustive list, but once these sections were open-coded, we saw patterns in our data reduction strategy (Miles & Huberman, 1994) related to how counternarratives (Solórzano & Yosso, 2002) about bullying drove a lot of the engineering design. In the second round of coding, we specifically looked at how Christopher's personal counternarratives shaped the social and technological dimensions related to the community ethnography data collection and how these resulted in expanded understandings of community related to critically engaged engineering in place. The third iteration of data analysis was on how different steps in the design process showed important learning opportunities for Christopher by including STEM experts and community experts his engineering design for sustainable communities.

The vignettes were then member-checked and cowritten in a final interview with Christopher to understand in greater detail the different steps taken in his engineering design process which became part of his narrative in this paper.

## 4.3 STEM mentors and Christopher's roles and positionalities in working together

Christopher joined the Green Club, at the request of his friend and club member, David. Although previously recruited to join the program by Community Center staff, Christopher expressed disinterest in participating in a STEM afterschool program. He enjoyed computers, and he liked playing Roblox and Minecraft, programs which were available in the Community Center computer room, and could be accessed at any time, without program involvement or intrusion. However, David persuaded Christopher to help him design a computer-based survey that he wanted to use to elicit community members' views on safety-related issues.

The same day that Christopher attended Green Club to help David, he was also recovering from a bullying incident at his school. This was when he discussed with us his goal of creating an "engineering design" that could have a changing impact on bullying. As he worked with David on his safety survey, he began to talk about ideas he had to use "engineering design" to impact bullying. He said he did not want to make something "physical," but rather use computers somehow to make something that could "use something that can be bad to make it good." As we will describe in Christopher's story, after four main iterations involving refinement of both social and technical specifications Christopher, with help from David and Kaleel, all of whom were victims of bullying in their respective schools and at the Community Center, created the SUSU app. Christopher provided the technology expertise by both moving his knowledge of app making and GIS/GPS mapping to the Green Club, and David and Kaleel provided support in gathering ethnographic data from community members and third-party websites as part of their data analysis and investigations.

In this process, Christopher served as a bully expert, computer expert, app developer, and insider-expert-community member. Our own roles in this process were as mentors, learners, and researchers. We sought to understand and support the narratives and counternarratives Christopher told about STEM, app making with and for the community and bullying. We worked closely with Christopher and his peers on designing and enacting approaches to ethnographic data collection and analysis. We helped him broker his developing knowledge and insights with peers and community members.

We all (youth and adults) placed great emphasis on our developing relationship in the Green Club. There were many commonalities in our positionalities as members of our communities, as well as STEM mentors and learners that often shaped when and why we talked about certain things together. This happened mostly during the time we member-checked the vignettes that were part of this manuscript where we constantly made sense of our experiences. This is one main reason why this paper was not just simply written or member-checked, but it was cocreated through many critical conversations and sensemaking of experiences in Green Club, and moments of pain and resilience.

For example, Christina (first author) shared many personal stories with Christopher during the design process. She is an only child who grew up in a single parent household and so was Christopher in his current situation. She is also a graduate student of Color and first-generation Latinx, where much of her success in school has been based on overcoming social/cultural/linguistic stereotypes while learning and reflecting on the stereotypical notions of academia. Similarly, Angie (second author) grew up in a lower-income community, where bullying was a common practice against lower-income kids with worn-out and hand-me-down clothes. Afterschool programs provided STEM-related compensatory experiences not offered in her school but offered in other more affluent places as a part of the standard curriculum.

In discussing his experiences, Christopher oftentimes opted to prioritize talking about his home or schooling situation before delving into his engineering project. He also balanced his interest in computing and gaming by going to the Community Center computer room, when it was open, and asking Christina to join him so that he could teach her how to the play the different games he cared about. The computer space was particularly important to Christopher in challenging his

bullying experiences in school as it was a safe space for him and other "kids … who wanted to get away from school stuff." The Green Club was hosted in the "all purpose room" and was often competing for space with other programs including afterschool snack. Christopher expressed that he did not always want to work in the Green Club room, but rather wanted to expand his participation in the engineering design process by "having fun all around the club" while designing his app with the community members he worked with. He did this by taking ownership of the space in moving around the Community Center to gather data and perspectives from community members, Kaleel and David throughout the design process and making sure we knew that he owned the app's design process by expanding where engineering could be done.

The sharing of these experiences through the research process helped to promote more humanizing relationships and ultimately dictated the paper format—the foregrounding of Christopher's "pancakes."

## 5 CHRISTOPHER'S STORY

Christopher's case strongly grounds his invention in bullying as a community issue, where he continuously sought out help from STEM experts and community members to inform important—critical steps—that served as parlaying sources of information needed to complete his engineering design. He also expanded the notion of community sustainability by not limiting engineering design to physical design, but rather using experiences to drive technological innovations to solve bullying in his community.

In this section, we present a series of vignettes that describe Christopher's codevelopment of critically engaged engineering in place through his localized counternarratives, as nondominant narratives in the community, which were ultimately expanded to include the expertise of community members and STEM experts, allowing for the successful development of his SUSU smartphone application. We follow these vignettes with a discussion of four key insights. The first two vignettes (On Being Bullied and Community Surveys) set the stage for Christopher's engineering narrative. The remaining vignettes—Pancakes 1–4, are narrated primarily by Christopher. They are titled "pancakes" because, as we (Christopher and Christina) describe later, they are how he began to understand and respond to the different data/place layers of his problem space and sustainable community solution.

### 5.1 On being bullied

For many years, Christopher has been a victim of bullying both in his school and at the Community Center of Great Lakes City. During 5th grade, he experienced a bullying incident that severely affected him. The bullying occurred online, but his bully, who was a classmate in his school, decided to physically attack him outside of his classroom during recess. Christopher, instead of physically reacting to his bully, decided to tell his teacher. He believed this approach would be the safest route. Rather than discretely handling the situation, the teacher publicly discussed the matter with his classmates, naming both Christopher and his perpetrator. This response, while likely well-intentioned by his teacher, created a retaliatory situation where Christopher was subsequently bullied by the same perpetrator at school and then, in what he previously considered his safe afterschool space.

Christopher lamented that by discussing the situation with his teacher, he not only did not solve his problem, but he, in fact, made it worse. He noted that his aggressor was now recognized for being a bully by his teachers and classmates, giving him more power over others, essentially instilling fear in his classmates. Further, since his aggressor knew that he had denounced him, he escalated the bullying toward Christopher, and his peers became more reluctant to stand up for fear of retribution. Because of these experiences, Christopher wished to take "action instead of a reaction" toward bullying. He said that by taking an action, something would be done with and for others. In contrast, he said that taking a reaction would cause the situation to become personal. He felt that these kinds of personal confrontations could fall out one's control creating a larger issue with graver consequences, such as he experienced.

Bullying has been a looming concern for Christopher. He describes how his quiet and removed demeanor, and lack of interest in "current" pop culture, but love for technology provided fodder for classmate ridicule. Christopher viewed the problem of bullying as much larger than himself. In addition to his own experiences and that of his friends, Christopher noted the pervasive fear of bullies among members of his local community. According to Christopher, bullying has even taken the lives of innocent youth. In fact, one of his Community Center peers whom the second author of this paper had taught in Green Club, had recently taken her life due to bullying in her high school. These experiences have taken a toll on Christopher (and his friends and teachers). He hoped his antibully application would allow for a renewed sense of purpose for Great Lakes City by acknowledging that bullying is a problem in his community and that it takes place, while also working together to eradicate it.

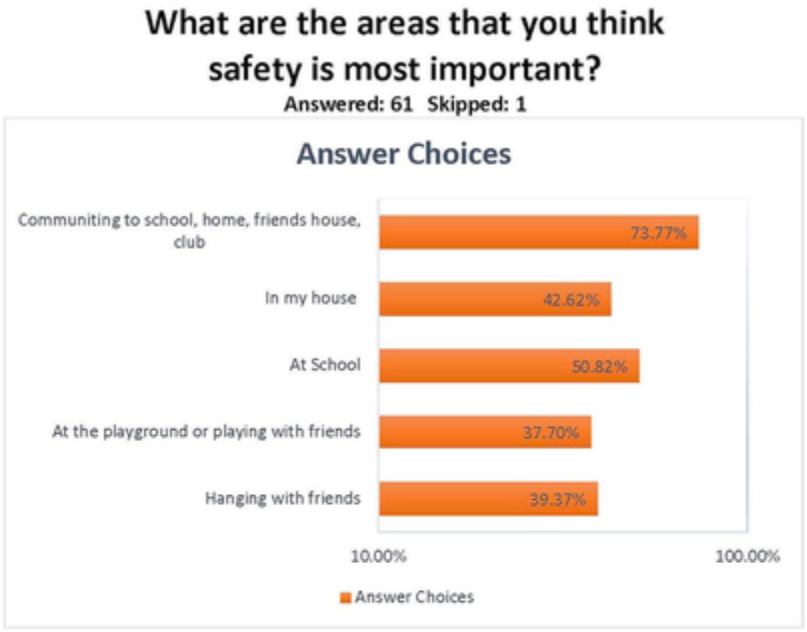
Even though Christopher felt it was hard to change people and how they view others, he believed with his SUSU app, he could stop bullying by preventing the physical "act of bullying." To him, the act of bullying is the "place where bullying happens." He believed that if individuals knew the common geographical locations where bullying occurred in his community, then by advising people not to go to those places, through a crowdsourcing platform constantly updated to include up-to-date bully zones, the act of bullying could slowly and collectively be eradicated. Furthermore, by building the app collectively with community members, the bullies would now need to acknowledge that community members know their place.

As we unpack in his story below, we see the production of SUSU (as a type of crowdsourcing app) as a powerful counternarrative to the narratives which dominate the experiences of young African American boys in urban communities. He not only drew upon his love of technology to solve a problem that was pervasive in his community, but also leveraged upon the community wisdom (through crowdsourcing through gathering data via community ethnography) to do so, especially when those in authority had not. Further, his response was deeply intellectual, indeed brilliant, and profoundly nonviolent, pushing back against the narratives which shaped how outside others stereotyped his lived experiences.

5.2 Community surveys as a way to identify problems of bullying in community

In preparation for the Green Club design year, as program facilitators, we prompted youth to engage in the engineering practice of identifying problems in their communities around safe

commutes (hereinafter referred to as safe commutes community survey), and how designing solutions for these safe commutes supported communities to become more sustainable. To begin their work in the Green Club study, Christopher and his peers created a survey for community members of the afterschool club and in the Great Lakes City area. Figure 1 shows important safety concerns community members ($n = 61$) identified. As a group, the youth analyzed the survey results by identifying important problems and perspectives around safe commutes, such as what problems were most prevalent in safe (or unsafe) commutes and perspectives community members believed negatively impacted commuting. Those surveyed were also prompted to discuss solutions/inventions they thought would help to solve these local problems.




| Answer Choices | Responses | Respondents N=61 |
|---|---|---|
| Commuting to school, home, friend's house, club | 73.77% | 45 |
| In my house | 42.62% | 26 |
| At school | 50.82% | 31 |
| At the playground or playing with friends | 37.70% | 23 |
| Hanging with Friends | 39.34% | 24 |

**Figure 1.** Safe commutes community survey.

Christopher and his friends identified "commuting safely to school or home" as the most salient community concern among respondents. In breaking down this main concern, he noted that respondents offered suggestions for inventions such as the following: "GPS navigation smartphones with internet service," "neighborhood/community alerts to suspicious people in the area," "something through a phone that signals when there's an emergency," and "a person who can transport kids home safely." It was clear that community members in Great Lakes City were concerned with alerting people of suspicious activities in their neighborhood and community.

Christopher personally knew many of the community members who took the survey and considered how many of the responses gathered were associated with experience around bullying—even though the survey did not ask questions around bullying as a problem with safe commutes.

As we (the facilitators and all the youth in the Green Club) began to identify problems as a group, and individual students (or student groups such as those that include Christopher, Kaleel, and David) began thinking about engineering designs to address these problems, Christopher detailed safety concerns related to bullying when walking home from school or going on the bus from his school to the afterschool club. He began tying these personal experiences to the problems associated with the safe commutes survey, and wanted to find an important solution to this ongoing problem but finding an engineer-able solution that was doable and impactful became an issue.

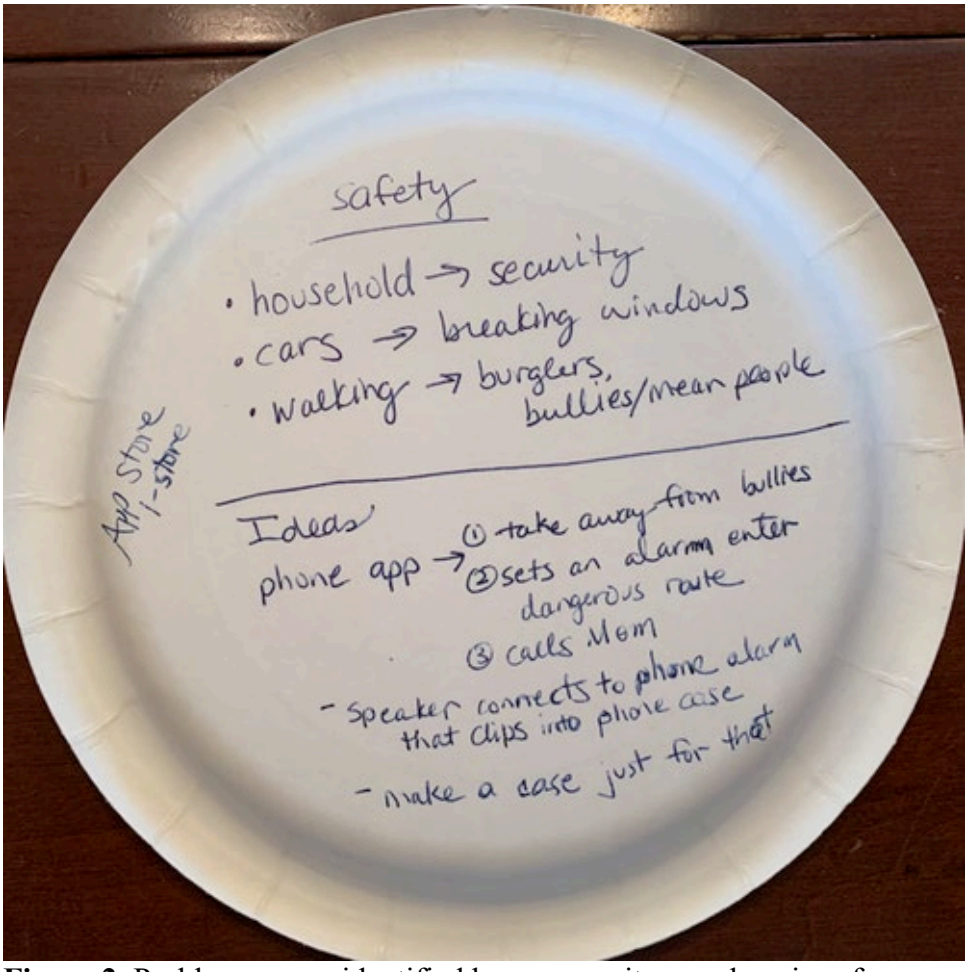


**Figure 2.** Problem spaces identified by community members in safe commutes survey.

At the Green Club meeting following the group analysis of the safe commutes community survey, Christopher raised problems and solutions related to safety. They were often complex, and multilayered and very emotional to him because he wanted to find an immediate, time-sensitive solution to the problem of bullying. He had seen many of his friends discussing

episodes of bullying, some even considered that the best solution to stop the terrorizing effects of bullying was to harm themselves. To write down this important information that began to surface during snack time, and to keep it in his design notebook, Angie (second author) helped him brainstorm his ideas on the paper plate (as it was the only item around on which to write) seen in Figures 2 and 3.

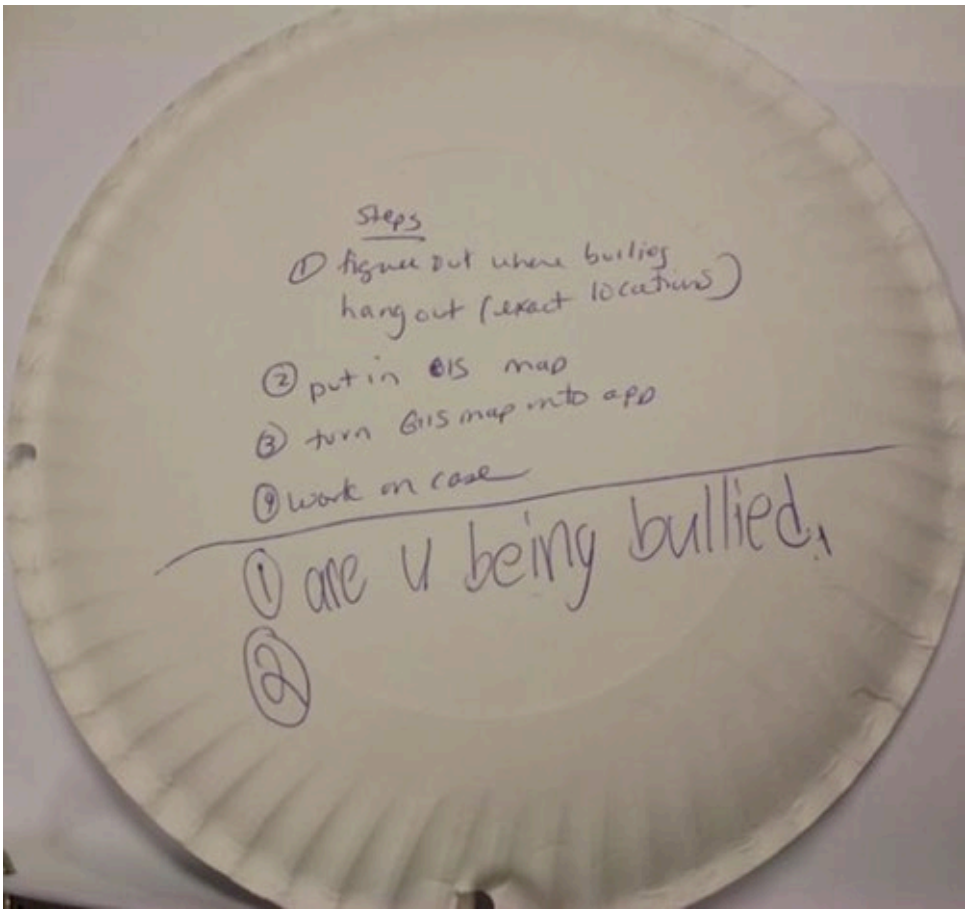



**Figure 3.** Christopher's steps to begin community bully survey.

Christopher identified household problems related to security, car problems related to breaking and entering (e.g., breaking windows to steal cars), and problems with walking where he stated "burglaries, bullies and mean people." His original engineering idea and solution was to create a "helicopter with a camera attached to it," such as a modern-day drone. His helicopter was going to monitor the community and alert the police of burglaries or bullies that were terrorizing walking/commuting areas.

At the same time, Christopher began to discuss his interest in emerging technologies such as creating smartphone applications ("apps"). He noticed that in the safe commutes community survey several respondents suggested that smartphone applications could be used as an invention to support safety in commutes (e.g., "an app that would work with existing fitness technology to notify someone if my blood pressure drops suddenly"—to address health-related safe commutes).

As Christopher's narratives about when, where, and how safety mattered in his everyday life began to surface, we began brainstorming with him how his concerns could be taken up with an engineering lens. Unlike many of the other youth in the program who were working on engineering designs, such as light-up jackets or solar-paneled hats (Nazar, Calabrese Barton & Rollins, 2017) Christopher was intent on working on a digital design as a solution. Eventually, he was set on an app that would gather information and share local information on bullying with others, and connect users to important people, like their parents or the police.

After discussing specific characteristics meant to be addressed with the app, Christopher began to think about the steps (see Figure 3) he needed to take to create the antibully application. He first needed to figure out where bullies "hanged out and their exact locations." He later dubbed these locations "bully zones." He then figured that he needed to put those locations on a GIS map, which he could then turn into an app that could be used by his community. He discusses: "

> I will show you why we needed to add "pancakes" to the way I gathered data for my app. I call them pancakes because pancakes can have layers and layers of "stuff," such as intersections where people get bullied, or the age and smartphone type they use. There are four layers of pancakes. The first layer is questioned on the online survey monkey that we gave to people in the Community Center so that they can tell us information about themselves and where they are most commonly bullied. The second layer of pancakes was the GIS map on Google Maps that helped us pinpoint locations, the third layer of data was using on-line crime websites like crimemapping.com and the fourth layer of pancakes is the real-time data of people experiencing bullying right here, right now.—Christopher discussing his "Layers of Pancakes" during his data collection.

To begin his data collection, Christopher needed to create a survey to understand community members' perspectives on bullying and what they believed were local intersections (or exact locations as described in Figure 3) where bullying happens/where they have been or seen people be victimized. He calls this survey "Pancake #1—Are you being bullied?"

5.3 "Pancake #1—Are you being bullied?"

Christopher's survey "are you being bullied?" focused on the importance of community wisdom as powerful knowledge toward preventing bullying. His questions center on the experiences of community members being bullied in place. However, in reviewing his survey with his mentors he noted that the data would be incomplete without also generating new information about: Demographic and age-specific details, if the community members saw or witnessed other people being bullied and where, and what type of smartphones community members used so that the application met the varying needs of smartphone users. This allowed him to think more broadly about who would benefit from the smartphone application, and if he needed to create separate phone applications for each type of smartphone operating system (e.g., iPhone, Android, and Windows)—which he did not think about before.

His goal with the survey was to outline the "bully zones" in survey format, transfer them into a GIS map and then to upload that map into SUSU. However, in answering the survey question, "where bullies hang out," Christopher was presented with a critical problem.

When community members ($n = 15$) were asked what "intersections" or exact locations where they have been bullied, the survey participants according to Christopher *did not answer the question with accuracy*. For Christopher, this was an important finding because he assumed that his community knew locations within the city, specifically the intersections they crossed when going from home to school or afterschool—even those near their homes. In his survey, many community members referred to specific places based on their proximity to commercial or developed areas in the locality. These included proximity to small businesses (e.g., local fish fry), or near large corporate stores (e.g., large megastores), schools, or places of worship. This meant they had limited geographical knowledge of the names given to streets in their community, but, in counternarrative fashion, had specialized place-based knowledge of intersections based on proximity to home/school/business locations. This insight became a looming concern for Christopher.

Another issue Christopher encountered during his data collection was that members began to discuss narratives of violence, racial segregation, and oppression near their homes/businesses in their community. Great Lakes City is informally divided into four areas based on geography, socioeconomics, and race: north, south, west and east sides. There are no official governmental demarcations of these quadrants, nor are they equally geographically defined. These quadrants are divided by traditional structures, such as a large highway, railroad tracks, a river, and socioeconomic and racialized patterns. Narratives of these quadrants tie to discussions of opportunities for work or higher education, crime and imposition of how/which types of benefits or services to which these members had access based upon where they lived and how easy it was to access these resources. Christopher observed that community members connected broader discussions of crime to issues of bullying. For example, one young community member described that near her home in the "south side" crime was "normal," and "bullying would not be a surprise in that area." So, for that community member, and as Christopher later discussed during our member checking, "if there was crime, then there had to be bullying there too."

After noticing trends in the community survey data about the location of crime and bullying, either by knowing or identifying specific geographic areas (Figure 4) in lieu of community intersections, it became imperative for Christopher to find a way to connect this knowledge to his problem space of bullying in designing his app. The frequency and location of bullying in violent or crime-prone areas became a new central concern for him. For one of his community responses, Christopher approached a community elder known as Granny (as she was affectionately called by everyone, we included) to complete his survey. Granny did not know the intersections where the bullying she witnessed occurred. Because she had a difficult time remembering, Granny asked Christopher to show her a map "like those you see on the GPS." Christopher opened a Google Map page for Granny to tell him where she saw the bullying happening. He noted that on the Google Map, it was easy to "click" and "drop a pin" the location on the map, allowing one to save the name and description of that location. Christopher and Christina later debriefed and noticed that Google Maps can be used to gather community ethnographic data with names and descriptions as an effective way to "see bullying" on the community map. While analyzing the first pancake he found: "Most people 11–15, my age, are being bullied. This is important because we need to solve bullying that happens in school. Place

is important because we need to know where to map places on the app. [The app] tells us which places are dangerous and to know where people are being bullied."

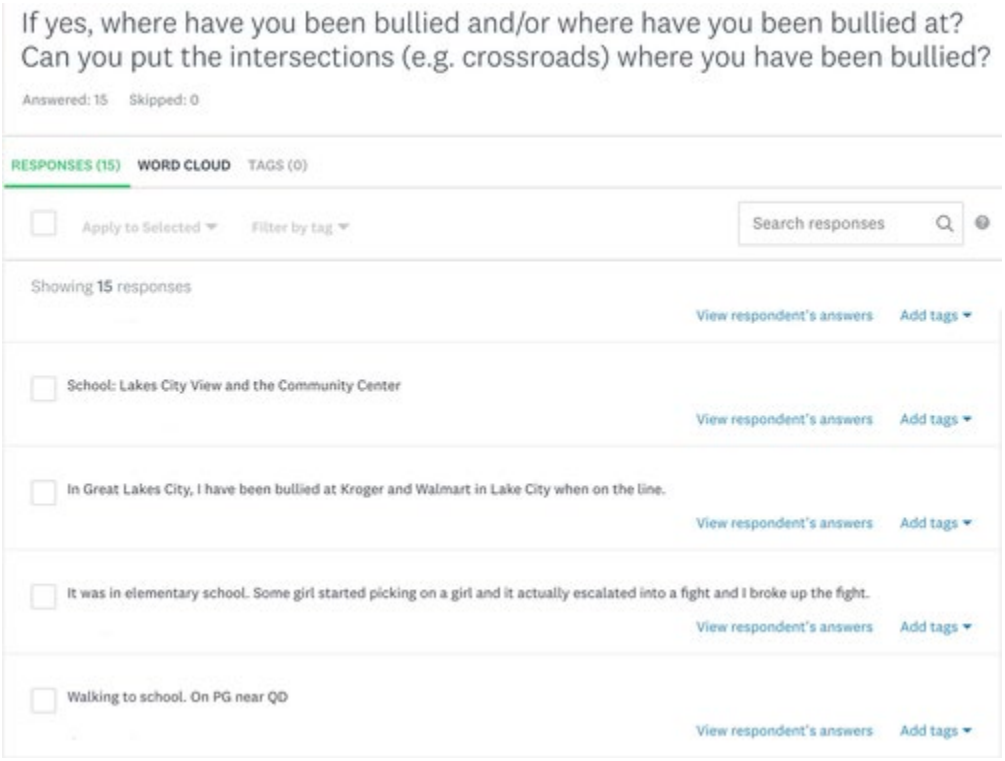



**Figure 4.** Are you being bullied? Survey responses.

Christopher did not know the extent to which (a) bullying was a problem in his community and (b) his community had limited knowledge of names of geographical intersections, but knew locations, based on how they saw them on the map. Furthermore, he did not realize how localized bullying was until he saw the extent to which on the Google Map survey community members pinpointed bullying locations, and the ensuing conversations of fear faced while he gathered his map community ethnographic data.

5.4 "Pancake #2"—Google mapping through pins

As we continued to collect data through "pinning" on the Google Map, Christopher noticed we could use this functionality to further collect ethnographic data by using different colors signifying different types of bullying events based on what the community members shared during data collection. Figure 5 shows that when the members dropped the pin, they could then give the location and a description of the bullying event that occurred.

This new data collection method, which centralized community wisdom as a part of engineering design, allowed him to focus on the geographical zones, and on the experiences of those locations. These counternarratives of place-based instantiations of safety provided information about whether multiple people were bullied in the same location, or in multiple locations, and the nature of those experiences, allowing him to make claims on frequency, time, type, and place of bullying.

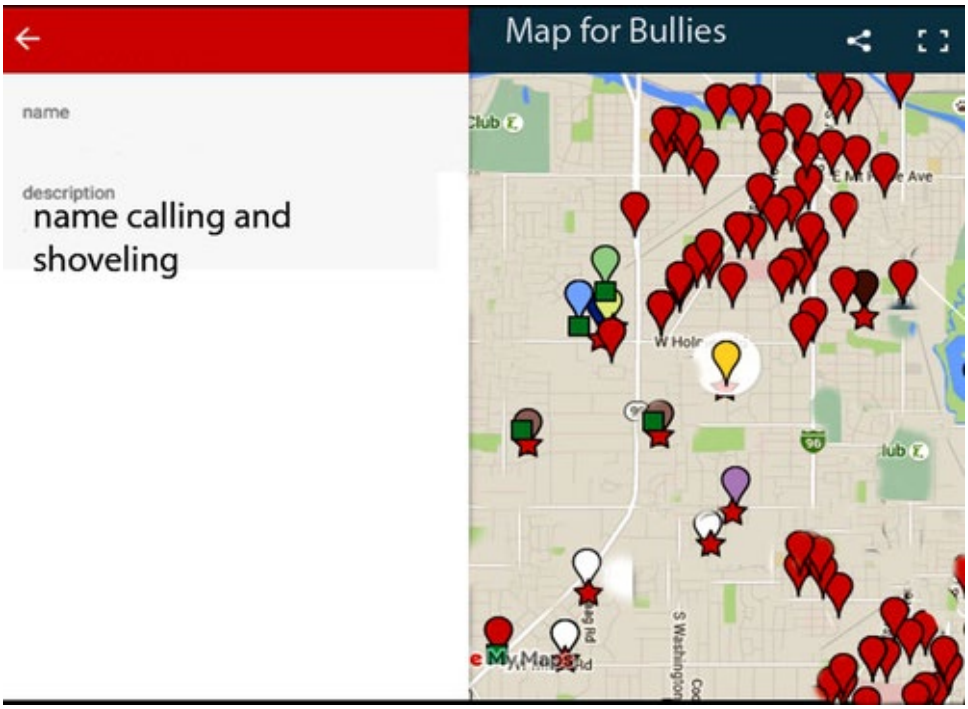



**Figure 5.** Geographic Information System survey data with pins from Google Maps.

The outcome of this process was different than the first survey, where Christopher asked, "are you being bullied?" only allowing for people to enter one bullying instance and its respective location. Furthermore, the pinning allowed for community members to expand their knowledge of bullying to ultimately include crimes that occurred in the city in days prior, based on either word of mouth, or discussions heard from family and other community members. Christopher also noticed that members were describing different types of bullying (e.g., physical and verbal abuse), while others were equating bullying with burglaries and assaults. After gathering the Google Map data from more community members than expected ($n = 30$), who detailed more than one bullying (and local crime) knowledge and experience, Christopher then worked on formulating a color and shape scheme to define the different types of bullying data he was gathering.

To organize this data on the map, Christopher created different pinpoint colors based on types of abuse. Red pins were for "physical abuse" and green were "verbal abuse." By expanding the definition of bullying into these categories, he felt that patterns could help educate community members on abuse/crimes and where these occurred. For example, he stated that instances of physical abuse were often bounded by a certain geographical area in his city. Although we did not challenge the notion that members of the club may live in similar sections of the city, to Christopher this repetitive abuse in these specific locations were not a coincidence. In making sense of this information, we prompted Christopher to look at online crimemapping sites and police department statistics to see if there was a pattern between what community members entered on the Google Map survey in relation to what people reported to him and what was officially recorded by the city sites.

5.5 “Pancake #3”—Looking at and mapping crimemapping.com

After collecting the ethnographic data, Christopher sought to figure out the counternarratives community members had about the crime areas connected to bullying in his data. These word-of-mouth discussions prompted him to do online research on assaults, robberies, and batteries that the members were stating in their pins. Through his research, Christopher found a website, http://www.crimemapping.com, that had layered information of crimes in Great Lake City by crime type and dates. These data, reported by local law enforcement, would provide a different perspective on what the community members provided in the surveys. The different crimes included, but were not limited to: arson, assault, burglary, fraud, homicide, and weapons.

Christopher believed this approach would allow him to find potential connections between the survey results his community provided about bully zones and places where recent crimes were taking place. As part of his research, he redefined the social and technological dimensions around criteria and constraints of his engineering design. He now layered this new data from the website onto his Google Map. He believed that these data added depth to his previous “layers of pancakes.” When doing so, Christopher discovered that the website provided an overabundance of data, and so he decided to limit the crimemapping statistics to dates between October and November 2014 and focused his analysis only on weapons and battery related crimes because he believed they were more closely aligned to his community's conceptualization of “bully zones.”

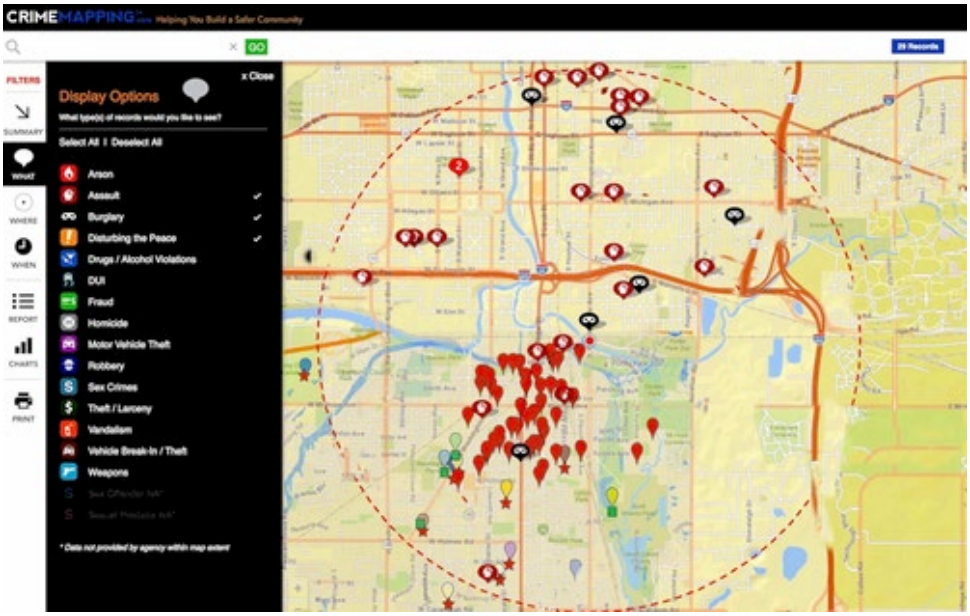



**Figure 6.** Geographic Information System pins combined with research from crimemapping.com.

Christopher discovered that most crimes involving burglaries and assaults were localized to specific locations in Great Lakes City. He pushed back against the dominant narrative that crime is pervasive in his neighborhood. Rather he identified, with the help and wisdom of community members, the places where the crime happened. Furthermore, he found that the greatest number of assaults, weapons, and batteries (red balloon pins in Figure 6) were near places inhabited by his surveyed community member participants. He concluded that community members’

knowledge of crimes could be a source of knowledge in support of bullying and crime prevention in his community. He believed this was especially true if those crimes were committed by the same perpetrator or connected to specific places and people.

These issues resonated with Christopher because they were connected to his experiences being bullied. Christopher noted (in ways that reflect patterns documented in the literature) that those in power did not actively take up actions to stop bullies and their attacks. He also noticed that youth who were bullied, like himself, could describe in detail the perpetrators and their locations. Similarly, he believed his data showed the same patterns for some of the local crimes.

It was Christopher's conjecture that a powerful solution to bullying and crime would be to arm community members with detailed information on the locations (dates and times) and the nature of the crimes and bullying. If those who make decisions for them (e.g., government officials and police) were not taking adequate action to reduce dangerous behavior, then community members, through their experiences, crowd sourced through his app, could have the collective information they need to take action. According to Christopher those actions could involve simply avoiding the specific location or person or having greater information to bring to others to demand action.

Ultimately, the inclusion of this data on the app itself was a counternarrative, meant to be educational for his community, grounded in place, and a community-empowered approach toward community safety. By using the application, in addition to discussing issues of bullying, community members could collectively support the eradication of crimes, which became a new focus of concern for Christopher as he entered this phase of analysis of community ethnography.

In his work, Christopher also concluded that the crime data website was not available to all community members (e.g., access to internet and knowledge of how to search for dates/keywords), and that structures of power were put in place that limited members from accessing knowledge related to areas of high crime. He noticed that these same places were often places that were “left out and not cared for” or marginalized and not frequented by police and other authorities (as his members discussed during the data collection phase). Many times, Christopher discussed the difficulty in entering dates and locations on the crimemapping website to get an output on crimes that recently occurred. They were often limited to small descriptions or unclear information. By using layered GIS mapping data on his app with the crimemapping.com website, Christopher believed that crime data would become more accessible to his community—making it into a sustainable design.

### 5.6 “Pancake #4”—Codeveloping knowledge of place(lessness) through the app

Throughout the engineering design process, Christopher names two powerful insights grounded in his counternarratives of place, bullying, and STEM. First, Christopher believed that there was collective wisdom and power in layering his community's “experiences and voices” about bully zone and crime locations in his app and that he needed to ensure that this process continued. Second, he realized he needed to devise a way to communicate the app's insights to municipal officials, including police, health departments, and others, in case someone needed to find help or shelter when using his app.

Christopher's final iteration of the app included features which reflected the above key insights. The final GIS map included pinpoints of locations he gathered through his second and third pancake layers (called BullyNET). He integrated a Bully Survey where users could crowdsource places where people have been bullied, similar to his first "are you being bullied survey." He included app features that would allow for community members to codevelop solutions with Christopher. For example, the Bully Wall (Figure 7), created by his peers, is a safe virtual space that has up-to-date bullying occurrences with descriptions of the events.

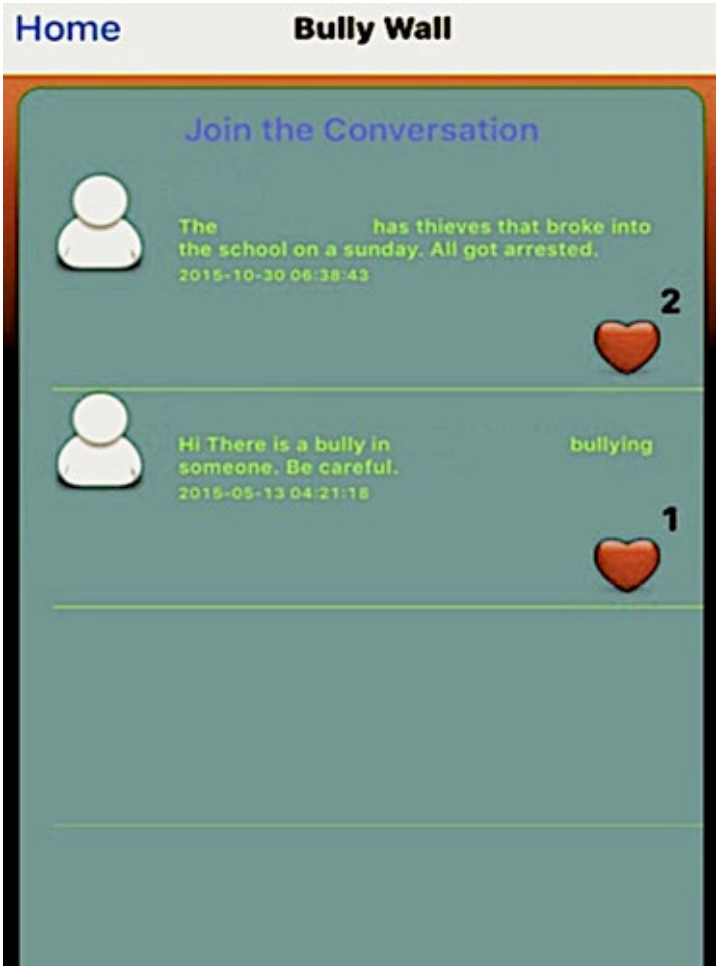



**Figure 7.** Bully Wall in the Speak Up Step Up (SUSU) app.

However, one also has the option of stating their name in case you want to "be rescued at the place" as Christopher discussed. Lastly, Christopher added two other features: Bully News, an RSS feed from the national StopBullying.gov website (http://www.stopbullying.gov, 2016), and I'm Da Map, which is meant to show your physical location on the GIS map. The layering of community ethnography data and using this to engage the community in preventing and eradicating bullying became a dialogic-educative tool for his community.

## 6 DISCUSSION

Christopher's four pancakes reveal the extent to which engaging engineering through a critical epistemology of place lens involved an iterative and generative process of layering community wisdom and knowledge and the counternarratives which accompany these, onto STEM. In our discussion section, we leverage these insights toward making sense of how this layering process mattered in three important ways: (a) How epistemologies of place—and their layers—challenge dominant narratives; (b) reimagining practices in place; and (c) transforming the dangerous territory of STEM. We discuss each point in greater detail below.

### 6.1 Localizing counternarratives toward democratizing access to engineering design

First, we consider how Christopher, in his development of the SUSU, localized counternarratives of place by tapping into and merging his own STEM knowledge and community expertise and parlaying these new hybrid insights onto future layers of pancakes. Originally, SUSU's goal was to gather and share information about local bully zones with others and to connect users to important people (e.g., family members, close friends, and club members) in ways that would educate and prevent further bullying in his community. By localizing his own counternarratives of being bullied, and then legitimizing his community-enlightened STEM expertise to solve the problem, he was able to democratize his community's participation in the iterative pancake layers of his design.

Christopher brought his counternarratives about bullying into the Green Club and chose to design a solution to prevent bullying. Christopher also invited his community members to be active members in gathering and interpreting the data necessary to create SUSU through the engineering design process. He used his knowledge of app design and coding to create pages in his app that would bring about these solutions. Christopher ultimately transformed these same online tools that mediate and exacerbate bullying (e.g., cyberbullying) into opportunities to stop it by legitimizing his expertise and enter the territory of STEM. Christopher believed that elevating these narratives to a public-plane would empower the bully if the story was the only proof without real, hard evidence. Christopher's design, however, shifted the discourse from specific individuals and/or people to one where the app itself became a space to publicly legitimize counternarratives (as a way to challenge master, and nondominant narratives told about the community and their members) and critically engaging these narratives with the broader Great Lakes City community.

Christopher's design further catalyzed the engineering of an epistemology of place through making sense of the ways “geographic area[s] … has meaning to people” (Taylor, 2017), elevating nondominant narratives of place. He did this in two ways. First, through his pancake iterations, Christopher realized that while community members had limited knowledge of the names of physical spaces in their community, they had intimate knowledge of locations and how they were occupied and used. Second, the codeveloped pancakes supported Christopher and community members to collectively reclaim their understandings of place, by making their narratives public and using those narratives to help transform those places (Relph, 1993). The final SUSU app became a space to share local crime/burglary/assault statistics related to geographical areas in the community in-the-moment and in real-time. Through these uses of the app, Christopher supported greater understanding of the knowledge a person needs to survive

and adapt to this environment and called attention to the multiple discourses needed to respond to bullying in ways that mattered in his community.

Furthermore, the systematic processes toward testing and refining solutions in collaboration with community led to the various components of the app (e.g., BullyNET, Bully Wall, I'm Da Map), taking more thoroughly into account community problems. In so doing, Christopher's app re-envisioned the role community knowledge of place played for social change and used the app's pages (e.g., Bully Wall, I'm da Map, BullyNET) as tools to challenge master, nondominant narratives. He noticed the limited information members had about crime statistics and reporting done by local officials, but also that officials did not consider community members' narratives and experiences in how to solve and prevent crimes. Christopher's engineering design revealed the powerful ways in which the community had deep knowledge related to bullying and crime that otherwise would not have been known (Tuck, 2009). He made significant design iterations to SUSU to legitimize community assets to stop bullying/crimes from happening. With his Bully Wall page, he wanted members to publicly legitimize feelings, experiences, and locations of bullying in a safe, but caring space that could be viewed by all community members. He did this to challenge the broader structures of power. First, how teachers ignored or served as bystanders in the bullying process, but also to challenge local officials' and government officials stereotype of communities based on their minoritized status in low income/high crime-prone areas.

### 6.2 Reimagining engineering practices

The engineering practices of defining design problems and refining solutions involved critical engagement with the technical and social dimensions of design. As Christopher developed the SUSU, he not only needed to consider how and why his community's counternarratives mattered toward articulating an engineering problem worth solving, he also had to find ways to meaningfully bridge these social concerns with technical possibilities for addressing those problems. We view this process as expanding engineering epistemologies, challenging master narratives of what counts as engineering, for whom and why.

We see the engineering practices and the gathering and interpreting of community data being taken up here, as foundational to Christopher's evolving engineering epistemologies centered on the place, and his increased facility when considering strategies for problem solving. Not only did Christopher leverage multiple sources and forms of data to clarify a problem space (e.g., the need to build a smartphone app to prevent bullying), he further sought out and tested the data he interpreted and the ideas that came from his analysis, toward a workable design. This design solution incorporated technical insights (e.g., the layered GIS data) along with "embodied knowledge" that included multifaceted understanding of interactions involved in their everyday cultural, sociohistorical, and sociopolitical evolution of their community. This allowed him to localize his counternarratives and engineer a solution that contributed to sustainable community solution that centered the Great Lakes City's nondominant narratives about bullying and place.

Christopher did not want this reporting to be the story told about a community, but rather created a space to hybridize it with the community's own views of what it meant to be victimized by these crimes. For example, as Christopher listened to community perspectives—through his surveys, conversations and GIS data collection—he included them as legitimate resources on his

app. To Christopher, it was imperative that these stories be heard. He redefined the data collection methods to include a *re-imagining of community assets* in his work. He created a space for public collective idea sharing and change—something that was more expansive and transformative than just a physical connection and epistemology of place—further catalyzing the idea of critically engaging engineering through epistemologies of place (Tuck, 2009).

Christopher saw through his data collection that members were taking up these minoritizing and dominant narratives. What he found was that youth—and adults—were bullied repeatedly. Further, he felt he found evidence that there were direct links between "bully zones," and areas where assaults and robberies most commonly occurred in his neighborhood. These locations were tied to the racial and ethnic segregation in Great Lakes City. However, Christopher through his work was able to obtain first-hand community ethnography data and collectively tell these stories through his app creation, making community members' knowledge and feelings, public and legitimate.

Through the layering of pancakes, Christopher took an ill-structured problem and optimized it given the resources and tools he had available, and sought—in collaboration with his community—to make available. While others (e.g., Cunningham & Kelly, 2017, Dym, Agogino, Eris, Frey, & Leifer, 2005) have indicated that this process is argumentative, as engineers engage in dialogue with each other about the affordances of different designs, Christopher kept in dialog with his community, leveraging upon their wisdom to inform his design decision. We see this as different from engaging with clients in ways that help to better set parameters and constraints (Hynes & Swenson, 2013). He was not simply just getting their feedback for that one instance between the two months he engaged on the project (although this is important). He also invited community members to envision new "pancakes" with him through creating a space on the app to continue co-constructing place together. These parlayed epistemologies were not unidirectional. Christopher considered the app a "dialogic conversation" between sources of information shared by those being bullied and those who could engage with the problem by receiving the information. Rather, this dialogue was fundamental to the production of solutions and the data, tools, and resourcing necessary for such production. Furthermore, the systematic processes toward testing and refining solutions led to the various components of the app (e.g., BullyNET, Bully Wall, I'm da Map) which would consider community problems, as the design was iteratively refined. This point is important for it advances how the field may consider the potential dialogic relationship between the engineer-learner and the social context for which he or she engineers.

### 6.3 Transforming the dangerous territory of STEM

Systemic inequalities (such as discourses and practices that position youth's cultural knowledge and practice as inferior, the lack of clearly defined and accessible pathways into and through STEM, limited access to or systemic delegitimization of strong social networks, resources, and opportunities) have combined with other inequalities to make STEM a dangerous terrain. We see the invocation of an epistemology of place—and the expansive forms of engineering practices it engendered—as helping to transform STEM into a less dangerous place (though perhaps still not fully welcoming).

First, social networks in support of learning and doing engineering can be expanded by involving community members—not just peers and STEM experts—in engineering design. Pattison, Gontan, Ramos-Montañez, and Moreno (2018) in their work on recognizing and positioning the situated identities of youth in engineering design activities state: “Youth, and especially those from traditionally underserved and underresourced communities, often must juggle multiple identities and navigate a variety of social and cultural barriers as they develop their relationships with engineering and STEM” (p. 1001). In Christopher's positionality statement, although he was recognized by his Green Club peers, David and Kaleel and his STEM mentors, he still did not feel that his engineering work was transformative for the people that would be best benefitted by his engineering design. He identified most with the practices of engineering, once the design became transformative for his community.

The process of engaging with the pancake layers promoted dialoguing with and expanding connections to a broader range of others toward breaking down binaries of what knowledge, experiences and voices matter in the engineering design process. Although the story of the creation if the app and how it came about is an important one to tell, we cannot divorce this from how this study brokered Christopher's expertise and legitimized him as a STEM expert. Before this experience, he described his engagement with STEM both in school and out-of-school as “minimal” at best. However, in this space, his STEM technology and app making expertise allowed him to think more critically about how he could combine these different platforms to create an engineering solution important to solve a long-standing community problem.

Second, new opportunities to see oneself in engineering can arise by enacting counternarratives as a part of the design. As stated earlier in this piece, one of the pedagogical goals of the NGSS in relation to engineering design is to provide science experiences to students who have been traditionally marginalized in science classrooms by making science relevant to their lives and futures (Next Generation Science Standards Lead States, 2013, appendix I, p. 2). It is argued that with engineering design, students can engage in a science that is socially relevant and transformative for their lives and futures. Particularly, by offering opportunities for innovation and creativity with engineering in classrooms, students who have not traditionally considered science as a possible career choice may then become interested in science (Next Generation Science Standards Lead States, 2013).

Christopher's case took up defining problems and attending to criteria and constraints of design by taking upon iterative “pancake” layers—as a type of data collection method and analysis—that would be used to improve the technology in the SUSU app. In doing so, he critically engaged engineering in place with his community members and systematically took up community knowledge and practices. Hence, the “pancake” layers and the act of purposefully hybridizing these various community knowledge and practices not only allowed him to connect science and engineering to a meaningful problem in his learning, but it also provided a way to support agency in STEM—which could have been completely absent from his design work if his counternarratives, STEM knowledge/expertise in app making, and community data were not important resources for cultural learning in science (Birmingham et al., 2017).

Most importantly, by using engineering to empower youth to think more expansively to cocreate solutions to problems already plaguing their communities and (re)imagining these solutions

using community assets, Christopher's experiences became a source of change in collective community participation that supported STEM learning. This point builds on, but expands the idea that engineering education ought to move beyond the technocratic to the caring and empathic realms, but also to situate the sociopolitical as the terrain in which engineering practice is reconstructed toward a social good (Gunckel & Tolbert, 2018). One of the greatest accomplishments for Christopher was using technology as a counternarrative to what counts as engineering design and how engineering design may be used in negative ways. Engagement in engineering practices was not only taken up by Christopher toward caring and just ends, but also redefined and made relevant to the local problem space by his community.

Third, critically engineering in place creates opportunities for youth to coopt tools of oppression toward social change. Secules, Gupta, Elby, and Turpen's (2018) piece remind of us the depth of the inequities young people face in engineering, in their account of the challenges they face in constructing what it means to an engineering student, when such constructions are reproduced in the tools, interactional norms and practices of engineering education. In our study, we noted that part of Christopher's dissembling of these barriers was in how he leveraged the tools of both STEM and social interactions, to reconstruct what it means to be an engineer.

Christopher often noted in his conversations and reasons for creating the antibully app, aside from him being interested in app development, is that people use social media and technology platforms as a way to propagate the problem of bullying—which the literature on bullying corroborates. Christopher created an engineering design solution that used technology as a form to counteract the negative use of that same technology (e.g., cyberbullying). For example, Christopher noted that people posted negative comments online on Facebook or in Instagram, and he used those same tools in his app (e.g., Bully Wall) as a way to share important messages of bullying, or creating spaces for positive message sharing on his app.

Christopher's use of technology to design this app has several implications for STEM education along these lines. The first is that youth can engineer a design using technology as a tool to stop the spread of hate and fear in the same ways that people have used technology to do the opposite. It is also a tool for educating community members on bullying and its impacts by educating members on the ways bullying affects people by creating safe spaces to legitimize experiences and fears and including news on the subject. Ultimately, he redefined what it meant to co-design solutions to community problems by expanding the use of engineering in science education. He did this by re-envisioning the use of technology in engineering, brokering himself into engineering using this knowledge, and legitimizing his expertise through hybridizing these layers of data with his community.

## 7 CONCLUSION

Christopher's story raises important implications for both the STEM education debt and the dangerous territory of bullying, and its impact on the education of our youth. We need to support youth who, like Christopher, want to legitimize their experiences and expertise in STEM in ways that take up not only their individual concerns, but that also support and position their community's sociocultural, sociopolitical, and sociohistorical underpinnings as legitimate resources for STEM learning. Christopher's engineering work highlights how *place matters in*

*engineering and the role of communities in contributing to engineering design, but also expanding what counts as engineering and participation in STEM.*

We must make greater strides to address the STEM education debt in our work as science and engineering educators. Using Christopher's case as a learning opportunity, teachers and educators can more broadly and more deeply consider what it means to redefine STEM engagement, and how we can authentically build on youths' identities, cultural knowledge, and practices in their learning.

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