Journal of Pre-College Engineering Education Research (J-PEER)

Volume 11 | Issue 1 Article 6

2021

The Ingenuity of Everyday Practice: A Framework for Justice-Centered Identity Work in Engineering in the Middle Grades

Angela M. Calabrese Barton
University of Michigan, angiecb@umich.edu

Kathleen Schenkel
San Diego State University, kschenkel@sdsu.edu

Edna Tan
University of North Carolina at Greensboro, e_tan@uncg.edu

Recommended Citation

Calabrese Barton, A. M., Schenkel, K., & Tan, E. (2021). The Ingenuity of Everyday Practice: A Framework for Justice-Centered Identity Work in Engineering in the Middle Grades. *Journal of Pre-College Engineering Education Research (J-PEER), 11*(1), Article 6.
https://doi.org/10.7771/2157-9288.1278

The Ingenuity of Everyday Practice: A Framework for Justice-Centered Identity Work in Engineering in the Middle Grades

Abstract

Inequities in opportunities to learn and become in engineering, especially for minoritized youth, are enduring and systemic. How students experience engineering education, through curriculum, pedagogy, and teacher/student interactions, all shape opportunities for identity development. In this paper we draw upon cultural studies and critical ethnography to explore how and why students engage in engineering for sustainable communities and its relationship to their identity work. We ground our work in a justice-centered asset-based stance that centers how people's lived lives and community wisdom yield powerful forms of cultural knowledge/practice relevant to learning and engaging in science, technology, engineering, and mathematics. We seek to accentuate students' ingenuity to leverage their assets for social change making; that is, in transformative and future-oriented ways. We view youths' everyday ingenuity as powerful assets for learning and participating in authentic engineering design for sustainable communities. Findings suggest that engineering for sustainable communities created opportunities for productive identity work because it created space for youth to authentically engage in engineering design in ways that allowed them to care about each other, their classroom and community, and to use both their everyday ingenuity and technical expertise to make a difference. We also suggest that students' identity work took shape through the emergence of new local contentious practices of engineering for sustainable communities that both amplified youths' ingenuity and challenged particular local, historical/sociocultural norms of engineering and schooling. These contentious local practices related to disrupting the authority to name what counts as engineering problems worth solving and disrupting narratives around what it means to persist through iterations in design. We suggest that an engineering for sustainable communities approach supports the production of local and productive contentious practice because it centers community co-ownership in the design, and supports students in leveraging their everyday ingenuity as critical knowhow in engineering design.

Keywords

identity, middle grades, justice, equity, ingenuity, engineering for sustainable communities

Document Type

Special Issue: Asset-Based Pre-College Engineering Education to Promote Equity

Available online at http://docs.lib.purdue.edu/jpeer

Journal of Pre-College Engineering Education Research 11:1 (2021) 89–112

The Ingenuity of Everyday Practice: A Framework for Justice-Centered Identity Work in Engineering in the Middle Grades

Angela M. Calabrese Barton[1], Kathleen Schenkel[2], and Edna Tan[3]

[1]*University of Michigan*
[2]*San Diego State University*
[3]*University of North Carolina at Greensboro*

Abstract

Inequities in opportunities to learn and become in engineering, especially for minoritized youth, are enduring and systemic. How students experience engineering education, through curriculum, pedagogy, and teacher/student interactions, all shape opportunities for identity development. In this paper we draw upon cultural studies and critical ethnography to explore how and why students engage in engineering for sustainable communities and its relationship to their identity work. We ground our work in a justice-centered asset-based stance that centers how people's lived lives and community wisdom yield powerful forms of cultural knowledge/practice relevant to learning and engaging in science, technology, engineering, and mathematics. We seek to accentuate students' ingenuity to leverage their assets for social change making; that is, in transformative and future-oriented ways. We view youths' everyday ingenuity as powerful assets for learning and participating in authentic engineering design for sustainable communities. Findings suggest that engineering for sustainable communities created opportunities for productive identity work because it created space for youth to authentically engage in engineering design in ways that allowed them to care about each other, their classroom and community, and to use both their everyday ingenuity and technical expertise to make a difference. We also suggest that students' identity work took shape through the emergence of new local contentious practices of engineering for sustainable communities that both amplified youths' ingenuity and challenged particular local, historical/sociocultural norms of engineering and schooling. These contentious local practices related to disrupting the authority to name what counts as engineering problems worth solving and disrupting narratives around what it means to persist through iterations in design. We suggest that an engineering for sustainable communities approach supports the production of local and productive contentious practice because it centers community co-ownership in the design, and supports students in leveraging their everyday ingenuity as critical knowhow in engineering design.

Keywords: identity, middle grades, justice, equity, ingenuity, engineering for sustainable communities

Introduction

Inequities in opportunities to learn and become in engineering, especially for youth from nondominant communities, are enduring and systemic. Recent studies in pK-12 engineering education shed light on how structural and curricular inequalities shape opportunities for learning and becoming (e.g., Blair et al., 2017; Eastman et al., 2019). How students experience engineering, through curriculum, pedagogy, and classroom interactions, all shape opportunities for identity development (Tonso, 2016). For example, Chu and colleagues (2019) found that eighth graders' engineering identities decreased across the school year during an argument-driven engineering curriculum. They posit this was because teachers, short on time, cut out societal connections and opportunities to iterate on design. We are thus concerned with how structural inadequacies perpetuate inequality by limiting opportunities for youth from nondominant communities to engage in identity work as a part of socially meaningful engineering learning.

Fostering engineering identities is central to pre-college engineering equity initiatives. Opportunities to engage in identity work that centers one's lived experiences and hoped-for futures can promote more just opportunities for learning and becoming in engineering. Studies show that identifying with engineering is critical in the pursuit of engineering careers (e.g., Danielak et al., 2014). Whether one sees oneself as capable and welcomed in engineering, and how one is recognized by others for one's engineering expertise impact opportunities to learn (Hughes, 2015). Even when students are academically successful, many still see engineering as disconnected from their lives and pursuits (Tate & Linn, 2005). Identifying with engineering has been shown to be important in engineering aspirations as early as pre-adolescence (Capobianco et al., 2013). This trend continues through high school, college, and into the professions, where women and people of Color remain underrepresented in engineering.

However, few studies examine deeply how these intersectional geometries of power shape opportunities to learn and become in engineering in pk12 settings. Even fewer research studies focus on how the *design* of middle grades' classroom experiences *supports productive identity work* in engineering in connection to enacting social change.

Consider what Louise, a sixth grader, said about her group's efforts to make the Helping Hands Encouragement Board, which hangs in the school's main hallway:

> We want the kindergarteners who walk down our hall to know that we, sixth-graders, care about them… They will see these "helping hands" and know. Their eyes will pop when the hands light-up, and they will know that they can do this kind of STEM work when they are in sixth grade, too.

Louise's comment speaks to how, as students engineered for sustainable communities in their sixth-grade science, technology, engineering, and mathematics (STEM) class, they engaged in identity work as engineers who cared about each other, their classroom, and community, and who used their community and technical expertise to make a difference. It also speaks to the excitement Louise had about the opportunities to engage in authentic design as a part of class.

In this paper we explore the questions: *How does youths' everyday ingenuity act as a powerful asset as they engage in engineering for sustainable communities? In what ways are their identity work and social change efforts impacted as a result?*

Specifically, we conceptualize assets in a future-oriented proleptic way as the ingenuity of youths' activity, made visible through their knowledge and practices brought to engineering for sustainable communities, and as grounded in their lived lives and communities (Anzaldua, 2002). These assets are rich in epistemic potential, specifically with the novel angles with which youth launch and engage in engineering processes. Viewing youths' ingenuities as assets offers a more robust way of seeing youth "innovate and leverage familial and other everyday knowledge to imagine and enact new practices" (Gutiérrez et al., 2017, p. 32) in engineering design in ways that make visible youths' desires for themselves and their communities, in the present and in a hoped-for future. Youths' assets significantly impact not only what they engineer, but also how they do so (Schenkel & Calabrese Barton, 2020). In this way, students' everyday ingenuity becomes critical knowhow in engineering design—in ways that inform both the iterative design process and societal connections (e.g., Chu et al., 2019). This assets-based approach also centers community co-ownership in the design and production of workable engineering design and requires the incorporation of multiple perspectives in problem definition and solution design through the incorporation of both technical and social expertise.

Why a Justice Stance is Needed in K-12 Engineering Education

Pre-college engineering education's focus on equity has centered on addressing the need for broadening participation in engineering among women and people of Color. While the majority of efforts focus on improving pipeline issues, some efforts have looked broadly at how pre-college engineering education can support youth in technological problem solving in their everyday lives (Gunkel & Tolbert, 2018). One important justice-related challenge in designing for engineering learning is the need to account for how engineering problems emerge out of social needs and are resolved through social processes (Tan et al., 2019). Inclusion of authentic social needs and processes asks designers and educators to be mindful of the cultural contexts, assets, and experiences that students bring to engaging engineering design. However, many educators lack the support they need to make sense of—let alone work with students to navigate—a wider range of experiences and ways of knowing that engineering practices entail. Further, questions of whose experiences and ways of knowing matter, and how, in engineering education, while highly contested, are deeply significant in organizing for justice.

One area of work that has advanced the field's understandings of how to support multiple experiences and ways of knowing in classroom-based engineering is the movement to incorporate making in school settings. Many of these studies focus on how and why making, as a practice of design, supports expanded ways of knowing and outcomes in learning design. For example, Sheridan et al. (2014) illustrate how the processes of making value multiple epistemologies which take shape in how students engage in the tools and practices (e.g., sewing, circuitry) of making as well as in the questions asked and artifacts designed and made (e.g., e-textiles). Valuing multiple epistemologies supports more expansive learning outcomes such as new forms of STEM expertise that value "historically feminized" practices, such as crafting, alongside more traditionally "masculinized" practices, such as electronics (Buchholz et al., 2014, p. 283). Such diversity in ways of learning, doing, and becoming potentially opens up making to individuals who have not historically seen themselves as a part of STEM. We see these same ideals echoed in Kafai et al.'s (2014) work, which shows how makerspaces bring together both "hard" and "soft" skills towards challenging what counts as legitimate learning in making. These studies provide useful direction in the kinds of design work students may do in classroom settings that support more expansive learning opportunities.

Studies focused on engineering and everyday life also provide insight into equity-oriented engineering. Within this domain, equity concerns tend to cluster around improving the kinds of opportunities that students have to engage engineering in empowering ways. For example, attention has been paid to how opportunities to engage in engineering spark interest (Ozogul et al., 2017), connect to children's and families' lives (Pattison et al., 2020), and frame engineering as a humanistic endeavor. These studies illustrate how a focus on engineering in and for everyday life can support more expansive learning opportunities.

Lastly, cutting across these areas of work is attention to how engineering is a people-centric discipline. Hynes and Swenson (2013) argue for framing the humanistic side of engineering through a more systematic inclusion of social science and humanities knowledge. The construct—engineering *for* people as one engineers *with* people—calls attention to how engineering education involves developing approaches to understanding the needs of people who will be impacted by design solutions as well as how people work together across different backgrounds, expertise, and stakes in a project. What we find insightful in this scholarship is how it can be applied towards entrenched equity considerations in engineering education and pathways into engineering. Entry points into engineering are not always math and science. Such a construct offers a real and malleable space for designing for broader participation. However, few studies investigate just how the social aspects of engineering by and with people may contribute to student learning and engagement in pre-college engineering.

Despite the advances in developing approaches to pre-college engineering that support more expansive learning, limitations exist. For example, studies of pre-college engineering education have not yet considered how students' learning opportunities are mediated by forms of structural inequalities perpetuated through systemic sexism, racism, and classism (Beddoes & Borrego, 2011). Such structural inequities are experienced daily in local practice, not only through expectations for what valued participation in engineering looks like, but also through a lack of critical attention to how the knowledge and awareness of engineers are *always* socially constructed along diverse social, political, and global lines (Calabrese Barton & Tan, 2019). Indeed, Hira and Hynes (2017) point out these sociopolitical dimensions of engineering that make it imperative for engineers "to realize who they are as people and their motivations" (p. 4). Thus, to advance engineering *for* and *within* pre-college classrooms requires careful attention to the powered dynamics that such socially mediated practices yield.

This is why we suggest that a justice stance must be taken to advance the above-outlined agenda. A justice stance focuses specific attention on the need to re-shift relations of power and position within engineering education and its intersections with historicized injustice. This stance foregrounds attention to making visible and upending injustices located in current practice but grounded in historical, social, and geographic histories.

Conceptual Framework: The Ingenuity of Everyday Practice

We ground our work in a justice-centered, asset-based stance for "proleptic and future-oriented arrangements for learning and the social world that involve more robust ways of seeing individuals, communities, and their practices" (Gutiérrez et al., 2017, p. 30). From this vantage point, people's life experiences and community wisdom yield powerful forms of cultural knowledge and practice relevant to learning and engaging in STEM. However, minoritized students' community wisdom continues to be de-legitimized among the discourses and practices of classroom learning, negatively positioning them in real and symbolic hierarchies. For example, Nasir and Vakil (2017) describe how classroom communities enact racialized and gendered notions of who belongs in STEM. Expectations regarding legitimate engineering knowledge and practice act as non-porous boundaries for acceptable meanings and meaning-making practices, positioning minoritized students as deficient. Teaching practices which center science and engineering as separate from the livelihood of communities delimit

http://dx.doi.org/10.7771/2157-9288.1278

the "agency of ordinary people to wield the power of science (alongside other ways of knowing)" to intervene in concerns they face (Morales-Doyle, 2017, p. 1057).

Our assets-based approach centers youths' strengths in such a way that accentuates the youths' ingenuity to leverage their assets for social change making (e.g., Freire, 1971) in transformative and future-oriented ways. We take a critical and political view of students' everyday ingenuity. We operationalize student ingenuity as (1) including the knowledge and practice of their life experiences and collective community wisdom; (2) the stances and strategies of action they take as they move and re-mix these powerful forms of knowing/being to cross and disrupt borders as they engage in expansive forms of learning; and (3) the production of new knowledge, tools, and resources as students engage in such movement and re-mixing. In privileging students' ingenuity, we call attention to their *already-present* brilliant, rebellious, and agentic acts of everyday practice and its transformative potential, but also to how we, as educators and researchers, perceive the possibilities of students *and* communities.

Youths' ingenuity in engineering design as made visible through technologies of engineering—the tools and materials used along with the artifacts produced—needs to be understood in terms of how these technologies are taken up through social relations rather than as stand-alone objects, e.g., Feenberg's (1991) critical theory of technology. Technology can only ever be understood in how it is taken up in socially mediated and culturally embedded ways. As Cutrim Schmid (2006) points out, in classroom settings this means that technologies, whether it be tools that teachers use or artifacts students make, can only be understood through the characteristics of the technology itself and classroom practices in relation to that technology. Such a stance calls attention to how interactions through technologies take place in power-mediated ways, and the roles that technologies play in both maintaining and disrupting powered relations.

The limited research studying youths' everyday ingenuity in engineering education has taken place primarily in out-of-school contexts. In out-of-school settings, we have witnessed the power of youths' ingenuity in how they have co-opted the tools of science and engineering to make visible their past and present lives, and their hoped-for futures, in how they seek to become as engineers (Calabrese Barton & Tan, 2018). Youth brilliantly re-mix the resources and tools of science and engineering with powerful community wisdom reflecting their agency to present their "authentic, often liminal, selves" (Gutiérrez et al., 2019, p. 51). In this study, we bring this lens to engineering education in middle grades classrooms.

Ingenuity and Identity Work

To see how students become involved in engineering education in classroom settings through their ingenuity and how this may be better supported in school-based engineering education, we use social practice theory. Social practice theory frames becoming through one's ongoing social existence in the world. As people move through time and space they are exposed to, positioned by, and react to a range of people, institutional and cultural structures, and forces (Holland & Lave, 2009). Social practice theory frames becoming through how people come to be in social context (rather than an internal attribute), where people figure themselves and are figured by others as they "adapt to author themselves in the moment" (Holland & Lave, 2009, p. 4).

Processes of becoming—because they take place in local practice and context—happen within and against local norms and expectations. However, they also take place with and against longer standing sociocultural and historical narratives. A person's becoming, made visible through interactions and taking up new practices, is not separate from their personal histories or broader sociohistorical narratives. How youth are positioned by others in classrooms shapes their opportunities to learn and become (Allen & Eisenhart, 2017). This includes the opportunities one has to engage in valued activity; to draw upon their wisdom, knowledge, and practices of their lived lives in ways as they do so and to have that welcomed by others; and to be recognized for their contributions. Processes of becoming are always about power because they are about who is regarded as someone who belongs (Urrieta & Noblit, 2018).

In our view, powerful identity work happens when such normative practices are *disrupted*, allowing for youth to engage in becoming in ways that open up possibilities for re-creating what it means to be an engineering expert, in our case, in a middle school STEM class. These possibilities center and amplify the cultural repertoires of practices—in other words, the ingenuity—that students bring to learning because of who they are, where and with whom they grew up, and their imaginations for the present and future. This is what is meant by centering students' ingenuity in identity work.

This dialectic of disruption/transformation is central to justice-oriented efforts in opportunities to become. Some engineering identity development studies have framed identity in terms of competence in the discipline and recognition for this competence (e.g., Hazari et al., 2010). As these studies indicate, being recognized as an engineer is related to what one knows, how one uses what one knows, and how that is valued by powerful others in the field. While we agree that an individual's engineering identity is related to normed knowledge and practices, we also think it is problematic to frame an engineering identity in terms of a settled view of the field. Competencies—and their underlying ideologies—need to be contested.

Acts of becoming, especially for youth of Color in engineering, are often tension-filled. When or why one bids for recognition, or how one is recognized by teachers, peers, and others in classroom life is an artifact of the powered relationalities that shape life in those spaces. Social practice theory provides a lens to examine the ongoing struggle between personal and historical narratives influencing participation within science by integrating "the study of persons, local practice and long term historically institutionalized struggles" (Holland & Lave, 2009, p. 1). The struggle between the two forms of history influences individuals' actions in local practices. The institutional and personal narratives experienced or brought into the classroom hold specific meanings for the actors in this space. Thus, the relations between history-in-personal and history-in-institutionalized struggles erupt primarily because local practice(s) comes about in the encounters between "people as they address and respond to each other while enacting cultural activities under conditions of political-economic and cultural-historical conjecture" (p. 3). Local contentious practice can be thought of as the *critical stuff* of becoming.

Examining how local contentious practice takes shape over time and across spaces allows for better understanding of how people negotiate new future-oriented identities in the tense relations between history-in-personal and history-in-institutionalized struggles (Calabrese Barton et al., 2012). This view foregrounds the importance of disrupting historicized narratives in how individuals participate in cultural activity towards new social futures. This space of becoming functions as spaces of refusal, resistance, and radical possibility, as much as it bids for recognition. The question here is what do people want to be recognized for, and how do such acts demand disruption and transformation of schooling and engineering?

Methods

An Engineering for Sustainable Communities Approach

An engineering for sustainable communities (EfSC) approach supports students in engineering for more healthy, happy, and just communities. EfSC explicitly connects students and teachers to communities, whether they be the classroom and school communities or the broader neighborhood and city communities. EfSC addresses problems and design solutions for the real world. Engineering for sustainable communities requires the inclusion of community-based forms of research as part of the design process. It requires engineers to ask, "Who is the project for? Whose knowledge counts? Who takes part in problem definition, data collection, and analysis? Who takes action?" (National Research Council , 2010, p. 8). Ongoing reflection opportunities on interactions among technological and social dimensions deepen understanding of the design process and on what it means to be an engineer (Tan et al., 2019).

An EfSC approach requires teachers and students to consider both the technical challenges of design as well as how problems and solutions are socially defined, adapted, and optimized in response to community needs and concerns (Chen et al., 2020). By integrating technical and social dimensions of problems and their solutions to the process of localizing engineering design, teachers can support students in seeing themselves as welcome and able to use engineering to support their community.

In previous work, we outlined the EfSC approach at the middle school level (Calabrese Barton & Tan, 2019). In this approach, students learn to identify and balance community needs and rights with the technical problem solving of engineering. This approach recognizes the active role that school community members can play in the engineering process. As students engage fully in the engineering design cycle, they are supported in doing so in ways that are meaningful to the discipline as well to their communities.

An EfSC approach supports students in developing their engineering identities by supporting them in having opportunities to leverage their ingenuity, grounded in their life experiences and community wisdom, towards making a difference in their communities and being recognized for it. It potentially challenges and expands what it means to be an engineer by connecting engineering practice to communities. By focusing on the technical and social problem-solving dimensions of engineering, an EfSC approach focuses on the needs and rights of communities. This not only enriches the engineering design process but opens up equitable access to engineering by connecting it to student lives.

Participatory Critical Ethnography

We used participatory critical ethnography methods in Mrs. L's and Mrs. P's sixth-grade classrooms in an urban elementary school. Critical ethnography provides insight into the power dynamics in a given community and supports praxis to address inequitable power distributions. Participatory methodologies were selected because they aim to disrupt power dynamics between researchers and participants. Our teacher and student partners, as noted below, significantly contributed to the design and enactment of our research together. As expert insiders, their insights challenged how we made sense of (in)justice and its enactments in the relationalities of classroom and school life.

School and Class Context

This study occurred with Mrs. P's and Mrs. L's class communities at Liberty School. This school is located in Great Lakes City, is a pre-K-6 school with a focus on global studies and Spanish language immersion. It is one of the most diverse schools in the city, with a student body that is racialized as 47%, Black, 28% White, 18% Latinx, 3% Asian, 3% other, and 1% Native American. The school has strong community support and connections across the cultural and linguistic groups it serves. Parents post about how much they like the teachers and the school on social media. There are many cultural nights and celebrations at the school. Students are constantly encouraged to share their project work with peers, teachers, and family members beyond their own classroom.

Both Mrs. P and Mrs. L have taught for over 20 years in the Liberty School's district. They both identify as mothers and have spent their adulthoods in Great Lakes City. As White women teaching children of Color, they reflect the majority demographic of middle school teachers in the United States. The teachers taught many of their students' siblings, aunts, uncles, and cousins. We would often see former students visiting to say hello, spending the day in the classroom, or helping out with a lesson. Evidence of strong relationships with students was seen in many ways including Mrs. P and her students ongoing jokes together and Mrs. L and her students actively working together to make the school better for the younger students. We have spent time weekly in our partner teachers' classrooms over years to build the kinds of relationships needed to engage justice-oriented work across positionalities and perspectives.

We generated data from 13 of the 14 class projects across the two classrooms (one group elected not to participate). Tables 2 and 3 show student demographics and project work.

Curricular Context

This study occurred during an EfSC unit grounded in the disciplinary core ideas of energy transformations, sources and systems, and sustainability within engineering practices (Table 1). This unit was enacted with support of the school leaders and district and in response to the need to incorporate engineering design into the standard curriculum in the sixth grade. The unit consists of two iterative design cycles: (a) design and iterate on electric art for loved ones and (b) creating sustainable, green-energy-powered engineering design solutions for the classroom. In this latter design challenge (and the focus of this paper), students were given the design challenge bounded with the criterion that they had to innovate something in the classroom in a way that would address a classroom and community sustainability problem. They were required to use a renewable energy source (e.g., solar panels, hand crank generators), 10-mm LED lights, copper tape, and any other materials available in their classroom. We selected these tools because they are affordable and are shown to be an accessible pathway into electronics and design (Buechley, 2006).

Students determined community sustainability concerns and solutions using community ethnography with interviews, observations, and surveys. The students administered surveys and made observations to discover what community issues mattered most in the school community. They analyzed their data and defined a problem they wanted to solve. Then, they designed a green energy solution to those challenges and conducted interviews with multiple community members to optimize their design sketch-ups. Lastly, they prototyped their designs and shared them in a showcase.

Table 1
How can I make my classroom more sustainable? Unit flow

#	Lesson	Key focus	Community ethnography integration
1	Introduction	Big ideas in engineering for sustainable communities Lesson 1: Engineering for sustainable communities introduction	Examining and discussing how youth of their age use community ethnography as a part of engineering design
2, 3	Iterative design cycle 1	Sustainable electric art: Using iterative design cycles to make electric art cards for family/friends, powered with green energy sources Lesson 2: Designing electric art Lesson 3: Sustainable electric art	Generating community narratives
4–9	Iterative design cycle 2	Sustainable classrooms: Defining problems and designing solutions through community ethnography Lesson 4: Engineering design challenge introduction Lesson 5: Defining the problem: using community ethnography to define engineering challenges Lesson 6: Initial design Lesson 7: Optimize design with community feedback Lesson 8: Prototyping Lesson 9: Refining designs through technical tests and community feedback	Using community ethnography as a part of engineering design Surveys and observations of peers and community members Dialogs with community on project ideas/design Observation
10	Community sharing	Lesson 10: Sharing engineering designs with the community	Community narratives

Table 2
Projects in Mrs. P's classroom

Project	Problem definition	Why the project mattered	How it works: technical and social specifications	Student engineers		How students felt about their project
Bully Free Zone  A light-up board that indicated a "bully free zone" in the classroom	The problem we addressed was school needs to be more fun and positive	Our invention solves the problem we identified because this will let students know that someone is there for them	We used a parallel circuit. We used a hand crank to send energy to the LED lights which then makes the lights light up. It helps the community not feel hurt. Two ways we improved our design were: (1) Instead of using a simple circuit we used a parallel circuit. (2) We disconnected the ends of each part of our circuits so it would work properly	Lataya, Black Nora, White Garet, White	Lataya: I like doing science Nora: I love animals Garet: I enjoyed working on the project	Our invention makes us feel: happy and excited
Good job Lobos  Anime drawing with a light-up thumb to encourage the school community, displayed in the hallway	The problem we addressed was people wanted to celebrate more accomplishments	Our invention solves the problem we identified because the students who feel they want to celebrate their accomplishments can use the hand crank and it will light up and look really cool	Our design works by using a hand crank which makes the energy flow through the copper tape. Then it flows through the LED lights and makes them light up. Some students might like the Anime Naruto because he is liked by many people. We think it will make students feel happier about themselves because it is fun to spin the hand crank	Jose, Latino Chad, Asian	Jose: I love to do experiments in science Chad: It was fun working on this project	Our invention makes us feel: proud We learned we can work well together

Table 2
(Continued)

Project	Problem definition	Why the project mattered	How it works: technical and social specifications	Student engineers		How students felt about their project
Positive Vibes Board  A positivity board decorated with hearts and feathers and displayed in the class that students can light up when they want to feel celebrated	The problem we addressed was people wanted to celebrate and there was too much sadness and negativity at school	Our invention solves the problem we identified because some of the people in our class are always sad or mad and never positive, and we want them to enjoy school so we made this board to light up everyone's day	Our design works with a parallel circuit and a hand crank. When you use the hand crank power is sent through the copper tape to the LED lights and they light up. It helps our community by bringing everyone together and making students positive instead of negative	Mario, Latino Rochelle, Black Josie, Black	Mario: I like drawing Rochelle: Fun fact, I like animals Josie: Yes! A fun fact I love to draw humans, and animals	Our invention makes us feel: It makes us feel happy knowing that we made someone's day positive. We learned that if you have a clear light, and a cloudy one, it won't work because one needs more energy than the other one
Smile to Succeed  A light-up smiling face for taking a break from negativity and to celebrate good deeds	The problem we addressed was more opportunities to celebrate accomplishments. We chose to address this problem because students don't get celebrated as much when they do something good	Our invention solves the problem we identified because: The class gets mad and frustrated sometimes and they need to take a break so at people that is why	Two ways we improved our design were we conducted different tests on our invention. We had to change it from a series circuit to a parallel circuit. We changed the name from smile to success to smile to succeed	Jalon, Biracial Tom, White Emmanuel, Black Liana, Black	Jalon: I came up with the idea to use glitter glue. Tom: I came up with the idea to make the name smile to succeed. Emmanuel: I loved working in groups. Liana: Working with people is very hard sometimes	Our invention makes us feel: Proud of what we had accomplished We learned that working in groups was hard, but our end result turned out great

Table 2
(Continued)

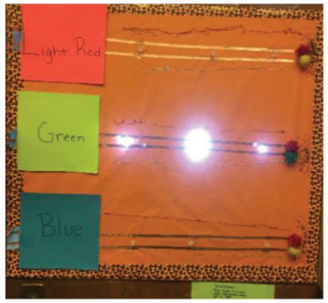
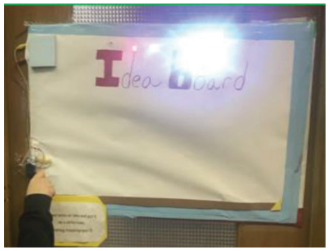
Project	Problem definition	Why the project mattered	How it works: technical and social specifications	Student engineers		How students felt about their project
Champs  Gameboard to support teamwork with weekly prizes	The problem we addressed was people wanted to celebrate success	Our invention solves the problem we identified because we built a fun board involved around giving treats	We used a parallel circuit and a hand crank. You move the hand crank to your groups color and the spin the crank to see your lights. It lightens the mood by giving treats. Maybe earning the treat of hanging out with your friends for a few minutes or getting a treat. It will encourage students to come to school	Kylun, Black Batoul, Arab-American Jayla, Black Damani, Black	Kylun: The project was fun to do Batoul: Learning is fun! Jayla: The things you can do in science are amazing Damani: I learned new things	Our invention makes us feel: Proud and creative. We learned it was fun working with a group
Door Light  A lighting system to quietly, and without disruption, indicate when someone is at the door	The problem we addressed was being more fun	Our invention solves the problem we identified because: It is more fun to crank the door light instead of knocking on the door!	Our design works with a parallel circuit when you crank the hand crank the energy flows through the copper tape and into the lights to make them light up for us to see and let the person in that was cranking the hand crank. Our design will help our class by eliminating distractions. If the class is taking a test and someone is trying to come in instead of knocking and being a distraction to the class they can just crank the hand crank and the teacher will let them in when she sees the lights light up, same if it is too loud in the classroom they can see the light and let the person in!	Kami, Black Alia, Black Alicia, Latina	Kami: The project was fun to do Alia: This project was really fun to make! Alicia: I think this project is going to be helpful	Our invention makes us feel good because instead of knocking on the door you can turn the crank and it will light it up and then we will know when someone is at the door

Table 2
(Continued)

Project	Problem definition	Why the project mattered	How it works: technical and social specifications	Student engineers		How students felt about their project
Idea Board  A board for students to write down their ideas and have them visible for the teacher	The problem we addressed was being more fun	Our invention solves the problem we identified because students can put their ideas down and the teacher will see them	Our design works with a parallel circuit and a hand crank as an energy source, the energy flow comes from the hand crank to the copper that connects to the LED lights. The Idea Board has bright colors so it is easy to spot and you won't have to hold the hand crank, the hand crank is taped onto the board. You can see the instructions easily	Jessica, Latina Malcom, Black Xandra, Black	Jessica: Fun fact about me is I like singing and dancing. Malcom: Fun fact about me is, I am funny. Xandra: Fun fact about me is that I like to draw	Our invention makes us feel: Good about ourselves We learned it is hard to work in groups. We came up with a good project by listening to each other's ideas

Note. The table's contents are all direct written and/or spoken quotes from student engineers.

Table 3
Projects in Mrs. L's classroom

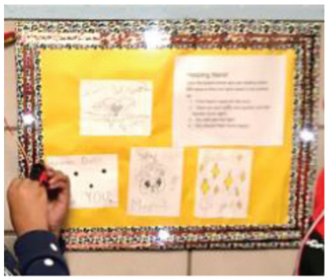
Project	Problem definition	Why the project mattered	How it works: technical and social specifications	Student engineers		How students felt about their project
Helping Hands Encouragement Board  A mood-supporting board with encouraging ideas and lights that hung in the main hallway	The problem we addressed was needed to be more happy and positive	We chose to address this problem because: people come to school sad so we decided to do more happy and positive	We uplift people if they are down. Our design works by a parallel circuit, the energy flows through the copper tape, and the energy source through the hand crank	Monet, Black Candace, Black Michelle, Black Elisha, Black	Monet: "I'm not a quitter when it comes to stuff like this" Candace: "I love animals so to me drawing the animals were fun" Michelle: "At first you're going to think it's easy but it's not" Elisha: "Keep calm and be a engineer"	Our invention makes us feel: Happy and confident that it's gonna make someone feel better when they get their feelings hurt. We learned we are capable of building
Caught Being Good Board  A light-up board on the principal's door to celebrate students' good deeds	The problem we addressed was school needs to be more fun We chose to address this problem because: on the survey 51.47% of kids said it needs to be more fun	Our invention solves the problem we identified because: when kids put their caught being good tickets in they get to light it up	Our design works with a parallel circuit and when you crank the hand crank light up the energy flows through the positive side then negative. Our design cheers everyone up. We made it out of recycled materials so when things broke we could find more. Two ways we improved our design were: testing the lights one by one	James, White Alam, Arab-American Aaron, Latino Cam, Black	James: "Don't get mad so easy if you do you can't win" Alam: "Work hard to succeed" Aaron: "If you always give up you can never achieve your dreams" Cam : Engineering is a great thing kids	Our invention makes us feel like we're winners and we can work together well. We learned we can work together

Table 3
(Continued)

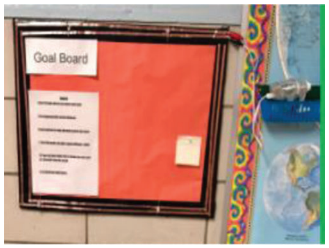
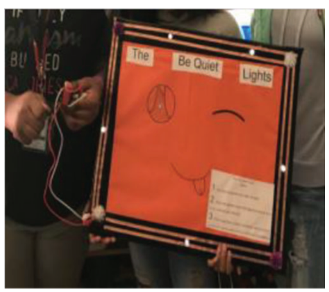
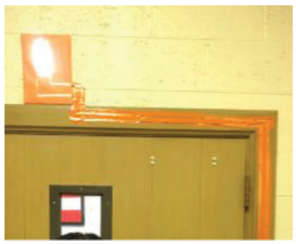
Project	Problem definition	Why the project mattered	How it works: technical and social specifications	Student engineers		How students felt about their project
The Goal Board  A board for students to write their goals and to celebrate progress towards them	The problem of kids not feeling recognized is what we tried to fix and we did it so kids don't feel like they are not recognized for things they accomplish	44% said it would help and they need a chance to celebrate more for what they did	We tested the lights. You crank the hand crank and the light up because the copper tape transfer the electricity Complete their goals	Mike, Black Alex, Latino Jeff, Black	Mike: Stay smooth Alex: Be weird be random be who you are Jeff: Let other people shine	Our invention makes us feel proud and happy. We learned that if we try hard enough we can accomplish a lot about ourselves in engineering
The Be Quiet Light  A board to support kids in being quiet	The problem we addressed was kids being loud and noisy	We chose to address this problem so that the teacher can get a break and be able to teach	Our design works with a parallel circuit & a hand crank with some designs. It helps the teacher get them quiet when she needs their attention	Amaya, Black Kaliah , Black Rosabelle, White	Amaya: Hard work pays off Kaliah: I like to make slime Rosabelle: I'm nice	Our invention makes us feel happy because we learned that you can do anything if you really focus and do all the parts step by step

Table 3
(Continued)

Project	Problem definition	Why the project mattered	How it works: technical and social specifications	Student engineers		How students felt about their project
Mr. B's Doorbell  A lighting system to alert the class when someone is at the door	People banged on Mr. B's door too much	It was annoying Mr. B and whoever was in his room	Our design is a door bell. When you crank the hand crank all that energy goes through the copper tape then to the lights and it light up	Jordan, Black Alayah, Black Melvin, White	Jordan: This was fun, I would do it again Alayah: Designing this was great Melvin: I like how we set this up	Our invention makes us feel good because we helped Mr. B solve his problem. We learned we are good at working together as a team
Recognition Board  A light-up board to celebrate students' presence at school	The problem we addressed was not having enough opportunities to celebrate accomplishments	We chose to address this problem because there's not enough recognition for the people that are here every day	Parallel circuit; the energy flows through the copper tape from the hand crank	Gloria, White Niger, Black Julene, Biracial	Gloria: Be happy when life comes to you Julene: Be here so your class wins attendance and can spin the hand crank Niger: I am nicer than people first think	Our invention makes us feel "PROUD!"

Note. The table's contents are all direct written and/or spoken quotes from student engineers.

Data Generation and Analysis

Data generation Data were generated during the implementation of the engineering unit in two middle school classrooms over the course of about 26 instructional hours during spring 2018. Each session lasted 60–120 minutes.

Field notes Detailed field notes of classroom interactions were kept for each class session, along with video recordings of select lessons and group interactions. Field notes were kept by multiple researchers to allow for many perspectives to inform how we understand the contexts and interactions. Field notes centered on whole group instruction, experiences of small focal groups, and student participants' efforts in the design challenge. We paid attention to patterns in the use (or lack of use) of individual ideas in interactions, ways that students' expertise and participation personas were recognized as contributing to the class community, role distribution, decision making about the social and technical dimensions of the class's efforts, variations in student positioning, resource access, and sources of expertise.

Interviews Mid-unit and end-of-unit "artifact interviews" with all focal groups were conducted. Here, the "artifacts" are engineering designs that youth prototyped, and included their design sketches, actual prototypes, and written reflections about their prototypes. Interviews focused on understanding the artifact, participation and engagement, knowledge, practices, meaning, and value (what this project says about oneself, etc.). We also conducted informal weekly conversations with the teachers to make sense of ongoing questions, concerns, and feel of the enactments, with a formal interview at the end of the enactment.

Video Video recordings were valuable for analysis of the class community's interactions. We video-recorded whole-class instruction with a fixed camera that captured the teacher's interactions with all students. We used GoPro cameras to video-record focal groups during group work.

Student work We collected copies of all student work produced, including activity sheets, sketch-ups, images of projects in various stages of development, and assessments (e.g., "project postcards").

Data analysis Data were analyzed in the grounded theory tradition, using a constant comparative approach (Strauss & Corbin, 1998). First, we engaged in dialogue with each other and with participating teachers to develop an initial working set of insights around student projects and our interpretations of them. Part of this process involved engaging in dialogue around the student projects. Another part of this process involved examining student written descriptions of project work to organize student work into a set of framing categories: problem definition, how the problem mattered, how designs work (technical and social specification), and how students felt about their projects. Participating students co-produced the text of these categories and we opted to leave major insights of these category descriptions in students' words (see Tables 2 and 3). Later, initial coding categories were established through perusing these insights along with our field notes to identify trends observed across students' experiences in this unit and that seemed most salient to their identity work. These categories included: the role of optimizing social and technical dimensions of the engineering designs, using engineering design solutions to support community members, recognition for hybrid expertise and care for the students' communities, and troubleshooting engineering design challenges. Then, the three authors each coded a subset of interviews from Mrs. L's and Mrs. P's students' artifact interviews using first these initial coding categories, and then adapting them, looking for additional categories. We shared codes with each other and reached consensus as we compared, refined, and collapsed codes from across our analysis. Those codes were then used to re-code the interview data as well as the video recordings and field notes.

Findings

Our findings are built around the following two main claims. First, students engaged in identity work as engineers who manifested their care for their community through leveraging hybrid and re-mixed forms of community and expertise to make a difference. Second, as students had opportunities to leverage their everyday ingenuity throughout the engineering design process, they disrupted and transformed the powered relationalities that limited who and what matter in engineering learning/becoming.

To elaborate on each finding, we initially draw upon *four* illustrative in-depth cases of project teams' work in Mrs. P's and Mrs. L's classroom in order to delve, with some depth, into *how* students engaged in engineering *identity work* through their project work and *why* this was important. We highlight how each group engaged in identity work as engineers who manifested their care for their community through leveraging their hybrid and re-mixed community and expertise to make a difference. We also provide a comprehensive table of the 13 group projects (see Tables 2 and 3). We then look across all 13 projects to illustrate how students engaging in this identity work accomplished things teachers and other school officials never imagined, shifting powered relationships that often limited who and what matters in engineering learning/becoming.

We follow these findings with a discussion of how, as students engaged in engineering identity work, the emergence of new local contentious practices of EfSC amplified youths' ingenuity and challenged particular localized historical/ sociocultural norms of engineering and schooling. These practices were contentious because they (a) disrupted who has the authority to define engineering problems worth solving and (b) challenged narratives around what it means to persist through iterations in design.

Identity Work as Engineers Who Care and Make a Difference in Their Community

Across the engineering for sustainable projects, students engaged in engineering identity work as engineers who care for their community by making a difference. Students did so by leveraging hybrid and re-mixed forms of community and STEM expertise both to name concerns that limited their opportunities to learn in happy, healthy, and just ways and to create engineering designs that could disrupt the structural inequities that perpetuated these injustices. Further, as youth described their engineering work, they articulated both clear problem foci and design solutions in ways that merged the technical and the social aspects of engineering design, thereby making visible new forms of engineering knowhow. We highlight this below by describing focal groups' students' identity work as they defined problems, designed solutions, and described their motivations to engineer solutions that made a difference in their community.

Positive Vibes Board: Spreading Love and Positivity

In Mrs. P's classroom, a group of four students engineered the Positive Vibes Board because, as they wrote in their project description, they wanted "to help people to feel happier." Josie, one of the group members, proposed the idea for the Positive Vibes Board design because she wanted to use their engineering design to spread "love" and "positivity," given that she and her friends felt that people in school were always "sad" or "mad." Another one of the student engineers, Rochelle, said that the group wanted to help the "class morale" in a "positive way" because "adults tend to focus on what is going wrong" rather than what was "right." As she further explained, "People are always negative, and they're thinking about things that can go wrong, and stuff like that." Rochelle, likewise, expressed empathy for her peers who felt sad, and how this impacted their opportunities to learn, saying negative feelings impacted how her peers "felt," "treated each other," and their "effort to learn."

The description of their engineering design speaks to how this group of students, all of whom are Black, desired to reorient teachers and others towards more humanizing learning experiences in the classroom. This focus echoes research which illustrates the need to shift teacher–student relationships to disrupt the ways that schooling has served as dehumanizing spaces for youth of Color (Legette et al., 2020). Rochelle, when demonstrating how the Positive Vibes Board works stated that the board "helps with making more and more [people] happier, and not sad. It could even, maybe, give them their own happy thoughts." She also said it would "stop them from being so mean to each other."

The students' ingenuity in introducing a humanizing element to learning was further made visible in how they merged the technical and social dimension of their engineering design.

In describing *how* their engineering design promoted positivity and love, the student engineers wrote that they created a poster with a heart that lights up "by using a hand crank to power a parallel circuit made of four LED lights. When you use the hand crank, power is sent through the copper tape to the LED lights and they light up." The heart was meant to represent their love and their care for each other. The placement of the lights was meant to show, "how pretty things can be in life. It shows you happy things, like with the board, when the light's on" (Rochelle, interview). Groupmate, Josie, who led the decorating, was known by her peers as a creative and talented artist. In fact, Josie often deviated from her own work to move around the room helping many peers with the artistic sides of their projects. She added colorful letters, feathers, and other designs to give the board a "happier" feel. The group used these decorations because they wanted their peers "to enjoy school so we made this board to light up everyone's day."

Idea Board: Helping Students Be Seen

Four students in Mrs. P's classroom engineered the "Idea Board." This board, as the student engineers explained, created a space for "students to put their ideas down and the teacher will see them." This group of students expressed concern that only the "smart" students had their ideas recognized. They wanted to change the classroom dynamic which led many of their peers to not have their ideas recognized, either because the teacher did not ask, or did not know what to ask, or because they might be quiet students. Jessica explained:

http://dx.doi.org/10.7771/2157-9288.1278

> It's an idea board, and they could put ideas on it. If they have an idea, they could use a hand crank or if the teacher chooses an idea, they could do the hand crank, like I've chosen an idea to use for the classroom.

Jessica's comments speak poignantly to the silencing and marginalization that many youth of Color experience in STEM classrooms (Le & Matias, 2019). The Idea Board worked by creating a welcoming space for students to record their ideas, and when they did so, they could use the hand crank to light up the board. This would make their ideas more visible, and as the student engineers noted, lighting the Idea Board itself would introduce "fun" into the classroom. This student-led idea sharing space disrupted the White-dominant norms of what and how ideas are legitimized in STEM class. The student engineers stated that they came up with this engineering solution to address the problem of "school needing to be more fun" and that "students had fun ideas but teachers wouldn't listen."

While making the Idea Board, student engineer, Malcolm, noted that the board was "more than an Idea Board" because it was a place for kids to be recognized and heard. For Malcolm, having one's ideas heard represents the larger issue of being visible in positive ways in school. This disrupted the practice of some students only being noticed for negative reasons. Such ingenuity in framing the problem space of how or what it meant to have a space to share ideas was critical to the board's formation and ultimate use. As one of the student engineers noted,

> the Idea Board has bright colors so it is easy to spot. You won't have to hold the hand crank, the hand crank is taped onto the board. The hand crank is an energy source, the energy flow comes from the hand crank to the copper that connects to the LED lights.

Their teacher, Mrs. P, described how she took down one of her own bulletin boards so that the group had a place for their project:

> I had a whole wall, but then I had to take it down because they wanted that space for their idea board. I was like, "Okay." When they wanted to choose a space, I told them, "Just let me know if I have to move stuff around or whatever." I ended up taking a few things down so they could put their board up.

Mrs. P explained that she found the Idea Board powerful because students would write down ideas she had "no idea" they were thinking. She learned things about her students that she would have "never known." Student engineers, too, were excited that the idea board was used throughout the rest of the school year. Malcolm, one of the student engineers, told us they had "run out of sticky notes" for the board because "so many students put their ideas on the board." He stated several times in excitement, "this actually works" as he referenced how the Idea Board got taken up as part of regular classroom activity. When we asked how that made him feel, he said "powerful" because he had "never done anything like that before," and in particular referencing how he changed how people got noticed in his classroom. The teaching intern in the room made a similar observation, stating, "The Idea Board is being used, actually, and they [the students] were adding stuff and then Mrs. P talks to them about it and stuff like that. That's cool."

The student engineers were proud of their work noting that they "felt good about ourselves." They also centered the value of each other's ideas: "We learned that it is hard to work in groups. We came up with a good project by listening to each other's ideas."

Helping Hands Encouragement Board: 'Picking Up' the Kindergarteners

One group of four students in Mrs. L's classroom engineered the Helping Hands Encouragement Board. They designed this to be a mood-supporting interactive poster. The four students decided to create an encouragement board because they were concerned about bullying in their school, and how this led students to be upset, sad, and depressed. As one team member, Candace, noted, bullying affected the whole school week, "Yeah, 'cause Monday starts out your week, and if you're getting bullied, that's the day that it starts. Then it just can take you throughout the week." Her friend Elisha explained that people get bullied for so many different reasons, including, "their size, their skin color, how they act." Elisha and Candace both reported knowing a student at their school who attempted suicide because of bullying. Both girls also talked about how being bullied made students act out, causing them to get in trouble, even when it "was not their fault." While the girls were realistic in their views and agreed that their poster would not necessarily fully solve the problem, they also felt the Helping Hands Encouragement Board had a chance of helping students feel "safer than before." Elisha's comments are important: Studies reveal that bullying in K-12 schooling is most prevalent at the middle school level, and students from marginalized groups are most at risk, with significant negative physical and mental consequences (Hicks et al., 2018).

The students beautifully decorated the board with a set of "helping hands" reaching out to those who passed by. It had images of happy animals, hearts, and diamonds. The students also included on the brightly written words "Shine Bright," in reference to the R&B hit recorded by Rihanna, "Shine Bright Like a Diamond" (Furler, 2012) because they wanted to remind their peers that each and every one of them was, as Louise noted, "beautiful" and "important." The students engineered the Helping Hands Encouragement Board to light up when the attached hand-crank generator was turned by someone who needed to be picked up. Their instructions read, "Use the board when you are feeling down (have a time out) and want to be picked up." The group of girls also put a pair of eyes on the poster, as Louise explained, "So it'll be like, 'Bullies, I see you.'"

The youth located their engineering design in the sixth-grade hallway—both for both their peers who might be asked to leave the classroom and sit in the hallway as an unsupportive form of discipline, and for the kindergarteners who walk down the hallways on the way to lunch. They were particularly concerned about the kindergarteners who were new to the school. As we shared earlier in the paper, Louise wanted "the kindergarteners who walk down our hall know that we, sixth graders, care about them… They will see these Helping Hands and know."

The group had two goals: To cheer up the kindergarteners, and also signal to them what STEM learning could be about, in sixth grade. The students' ingenuity in engineering the Helping Hands Encouragement Board was intended to shift hallway "time out" into a space of care, support, and encouragement by peers, rather than a punitive space. It was also meant to humanize the experience that kindergarteners had when they passed by the poster daily to get to the lunchroom. The Encouragement Board became a playful place of welcome where kindergarten teachers allowed students to play with the board, shifting what it meant to be a kindergartener walking through the sixth-grade hallway. Rather walking "with a bubble in your mouth" kindergarteners could be playful and giggly.

In describing what this project meant to them, Candace and Elisha stated that the project changed their views of themselves. Both girls emphasized it was important to "stay Black and don't look back" in their engineering work, noting that they could engineer on issues that mattered to them. Elisha explained that by working on this project she had become "more of a builder person now." Louise later explained that because their project was in the hallway, it not only showed their schoolmates that they were engineers, but it showed them "that they could be [engineers] too" when they saw "what they could do when they're in sixth grade too."

Caught Being Good Board: Recognizing More Students

A second group in Mrs. L's classroom designed and built the Caught Being Good Board. The four boys in this group created a light-up system for younger students to use when they were "caught being good." The student engineers wanted to "address this problem because on the survey 51.47% of kids said it needs to be more fun." They were particularly worried about the younger students at their school and wanted to be able to reward them for helping to make their school a better place. They thought that if students who were caught being good would be able to go to the principal's office and light up his door, they would have fun and be recognized for their contributions by more than just their teacher. Furthermore, because the school had a practice of offering raffle tickets to students for being good, they wanted to ensure that all students received positive recognition because not all students who received a raffle ticket for being good would win. They wanted to ensure that "everyone" would be "cheered up." Furthermore, the youth pointed out that many of their peers received attention from teachers and the principal for getting in trouble, but not necessarily for being good, which reflects highly racialized practices regarding school discipline (Walker, 2020).

Their principal, Mr. G, encouraged and welcomed the students to take ownership of the door outside of his office. The group members were recognized for both their care for the younger students and their engineering success by each other, students, and adults. They introduced a new form of recognition and having fun into the school office space.

Their project used "only recycled materials" so that "when things broke we could find more" (James). It contained several LED lights in a parallel circuit and powered by a hand crank. As Cam noted, "Our design works with a parallel circuit, and when you crank the hand crank, it lights up, and the energy flows through the positive side then negative." The importance of this design to the group was seen in how they showed younger students how to use the board, checked on it weekly to ensure it worked, and always told others in the office that they made it. Their goal of supporting the younger students in spreading positivity was met, too. As their teacher, Mrs. L, said, "The Caught Being Good board in Mr. G's office, I thought that was very cool, and bringing the little kids and exposing the littler kids to that, 'cause they get a real kick going down there and cranking the handle."

Ingenuity in Engineering to Disrupt Injustice and Center Care

Across these projects, students took up the challenge of the community-identified need of supporting sustainable classrooms in different ways, such as increasing opportunities to be recognized, humanizing learning and life in schools, and increasing fun and fostering happiness. These ideals disrupted normative practices of schooling in ways that showcased students' care for each other, and their ingenuity to frame engineering problem spaces in ways that mattered to their peers.

Projects built on some practices already in place in their classroom and school community, which the students felt could be adapted towards more just outcomes. For example, the Caught Being Good Board was meant to advance the raffle ticket program at the school in support of students doing good deeds. Not only would more students "get caught being good" but also all students who were caught would be recognized rather than only those who had their raffle tickets selected. However, some projects also challenged schooling practices which limited students' opportunities to learn and become in more humanizing ways. For example, the Encouragement Board challenged what it meant for students to "sit out in the hallway" and or how kindergartners might engage with sixth-grade students. Students' projects reflected the students' desires to transform the classroom and school communities to open up possibilities for empowering learning and becoming, and their efforts to be and become engineers who made a difference in their schools. Lastly, some projects created new practices meant to promote more just experiences, such as the Idea Board creating a new practice that was taken up by the teacher to make visible students' ideas. The Positive Vibes Board created a practice of making visible and fostering discourses of love and positivity.

Everyday Ingenuity Disrupting and Transforming Powered Relationalities of Engineering Identity Work

In this section we report across all 13 project teams to further illustrate how students engaged in engineering identity work through leveraging their everyday ingenuity as critical and legitimate knowhow in engineering design. We also show how these efforts disrupted and transformed power dynamics. These shifted power dynamics that previously reinforced the societal, racialized oppressions that acted to limit who and what matters in engineering learning/becoming. First, we illustrate how students' efforts to center community concerns (which made visible unjust/oppressive experiences in schooling) as legitimate problem spaces for middle school engineering expanded narratives of what it means to be an engineer and how, why, and for whom one engineers. Solving real problems that were rooted in power relationalities within schools gave students a sense of accomplishment. Second, we explain how opportunities to iteratively refine their projects, by bringing in multiple perspectives and forms of expertise increased opportunities for students to feel good, proud, and motivated to persist in their engineering efforts. Lastly, we show how being and becoming engineers who care and make a difference through disrupting and transforming power relationalities shifted the ways students were recognized by themselves and others.

Centering Community Concerns and Expanding Engineering Identities

Students' efforts to make visible and take action upon community concerns that called attention to unjust power dynamics expanded what it meant to be and become an expert engineer. Many students expressed a sense of accomplishment about solving real problems that were manifestations of oppressive power dynamics.

For example, it mattered to the students specifically that they were supported in identifying problems and solutions that addressed injustices they experienced. Collectively the student engineers described their work as important because it helped their peers to feel happier, safer, and welcomed in their schools and classrooms. They were proud of their efforts, especially when teachers took up their projects as a regular part of classroom practice. Students were recognized for their technical expertise of what they knew and could do. At the same time, and more importantly, they were recognized for making projects that changed how they experienced schooling. That is, not only were nontraditional forms of expertise valued in what was upheld by the teacher and students as powerful engineering, but they also stated that their projects "actually worked" (Malcolm, Idea Board) in addressing the problems they named.

If we return to the Helping Hands Encouragement Board, the student creators were concerned with enacting care for their school community, both by creating a space for people who were bullied to feel joy, and to help "pick up" the moods of anyone feeling down. They explicitly drew upon their understandings of how their peers found joy in popular culture and included many references to youth and popular culture. Monet explained that they used "Shine your light, and shine, shine bright like a diamond" because "a lot of people feel like they aren't noticed, so we want them to feel like they are noticed, so shine bright." Furthermore, the drawn diamond represents, "I can do this. I'm gonna ace this."

James, one of the designers of the Caught Being Good Board, stated that the surveys showed that "51 percent of people said it needs to be more fun in school." James and his peers felt that school was "boring" and as a result, many kids got in trouble. He further explains:

> School is boring, and kids wanna have fun so they don't get bored and get in trouble. People started drawin' cuz they're bored. They get a phone call home and stuff like that.

He said that while the Caught Being Good Board was for the whole school, he was particularly concerned with the "kindergarteners and the first graders, to help them to feel happier and help them to keep going."

This engineering work was important because the students felt that the adults in their school had not solved or did not know how to solve the problems they identified. Student engineers felt that their teachers cared about the problems they identified but *did not necessarily know enough* about how to address them. For example, the student creators of the Bully Free Zone believed that school-wide adult-created solutions to bullying inadequately addressed students' experiences of bullying or being bullied. As Jaime noted, it was not that their teacher did not know bullying was happening or that the adults did not take action. Rather, adult-led solutions failed to fully consider how and why kids bullied each other. As they worked on their project, they described stories of bullying and being bullied and why this happened. Lara told a story about how some days she was really "cranky" because "I was tired," and having to "sit right next to other kids all day long" irritated her, causing her to unintentionally lash out at them. In her view, the Bully Free Zone would create a special place in the classroom that would give students a space "to just be themselves." If someone is "having a bad day" they would not "need to sit up all crowded" with other kids. They could have a place to stretch out and "start to feel better." As Jose, one of the student engineers stated, the Bully-Free Zone would "help people not be bullies," and "stop problems before they start." Jose further explained, "I wanna see people be a star…to see the world and school be a better place."

That the youth could engineer in ways that mattered to members of their community—but in ways that were not predicted or designed for by teachers—cut across nearly all project work. Consider what the makers of the "recognition board" had to say about their project, which was a light-up system that sat in the school main foyer and was meant to recognize students for being present at school.

The four youths in this group created a light-up system for students across the school to celebrate when their classmates were present at school. They wrote that they wanted to solve the problem of "not having enough opportunities to celebrate accomplishments." The students worried that "there's not enough recognition for the people that are here every day." The three girls themselves had challenges with consistent school attendance, and worried that the focus on attendance was primarily punitive. As they noted, their projects accomplished something new and different with respect to attendance, explaining, "the lights help the kids celebrate and be happier to be at school." Two of the girls added:

> *Juliana*: Little kids would see it, and see what they could do in this experiment and make 'em excited about it.
> *Jayla*: To be honest, it's a part of my heart here in the school. It's a piece of all our hearts here in the school, recognition of us, not only making it, people who made it happen.

Niger adds to this point when she explained how the recognition board reached their goal of helping children to be happier:

> Because kids [used] it. They're just happy inside that they had someone that actually cares about them. People care about them, but care about their recognition and them being here.

Niger, like her classmates, pointed out the imperative to address students' needs to know that they are seen, valued, and cared for in school. As a sixth grader, she worked hard to help the kindergarten students know that she and others cared about them. Niger drew on her own experiences of feeling sad for not being recognized for the positive things she did. She wanted to shift norms within the school to make all students feel welcomed and loved through her engineering. Cadence, Juliana, Jayla, Niger, and their fellow sixth graders actively shifted relational norms within their schools that often positioned themselves and others as less than welcomed to be who they were in that space.

The youth had novel solutions that teachers did not think of, as they drew upon experiences in their lives. As noted earlier with the Encouragement Board, students described how their engineering design supported them in resisting the oppression they felt in school and in finding solutions to it. They highlighted the ways that socialization within and beyond classrooms perpetuated racism in their school. For example, Candace elaborated that having independence to draw upon her own expertise allowed her group to come up with ideas that were worth solving. She said that she and her team could design their own direction and did not need to follow teacher-directed instruction. She rated herself a "a good solid seven" (out of 7) on her engineering design work for the Encouragement Board, whereas in typical science class she rated herself "more of a five point five." When asked why, she stated that:

> Because the other science, we didn't get to do all the steps. Our teacher had to help us do some steps. We didn't get to be as independent as in [engineering]. In the science we did before, there was some chemicals that I guess we couldn't touch… But in [engineering] you have to figure out what your group wants to do, not what the teacher wants you to do.

Students were proud and felt accomplished for addressing these concerns in ways that were accessible across community members. Across the 13 project teams, students were proud of being able to meet the needs of the people in their community. This included meeting their community's social needs, such as promoting positivity, and meeting the developmental needs of people who may benefit from their projects, such as making projects accessible to "little kids."

As pointed out above by James, being able to meet the needs of younger people in the school was important to the students. Isabella, for example, in describing the recognition board said she was most proud of the fact that they specialized the technical dimensions to meet the needs of the younger students at their school. Specifically, Isabella noted that they set up their parallel circuit with two lights in one direction and two lights in the other direction, so that no matter which way the students cranked the hand crank, they would get some lights to light up:

> [I was most proud] that it works, and it we made it easier because we put lights on backwards and frontwards, so when they switch it, they can do it both ways. The little kids won't be mad if they just did it one way and it didn't work.

In these comments, Isabella is most proud of creating a design that that is easy for "little kids" to use. She used her technical knowledge of electrical flow and energy transformations, along with her knowledge of the needs of younger kids, to ensure that anyone who wanted to use the recognition board could do so with success.

Multiple Design Iterations as Integral to the Identity Work of Engineers Who Make a Difference

As students engineered, they explained that they felt good about themselves for working through challenges, including teamwork and troubleshooting problems. Nearly all of the students in all 13 groups noted that their engineering design work was hard and frustrating, making them angry or upset at times. Most of the time this was due to working through technical challenges, such as figuring out the power requirements of their design, how to build a working circuit and switch, and finding ways to assemble their design with durability. However, all of these students explained feeling happy or accomplished when their project finally worked. This satisfaction was linked to making something authentic that worked, that was useful for others, and *that addressed a community-identified concern*.

Below we provide examples of students from multiple groups who engaged in multiple design iterations as they worked to engineer in ways that made a difference. Niger explained that she was really happy "because it was something I made," and "that it actually worked really good." However, she explains that she was really focused on designing and building the Recognition Board "because you're actually depended on, and you're working with people, so you don't want to let them down. Also, you don't want to let yourself down." She also did not want to put up a project on the hallway wall that did not work because she worried she would let people down who tried to use the project. "I didn't want to put it up and it not work, and then see that other people see that it doesn't always work. It may lower *their* self-esteem."

Jose, like many of the youth, explained that students were able to work through their technical frustrations because students were allowed to walk around and learn from other groups. As he explains, "When we didn't know what to do we had others—we check out—we'd walk around and look see how others would do it. Other people gave us advice of how you should do it." He then shared that he felt "surprised that the whole group could work together." Being supported to learn to work better with his peers beyond his immediate group supported Jose in seeing himself as someone who could engineer to make a difference in his community.

Working through these challenges mattered because students' views of who they could be as engineers shifted. They recognized themselves as collaborators working together to solve problems using varied expertise while dealing with frustration and disagreement. As James and Amit, the makers of Caught Being Good Board stated, "we feel like we're winners and we can work together well" when asked what they learned during engineering work.

Increased Recognition for Engineering to Make a Difference Shifting Relational Norms

Becoming engineers who care and make a difference shifted how students were recognized by themselves and others. Throughout the examples shared, an important part of engaging in engineering involved bringing about change and helping people through applying their technical and social expertise. Through this process, students had more opportunities to be recognized for their expertise and care as engineers.

Many of the youth described sharing projects with family and friends outside of school. For example, Rochelle explained how she told her mom and sisters about the Positive Vibes Board:

> I told them that it was a positivity board. I told them that it was nice to make the whole board light up. Then, I told them that it was electrical, or copper tape… They said that was really cool, and then I was really creative, and smart.

Isabelle, from the Recognition Board group, noted that she told her family about her project: "They said it was cool 'cause they've never really seen it before."

Many youths recognized themselves as engineers for the first time because they built things that mattered. Damani explained, "Before this unit, I didn't know I could make all these things, and build these things, but turns out when I try, I can do engineering. I saw myself actually putting time into it and making *it work*." She contrasted this with other subject areas where she "puts the time in," but does not necessarily "try as hard" as she did on her Champs board (a light-up board that recognizes people for doing nice things for their community). She explained that this project presented her with many challenges, but she stuck with it, stating, "I'm just like, 'Maybe I'll try again' and 'What motivated me to keep trying was I knew that I *had to get this done*.'" When she made her working Champs board, Damani explained it felt good because she made something. She shared, "I feel happy because I was, like, *I'm making something*." The recognition of students' success disrupted norms that positioned students as unwelcomed to make meaningful change through engineering.

Additionally, the recognition of students for their engineering to make a difference resisted assumptions about the sixth graders. Remember how happy Niger was that the kindergarten students would feel more welcomed because of the Recognition Board. In addition to that meaningful outcome, Niger was recognized for her humanity, value, and potential in the school community. She shared:

> My friend said when I first came to the school, I looked mean, but I'm not… I'm a happy person, and I know I'm not that person. I'm not that person at all. It just shows that I care about people and that I'm really not as mean as people think in first impressions. 'Cause I care about them being at school and not at home, getting an education, so they have to learn, have more knowledge on what to do in life, and just maybe that.

Niger was aware that her peers and teachers sometimes thought of her as "mean." This could be connected to her not readily adhering to the pleasantry and emotive norms expected of middle school-aged, Black girls in the USA (Walker, 2020). However, Niger resisted narratives that she was mean, but she declared that she cared deeply about people. The recognition of both the success and care behind the Recognition Board supported others and Niger herself in being seen as a person who could engineer to make a difference and cared about the humanity of others.

Discussion: Local Contentious Practice in Justice-Oriented Engineering Identity Work

We have argued that opportunities for identity work in middle school engineering take place in social practice, as students engage in engineering design with and for communities. Students' identity work as engineers who care about their communities took shape through the emergence of *new local contentious practice* that *both amplified youths' ingenuity and challenged particular local, historical/sociocultural norms of engineering and schooling*. Their identity work was supported by what they designed, *and* how their designs were then taken up in social interaction (Feenberg, 1991).

As students engaged in identity work, their efforts put into stark relief the tension between the ways in which youth of Color have been historically positioned in engineering/STEM classes, and the presents and futures that youth were imagining for themselves and others. This identity work focused on meeting the needs of people in their community, accomplishing things that teachers could not imagine, and feeling good about themselves for working through challenges or being recognized for making positive change. This is why we refer to local contentious practice as the *critical stuff* of becoming.

These contentious local practices related to disrupting (a) who has the authority to name what counts as engineering problems worth solving and (b) narratives around what it means to persist through design iterations. Acts of both naming and persisting anchored in students' primary identities as community insiders of their school, with ties to other members including teachers, kindergartners, and school administrators, are made visible and actionable in the EfSC approach. The *locality* of students' identities as community-situated engineers upended the traditional notion in engineering education of an external, more powerful "privileged server"—the engineer—providing otherwise inaccessible expertise to the "underprivileged served" (Henry, 2005). In the cases shared, students were *at once* the underserved and the engineers who defined a constrained engineering problem and iterated it to address salient, justice-oriented, embodied concerns. This mode of engineering departs from the canonical framing of engineering as an apolitical and benign enterprise (Gunkel & Tolbert, 2018). The student engineers themselves as community insiders conducting an investigation on their own turf, drawing on established ties with various community stakeholders were instrumental in seeding social change.

In the middle school context, the practices were also contentious as the issues students deemed pertinent were counternarratives to the dominant school discourse involving student behavioral norms and expectations. Disrupting who has the authority to name what counts as engineering problems worth solving involved an active seeking out of multiple community voices, through surveys, interviews, and follow-up conversations during the prototype iteration processes. Drawing from and listening to multiple perspectives made visible multiple forms of expertise which were essential for the prototypes to work as the student engineers desired. It is important to note that community members offered expertise that was not necessarily technical but nonetheless informed the technical iterations student engineers then implemented. Although students had to adhere to the design challenge specifications, community-offered expertise centered on social aspects focused directionality to technical iterations that focused on the prototypes' potential impact in enacting social change. A common feature across the projects was the goal to help improve the emotional and mental well-being of the student community. Engaging in engineering in ways that purposefully centered their assets in all phases of engineering design demanded that the sixth graders cared for others, exhibited empathy, and translated, through everyday ingenuity, these relational forms of capital into a material prototype that could bring about real change in some degree.

Further, because the genesis of the engineering problems was borne out of local relationships and embodied experiences, student engineers tackled what they named as "real" and "actual" problems. These authentic (versus scripted scenarios dictated by curricular units) issues also required students to imagine and generate their own paths forward—who to talk to in order to further refine the problem space, what the process of iterative design might entail materially and relationally, how to test the prototype, etc. Such an approach disrupted narratives around what it means to persist through iterations in design. Students felt encouraged to get help from peers when work was positioned as community-owned rather than an individual achievement. This collective endeavor challenges traditional individualized notions of learning and diminished the competition among groups. It also increased opportunities for students to recognize (and be recognized) and value the varied strengths students brought to the work, enabling different people to step in and help out when needed.

Iterative design discourses were centered on the high stakes of the prototypes working, not for a test score or a right answer but for social change—increasing community well-being. Beyond an engineering class task, community members with whom students have ties were depending on their projects working. We argue that these empathetic relationalities were more than a feel-good emotional trope—they translated into concrete action that resulted in students' deepening engineering knowhow while simultaneously taking justice-oriented action relevant to community well-being. Related pedagogical outcomes included both Mrs. P and Mrs. L actively engaging in conversations with students and supporting students' iterative process by providing additional time for engineering, including free periods and during recess.

Centering community expertise made local contentious practices possible by allowing for many forms of expertise to matter in problem definition and solution design. This approach recognized and valued students and their communities' broad expertise from multiple areas of their lives. Students had opportunities and the motivation to leverage their everyday ingenuity as critical knowhow in engineering design. The design solutions students created challenged oppressive norms. As students made their communities happier and healthier, they created new norms that recognized the humanity of their community. Not only did this expand *whose* expertise matters, but also *what* expertise matters, challenging how engineering education often positions scientists and engineers as the only experts.

Conclusion

Students' identity work took shape through the emergence of new local contentious practices that amplified youths' ingenuity and challenged particular local, historical/sociocultural norms of engineering. As community insiders in their school and classrooms, students have a wealth of knowledge and wisdom that can positively impact their communities. However, oftentimes their ideas and perspectives are not taken up in engineering design, even when the challenges addressed by engineers are grounded in the community. By creating spaces for students to re-mix the resources and tools of science and engineering with their powerful community wisdom supports their agentic acts of presenting their authentic, often liminal, selves. Designing to welcome youths' ingenuity within engineering can support students to feel welcomed and capable to engineer in meaningful ways while transforming the learning community itself.

Acknowledgments

This study was supported by the National Science Foundation (Division of Research on Learning Award No. 1502755).

Author Bios

Angela Calabrese Barton is a professor of the learning sciences and STEM education at the University of Michigan. Her research focuses on issues of equity and justice in STEM education in school and community settings. She takes a historicized and future-oriented ecological and participatory approach to give witness to and learn with school and community partners. Email: angiecb@umich.edu.

Kathleen Schenkel is an Assistant Professor at San Diego State University. Her research focuses on critical science agency and student learning in STEM in the middle grades. Email: Kschenkel@sdsu.edu.

Edna Tan is a professor of science education at the University of North Carolina at Greensboro. She takes a critical, ethnographic approach in her work with youth and science educators, across formal and informal settings. Email:e_tan@uncg.edu.

References

Allen, C. D., & Eisenhart, M. (2017). Fighting for desired versions of a future self: How young women negotiated STEM-related identities in the discursive landscape of educational opportunity. *Journal of the Learning Sciences*, *26*(3), 407–436. https://doi.org/10.1080/10508406.2017.1294985

Anzaldúa, G. (2002). Speaking in tongues: a letter to 3rd world women writers. In *This bridge called my back: Writings by radical women of Color*. Berkeley, CA: Third Woman Press.

Beddoes, K., & Borrego, M. (2011). Feminist theory in three engineering education journals: 1995–2008. *Journal of Engineering Education*, *100*(2), 281–303. https://doi.org/10.1002/j.2168-9830.2011.tb00014.x

Blair, E., Miller, R., Ong, M., & Zastavker, Y. (2017). Undergraduate STEM instructors' teacher identities and discourses on student gender expression and equity. *Journal of Engineering Education*, *106*(1), 14–43. http://doi.org/10.1002/jee.20157

Buchholz, B., Shively, K., Peppler, K., & Wohlwend, K. (2014). Hands on, hands off: Gendered access in crafting and electronics practices. *Mind, Culture, and Activity*, *21*(4), 278–297. http://dx.doi.org/10.1080/10749039.2014.939762

Buechley, L. (2006, October). A construction kit for electronic textiles. In *2006 10th IEEE International Symposium on Wearable Computers* (pp. 83–90). IEEE.

Calabrese Barton, A., Kang, H., Tan, E., O'Neill, T., & Brecklin, C. (2012). Crafting a future in science: Tracing middle school girls' identity work over time and space. *American Education Research Journal*, *50*(1), 37–75. https://doi.org/10.3102/0002831212458142.

Calabrese Barton, A., & Tan, E. (2018). A longitudinal study of equity-oriented STEM-rich making among youth from historically marginalized communities. *American Education Research Journal*, *55*(4), 761–800. https://doi.org/10.3102/0002831218758668

Calabrese Barton, A., & Tan, E. (2019). Designing for rightful presence in STEM: Community ethnography as pedagogy as an equity-oriented design approach. *Journal of the Learning Sciences*, *28*, 616–658. https://doi.org/10.1080/10508406.2019.1591411.

Capobianco, B., French, B., & Diefes-Du, H. (2013). Engineering identity development among pre-adolescent learners. *Journal of Engineering Education*, *101*(4), 698–716. http://doi.org/10.1002/j.2168-9830.2012.tb01125.x

Chen, D. A., Chapman, M. A., & Mejia, J. A. (2020). Balancing complex social and technical aspects of design: Exposing engineering students to homelessness issues. *Sustainability*, *12*(15), 5917. https://doi.org/10.3390/su12155917

Chu, L., Sampson, V., Hutner, T. L., Rivale, S., Crawford, R. H., Baze, C. L., & Brooks, H. S. (2019). Argument-driven engineering in middle school science: An exploratory study of changes in engineering identity over an academic year. *Journal of Pre-College Engineering Education Research*, *9*(2), Article 6. https://doi.org/10.7771/2157-9288.1249

Cutrim Schmid, E. (2006). Investigating the use of interactive whiteboard technology in the English language classroom through the lens of a critical theory of technology. *Computer Assisted Language Learning*, *19*(1), 47–62. https://doi.org/10.1080/09588220600804012

Danielak, B., Gupta, A., & Elby, A. (2014). Marginalized identities of sense-makers: Reframing engineering student retention, *Journal of Engineering Education*, *103*, 1–14. http://doi.org/10.1002/jee.20035

Eastman, M., Miles, M., & Yerrick, R. (2019). Exploring the White and male culture: Investigating individual perspectives of equity and privilege in engineering education. *Journal of Engineering Education*, *108*(4), 459–480. http://doi.org/1010.1002/jee.20290

Feenberg, A. (1991). *Critical theory of technology* (Vol. 5). New York: Oxford University Press.

Freire, P. (1971). *Pedagogy of the oppressed*. New York, NY: Continuum.

Furler, S. (2012). Diamonds. [Recorded by Rihanna]. *On Unapologetic* (album). New York City. StarGate.

Gunkel, K. L., & Tolbert, S. (2018). The imperative toward a dimension of care in engineering education. *Journal of Research in Science Teaching*, *55*, 938–961. http://doi.org/10.1002/tea.21458

Gutiérrez, K. D., Cortes, K., Cortez, A., DiGiacomo, D., Higgs, J., Johnson, P., Lizárraga, J. R., Mendoza, E., Tien, J., & Vakil, S. (2017). Replacing representation with imagination: Finding ingenuity in everyday practices. *Review of Research in Education*, *41*(1), 30–60. https://doi.org/10.3102/0091732X16687523

Hazari, Z., Sonnert, G., Sadler, P., & Shanahan, M. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, *47*(8), 978–1003. https://doi.org/10.1002/tea.20363

Henry, S. (2005). "I can never turn my back on that": Liminality and the impact of class on service-learning experience. In D. Butin (Ed.) *Service-learning in higher education*. Palgrave Macmillan.

Hicks, J., Jennings, L., Jennings, S., Berry, S., & Green, D. (2018). Middle school bullying: Student perceptions and prevalence. *Journal of Child & Adolescent Counseling*, 1–14. https://doi.org/10.1080/23727810.2017.1422645

Hira, A., & Hynes, M. (2019). Design-based research to broaden participation in pre-college engineering: Research and practice of an interest-based engineering challenges framework. *European Journal of Engineering Education*, *44*(1–2), 103–122. https://doi.org/10.1080/03043797.2017.1405243

Holland, D., & Lave, J. (2009). Social practice theory and the historical production of persons. *Actio: An International Journal of Human Activity Theory*, *2*, 1–15.

Hughes, R. (2015). An investigation into the longitudinal identity trajectories of women in science, technology, engineering, and mathematics. *Journal of Women and Minorities in Science and Engineering*, *21*(3), 181–213. http://doi.org/10.1615/JWomenMinorScienEng.2015013035

Hynes, M., & Swenson, J. (2013). The humanistic side of engineering: Considering social science and humanities dimensions of engineering in education and research. *Journal of Pre-College Engineering Education Research (J-PEER)*, *3*(2), 4. https://doi.org/10.7771/2157-9288.1070

Kafai, Y., Fields, D., & Searle, K. (2014). Electronic textiles as disruptive designs: Supporting and challenging maker activities in schools. *Harvard Educational Review*, *84*(4), 532–556. http://dx.doi.org/10.17763/haer.84.4.46m7372370214783

Le, P. T., & Matias, C. E. (2019). Towards a truer multicultural science education: How whiteness impacts science education. *Cultural Studies of Science Education*, *14*(1), 15–31. https://doi.org/10.1007/s11422-017-9854-9

Legette, K. B., Rogers, L. O., & Warren, C. A. (2020). Humanizing student–teacher relationships for Black children: Implications for teachers' social–emotional training. *Urban Education*. https://doi.org/10.1177/0042085920933319

Morales-Doyle, D. (2017). Justice-centered science pedagogy: A catalyst for academic achievement and social transformation. *Science Education*, *101*(6), 1034–1060. https://doi.org/10.1002/sce.21305

Nasir, N., & Vakil, S. (2017). STEM-focused academies in urban schools: Tensions and possibilities. *Journal of the Learning Sciences*, *26*(3), 376–406. https://doi.org/10.1080/10508406.2017.1314215

National Research Council. (2010). *Engineering, social justice, and sustainable community development: Summary of a workshop*. Washington, DC: National Academies Press.

Ozogul, G., Miller, C., & Reisslein, M. (2017). Latinx and Caucasian elementary school children's knowledge of and interest in engineering activities. *Journal of Pre-College Engineering Education Research (J-PEER)*, *7*(2), 2. https://doi.org/10.7771/2157-9288.1122

Pattison, S., Svarovsky, G., Ramos-Montanñz, S., Gontan, I., Weiss, S., Nuúñez, V., Corrie, P., Smith, C., & Benne, M. (2020). Understanding early childhood engineering interest development as a family-level systems phenomenon. *Journal of Pre-College Engineering Education Research, 10*(1), Article 6. https://doi.org/10.7771/2157-9288.1234

Schenkel, K., & Calabrese Barton, A. (2020). Critical science agency and power hierarchies: Restructuring power within groups to address injustice beyond them. *Science Education*, *104*(3), 500–529. https://doi.org/10.1002/sce.21564

Sheridan, K. M., Halverson, E. R., Brahms, L., Litts, B. K., Jacobs-Priebe, L., & Owens, T. (2014). Learning in the making: A comparative case study of three makerspaces. *Harvard Educational Review*, *84*(4), 505–531. https://doi.org/10.17763/haer.84.4.brr34733723j648u

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (2nd ed.). Sage Publication.

Tan, E., Calabrese Barton, A., & Benavides, A. (2019). Engineering for sustainable communities: Epistemic tools in support of equitable and consequential middle school engineering. *Science Education*, *103*(4), 1011–1046. https://doi.org/10.1002/sce.21515

Tate, E., & Linn, M. (2005). How does identity shape the experiences of women of color engineering students? *Journal of Science Education and Technology*, *14*(5/6), 483–493. https://doi.org/10.1007/sl0?56-005-0223-l

Tonso, K. L. (2016). Enacting practices: Engineer identities in engineering education. In *Engineering professionalism* (pp. 85–103). Brill Sense.

Urrieta, L., & Noblit, G. (2018). *Cultural constructions of identity*. Oxford University Press.

Walker, B. L. T. (2020). "Loud, proud, and love a crowd": African American girls and school discipline practices. *Middle School Journal*, *51*(1), 12–18. https://doi.org/10.1080/00940771.2019.1689776