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LEARNING

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# Critical science agency and power hierarchies: Restructuring power within groups to address injustice beyond them

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## Abstract

Promoting critical science agency (CSA) may be one way to promote educational justice. CSA is using science with other powerful forms of knowledge to address issues of injustice. However, the process of enacting CSA is always embedded within a sociopolitical context, which positions some students with more power than others. Drawing upon a social practice theory analytical lens with a focus on power and using critical participatory ethnography methods, this study investigated the ways middle school students restructured power hierarchies as they worked to complete the design challenge of making their classroom community more sustainable, and how power hierarchy restructuring impacted students' opportunities to enact CSA. Findings show as the students enacted collective CSA, they were responding to unmet students' needs grounded in systems of power operating within their classroom. Throughout the engineering design process, students' understandings of their defined issue of injustice was both refined and critical to their technical and social design considerations. Finally, as the groups enacted CSA, power hierarchy disruptions, though incomplete, through the recognition of students' expertize and distributing roles, supported their efforts to address their class-wide concerns. These findings highlight how restructuring power hierarchies supported youth enacting collective CSA, which then further supported them in reshaping their classroom community to be more justice-oriented.

  

**KEYWORDS**
collaborative learning, critical science agency, engineering, justice, power

> *"I think they would be probably surprised because I'm not like, I'm younger and I made this and it really does work. So, if they found out I made it they'd be like, "oh my gosh" because I made it with my group, and it was actually pretty hard to do so I think they'd be surprised."*
>
> –McKenzie predicting how people would react when they found out that Lucena, Cory and she made the light-up Limbo Stick.

## 1 | INTRODUCTION

Efforts have long worked to promote equity in science education. However, efforts focused primarily on access have often ignored the barriers that impact students' opportunities to use science in ways that matter to their local communities and themselves. Such barriers include promoting a narrow definition of science and ongoing sociohistorical narratives about who can and should do science (Calabrese Barton, 2001; Philip & Azevedo, 2017). These barriers operate at both a systematic and classroom level (Milner, 2013; Tate, 2001).

McKenzie's quote also illustrates the ways in which students can restructure dominant hierarchies that oppress students of color and girls as they seek to engage in science and engineering in ways that matter. McKenzie and her groupmates, Cory and Lucena, worked together to make a light-up Limbo Stick in an effort to make school more fun for their peers. McKenzie highlights how the group members collaborated together, and how their work would surprise others because it was such a challenging project for youth their age. Her words also point to the ways in which epistemologically driven power hierarchies were disrupted in their classroom, as they redefined who could do science, the purpose of science, and what it looked like to do science in their classrooms. The students challenged the ways that dominant equity narratives of access are inadequate in supporting students to use science meaningfully.

The Limbo Stick group shows how promoting critical science agency (*CSA*) may be a powerful way to promote justice in science classrooms. When youth leverage upon robust understanding and practices of science in conjunction with other powerful forms of knowledge toward addressing issues of injustice in locally meaningful ways, they are enacting CSA (Basu & Calabrese Barton, 2010). Opportunities to enact CSA thus require students to be supported in deep and meaningful engagement in the discipline in ways that value their insider classroom, school and local community knowledge. It also requires that students be supported in seeing themselves as experts for their skills to merge their varied expertize and community resources to take action. However, students' opportunities to enact CSA are shaped by the power hierarchies that operate within learning environments.

This study seeks to understand the relationship between opportunities to enact CSA and power hierarchies found in classrooms that are grounded in systems of power and oppression. We are particularly interested in how peer-to-peer interactions shape opportunities to enact CSA collectively, as well as how opportunities to enact CSA can possibly restructure existing power hierarchies. The following questions guided this study:

1. In what ways did students restructure power hierarchies as they worked to complete the engineering design challenge to make their classroom community more sustainable?
2. How did power hierarchy restructuring impact students' opportunities to enact CSA?

Exploring these questions will support more students in enacting CSA and developing more justice-oriented science classroom, schools and local communities.

## 2 | EXAMINING THE RELATIONSHIP BETWEEN CSA AND POWER

### 2.1 | Agency and science education

While enacting agency has shown to be a promising social practice and outcome of learning, few studies have explicitly investigated agency in science education (Arnold & Clarke, 2014). However, a focus on agency is compelling because it potentially addresses long-standing justice-related challenges in science education, including how or why individuals may find utility in science toward the issues that matter in their lives (Sharma, 2007). As Arnold and Clarke (2014) note, "the contemporary interest in researching student agency in science also reflects a shift in science education toward understanding science learning as a complex social activity" (p. 736).

Broadly speaking, from a social practice theory perspective, the construct of agency calls attention to how people act purposefully in socially constructed interactions, with attention toward changing those situations (Holland, Lachicotte, Skinner, & Cain, 2001). In science education research, attention has been given to the structure-agency dialectic; that is, how action is always situated within sociohistorical contexts. The structures of those contexts shape opportunities to act in-the-moment and across time. Of importance here is that agency is not something that individuals possess, but rather it is only ever enacted in-practice, through "socioculturally mediated and contingently creative dialogue with the world" (Sharma, 2007, p. 300).

Within classrooms, students' opportunities to enact agency are always situated within, impacted by, and impact the institutional and cultural structures of schooling. Consider, how Carlone, Johnson, and Scott (2015) describe the case of Mirabel, and her opportunities to enact agency in her science classes across the 4th through 8th grades. Mirabel's opportunities for agency became constrained, over time, by institutional and cultural structures. In fourth-grade, Mirabel experienced alignment among these experiences, however as she moved through different classrooms over the next 4 years, she experienced tensions between what it meant to be a good science student, act like a girl, and fit in with her peers. This structural mismatch did not support Mirabel in doing science as easily as when she was a younger student. In navigating those structures, Mirabel had varying opportunities to enact agency.

### 2.2 | Critical science agency

There are important differences in how agency has been taken up in science education research, even despite the limited number of studies published. While some scholars write about agency where the focus is intentionally on activity in social practice, others, including ourselves have written about science agency. This is leveraging science knowledge and practice to take action. For example, work has been done that investigates how participation in local community and citizen science programs supported students in enacting environmental science agency. Youth enacted environmental science agency when they developed environmental science inquiry practices, used those practices, and saw themselves as capable of supporting environmental conservation (Ballard, Dixon, & Harris, 2017).

We purposefully use the term "critical" to frame a particular kind of science agency that takes a more explicitly political stance, linking agency to broader notions of justice. From this perspective, *CSA*, involves using science knowledge and practices *with other forms of expertize to address issues of injustice* (Schenkel, Calabrese Barton, Tan, Nazar, & Flores, 2019). We argue that CSA is important because it focuses on how intentional social activity can be transformative (Mueller, 2015). It is also important because it advances beyond an access view of educational equity often promoted as science for all. Enacting CSA can support youth moving beyond a functional view of science literacy, which attends to participation in the world as it is now, without attention to what it could be. CSA foregrounds the integrated knowledge and practice that may support students in working with and in science to bring about a more just world for individuals and their broader communities.

Enacting CSA requires multiple forms of expertize as students seek to address issues that matter. This is also seen in research about critical math agency, which informs CSA. For example, Turner's (2012) study shares young people's experiences of developing and leveraging different expertize to address the inequitable overcrowding at their school. Students' math expertize was not enough to address the injustice. The young people also had to grapple with how to best convince adults that their problem mattered, which required their broad and unique community expertize, and bridging together that expertize with their mathematical knowledge. While not directly addressing CSA, Morales-Doyle (2017) describes how students need to be understood as transformative intellectuals, who can powerfully leverage upon both disciplinary and cultural knowledge and practice along with a commitment to their communities to take socially transformative action with science. His work highlights the importance of a commitment to people and place as a part of developing agency in science education.

Enacting CSA is a process that requires interactions with others. When students have opportunities to combine different forms of expertize and resources in supported ways, rather than leveraging such resources independently, they tend to have more opportunities to expand their CSA (Basu, Calabrese Barton, Clairmont, & Locke, 2009). Furthermore, there is an important social element involved as well. When students have opportunities to leverage collective expertize distributed amongst themselves, greater opportunities for CSA arise. However, power hierarchies within groups can impact students' opportunities to develop and be recognized for their expertize. This study pays particular attention to the relationship between power hierarchies and CSA to better support students' outcomes and designing collaboratively for more equity-oriented learning communities. We pay attention to both individual's opportunities to enact CSA as well as groups' collective enactments of CSA. Paying attention to the collective enactments of CSA pushes the field to explore how enacting agency is always impacted and sometimes amplified by interactions with others, in this case, a classroom community.

## 2.3 | CSA and power

In this study, we explore the relationship between CSA and power hierarchies. To do so, we draw upon social practice theory because it "emphasizes the historical production of persons in practice, and pays particular attention to differences among participants, and to the ongoing struggles that develop across activities around those differences" (Holland & Lave, 2009, p. 1). This lens allows attention to be paid to the ways in which power hierarchies, grounded in historical narratives, are made salient through interactions and how students collectively enact CSA. Power within a classroom is seen in how individuals interact, how students' statuses are maintained or disrupted, and who has access to different spaces and actions (Esmonde & Langer-Osuna, 2013). All of these aspects of power hierarchies are relational and are also situated within a sociohistorical context. Power impacts students' access and opportunities to develop and enact certain roles, which impacts their opportunities to enact CSA.

Understanding the characteristics of power is critical to understanding how students and their class enact CSA. Power is enacted everywhere and how it operates is often rendered invisible especially for those who benefit from its enactments (Leonardo, 2013). Moje and Lewis (2007) explain "power is produced and enacted in and through discourses, relationships, activities, spaces, and times by people as they compete for access to and control of resources, tools, and identities" (p. 17). Power is distributed and dynamic. A student may be able to enact more power in one space and be oppressed more in another space.

This dynamic, interactional view does not ignore the systematic ways power has served to position specific socially constructed groups (e.g., men, White people, English-only speakers) with power over others (e.g., women, people of color, multilingual speakers). Rather, local interactions are influenced by the ways power has been enacted across space and time (Foucault, 1980). These interactions have shaped and formed institutions and structures that continue to oppress people through multiple systematic levels (Holland & Lave, 2009). Enacting power is not just about controlling actions and resources, but also about controlling the ways that people define each other through their various identities.

Communities have long used social markers, such as race, gender, language, and class, as ways to limit what opportunities for participation and action different social groups' members can enact. In doing so, they were solidifying systems of power (Gutiérrez & Rogoff, 2003). Oppression, such as racism and sexism, plays out through individual interactions, and is supported by larger systems and their policies and structures, such as capitalism, schooling, and the criminal justice system (Bell, 1992). For example, White supremacy is maintained through ideology impacting interactions that develop and support policies and structures, overtime, that serve to perpetuate racism by positioning White people with more privilege than people of color (Kendi, 2017; Rothstein, 2017). Even though students, teachers, and researchers may not buy into the oppressive ideologies, through their actions they still enact these oppressive ideologies (DiAngelo, 2018). Multiple forms of oppression can influence the way that actors enact power as they impact others' opportunities for participation and access to resources. Therefore, in this study, we pay attention to the intersectional nature of how power operates and impacts students' experiences (Crenshaw, 1991). Due to the ways that power is enacted in complex ways, it is necessary to pay attention to the textured lives and identities of classroom community members.

Power is always enacted in local practice in schools, in ways that take shape across scales of activity, from small group work to society supported school-wide policies and practices. Sometimes the ways in which power is enacted is highly visible at the structural level, such as when schools with more White students have more financial resources and access to science classes compared to schools with more students of color (Tate, 2001).

Power always operates through multiple mechanisms, including the everyday sanctioned activities of schools and classrooms at the local level. Nasir and Vakil (2017) describe how classrooms "carry explicit and implicit racialized and gendered notions of who does and does not belong in these classrooms" (p. 378). Such patterns of how students are racialized and gendered through *routine* practices of teaching and learning have been reported along with concrete resultant inequities. For example, "settled" expectations in school science act as "boundaries that control the borders of acceptable meanings and meaning-making practices," positioning students from nondominant communities in deficit-oriented ways (Bang, Warren, Rosebery, & Medin, 2012, p. 303). Additionally, normative discourses about and enactments of disciplinary learning, for whom and why, can differentially position students with or without epistemic authority and/or agency (Birmingham et al., 2017).

Research in math education has highlighted how local enactments of gendered and racialized power hierarchies in classrooms can be disrupted and restructured through new modes of participation and opportunities to recognized for their expertize. For example, Esmonde and Langer-Osuna (2013) describe how Dawn, an African American girl, shifted her groups' power hierarchy when she took on a more collaborative decision-making role. She restructured interaction patterns within her small group by positioning herself as a mathematics expert and a social insider in the classroom. In Dawn's classroom and others, power is made visible in how individuals interact, how student statuses are maintained or disrupted, and who has access to what spaces and actions. This also highlights how power is relational, fluid, and situated within a sociohistorical context.

This study contributes to the literature by exploring how power dynamics impact CSA enactments, and how collectively enacting CSA impacts further restructuring of power hierarchies. We pay particular attention to students' CSA and power restructuring in their groups. Esmonde and Booker (2017) explain, "Power is made visible in the ways social relations between people enable some forms of agency, and constrain others" (p.21). As people enact agency, they require access to resources such as recognition, others' cooperation, spaces and ability to take action (Esmonde & Langer-Osuna, 2013). Paying attention to who is able to enact various forms of agency through interactions within their classroom is useful for understanding and redressing how power is operating.

## 3 | METHODS

We used critical ethnography methods with participatory approaches in a sixth-grade classroom in an urban elementary school in this study. Critical ethnography provides insight into the power dynamics in a given community and supports praxis to address inequitable power distributions (Weis & Fine, 2012). Participatory methodologies were selected because they aim to disrupt power-dynamics between researchers and participants (Cammarota & Fine, 2010). The teacher, students, and researchers actively collaborated to define problems that mattered to the classroom community and address them through their engineering design challenge using community ethnographic methods. Additionally, students and teachers actively suggested changes to the curriculum that were taken up in the next implementations of it. Each implementation of this unit was improved by collaborating with young people and teachers to make it better. Students provided insight into the data as it was generated. While the students graduated and moved schools after this implementation, their teacher continued to provide insight into the data analysis. These participatory approaches align with the study's goal to understand how to disrupt and restructure power hierarchies and support young people in enacting CSA.

## 3.1 | Context

### 3.1.1 | School and class context

Wilkerson School is a STEM school located inside a medium-sized city. The school serves a diverse student body in terms of race, gender, religion, and language. The self-identified racial background of the students are as follows: 11 students are Black, two students are Southeast Asian, two students are biracial, four students are Latinx, and seven students are White. One student transferred from the school mid-unit. There were 10 girls and 16 boys in the focal class. Half of the students in the class immigrated to the United States from Latin America, East and West Africa, South East Asia and the Middle East. There was a range of socioeconomic statuses. In many ways, the school community rallies around supporting and welcoming all of their students, but not always. In the findings, we highlight how students, teachers, and policies positioned students with varying opportunities within the school community depending on their socially constructed identities.

### 3.1.2 | Participants

Six students (who made up two groups of three students each), Mrs. K (the teacher) and Katie (author) were the focal participants in this study. Angie (author) codeveloped the curriculum utilized in this study and supported the unit enactment across all four sixth-grade classrooms while Katie focused predominantly on coteaching the unit with Mrs. K in her classroom. The groups were selected based on students' interest to participate in the study. Additionally, the focal groups were representative of the larger classroom community in terms of gender, linguistic, and racial diversity (see Table 1). Additionally, the groups were positioned by their teachers and students with a wide range of social and academic statuses in the classroom community.

### 3.1.3 | Mrs. K. and her classroom

Mrs. K taught for over 30 years, and this was her last year teaching. She grew up in the local community. She taught many subjects, but she saw herself as an English Language Arts teacher. In her words, she "will out English you any day." She was not as familiar or confident in teaching energy content knowledge and practices especially because the sixth-grade curriculum usually focused on Earth science. Mrs. K is a White, monolingual, English-speaking woman. She has positive relationships with the staff and students and continues to volunteer at the school now that she is retired.

**TABLE 1** Focal participants

| Focal participants | Students | Gender | Race | Spent younger years in: | I-Engineering attendance |
|---|---|---|---|---|---|
| Limbo Stick Group | Lucena | F | Latinx | United States | Missed 3/5 of I-Eng. for special education interventions |
| | McKenzie | F | Multiracial (Latinx and White) | United States | Rarely missed class |
| | Cory | M | White | United States | Missed 2/5 of I-Eng. for reading interventions |
| "All the Way Up" Accomplishment Board Group | Danny | M | White | United States | Rarely missed class |
| | Issa | M | Black | Kenya | Rarely missed class |
| | Amir | M | Black | Tanzania | Missed 3/5 of I-Eng. for English Language interventions |
| Teachers | Mrs. K | F | White | United States | Rarely missed class |
| | Katie | F | White | United States | Rarely missed class |

Mrs. K was a dedicated educator. She was well known and respected for fostering a fair and caring classroom community. Her students valued and felt welcome to contribute to this positive classroom community. For example, students expressed desires to create engineering designs that further supported the well-being of their classroom community, such as recognizing peers' accomplishments, doing things to make a difference, and increasing classroom fun.

However, classroom interactions were often shaped by unofficial power hierarchies that operated in Mrs. K's class, informed by sociohistorical narratives. Mrs. K's students' academic and social statuses often seemed to be connected to their racial, gender, and linguistic socially constructed identities. These statuses and participation patterns were maintained by the teacher, students, and school-wide practices.

For example, Mrs. K, in an effort to support all students by having English-speaking students tutor emergent multilingual English speakers, unintentionally positioned monolingual students with more authority. Further, boys most often dominated classroom discussions and activities, by being called on more often by Mrs. K, yelling out answers and making most group decisions. This was witnessed across the daily whole-class discussions and group interactions that were video-recorded across the engineering unit. At the same time, boys would be disciplined more by their teachers and administrators, which limited their opportunities to learn and participate. Boys of color, in particular, explained in interviews that they were treated unfairly because the White boys do not get in trouble as much with similar infractions. This observation was also apparent in video across the unit. Furthermore, more White students then students of color and more girls than boys were members of the student leadership program that recognized students for completing work and not getting into trouble, and rewarded them with special privileges like working in the hallway. These and other, gendered, linguistic, and racial disparities in who is positioned to learn through both sanctioned and unsanctioned practices within classrooms is well documented in the research literature (Hand, Penuel, & Gutiérrez, 2012; Nasir & Vakil, 2017). These participation, social popularity, and disciplinary patterns reflect and reproduce the ways that racism, sexism, and nationalism operate within the United States (Milner, 2013). Mrs. K and her students worked to make visible and disrupt these power imbalances in the classroom. This study focuses on those generative moments of power restructuring.

### 3.1.4 | The researchers

Katie is a former middle school science teacher who taught in urban schools. She moved to the area when she began to work at a nearby university. She is a White, monolingual, English-speaking woman. She had developed collegial relationships with students and teachers at the school. She taught most content-specific instruction during the unit and worked most with the two groups in this study. Angie is White and female, and has worked in urban schools and communities for several decades. She worked closely with Katie and the teachers to codesign the experiences described in this paper. She is particularly interested in centers youths' lived lives and community wisdom as ways to disrupt dominant sociopolitical and epistemological hierarchies in classrooms. Having grown up as a woman in a working-class community she experienced the ways in which STEM learning opportunities were limited to what her local public school offered as part of the standard curriculum. Yet, she also benefited from being White in these White dominant spaces. These intersectional stances both we (authors) experienced have helped us to make sense of the layered ways in which power plays out in classrooms, though we both realize and hope we have created spaces for our partner young people and teachers to help us to see in new ways what our privileges have made invisible to us. These tensions, as we note in our methods of data analysis, were central to how we sought to critically examine and challenge data interpretation. We have been working with the Wilkerson School community for 4 years.

## 3.2 | Curriculum

This study occurred during an integrated science unit focused on engineering for sustainable communities, grounded in the disciplinary core ideas of energy transformations, sources and systems, and sustainability, alongside engineering practices. The overarching goal was to expand disciplinary knowledge/practices identified above within a sustainability framework by incorporating local community knowledge and practice (see Table 2). The unit is made up of two iterative design cycles. The first design cycle is anchored in the creation of electric art. Students created electric art cards for a loved one which supported them in learning about the engineering design cycle, alternative energy sources, parallel, and series circuits. The students then applied and deepened that expertize while critically engaging with school and local community stakeholders in the second iterative design cycle, which is creating sustainable engineering design solutions for their classroom. In the second design challenge, which is the focus of this study, students were given the design challenge bounded with the following criteria: students had to innovate something in the classroom in a way that would address a classroom and community sustainability concern. They were required to use a renewable energy source, such as solar panels or hand crank generators, 10 mm LED lights, copper tape, and any materials available in their classroom.

Students determined community sustainability concerns and solutions using community ethnography. The students administered surveys to their school community members (peers, teachers, younger students, and staff) to discover what school community issues mattered most. They analyzed that data and defined a problem they wanted to solve. Then, they designed a green energy solution to those challenges and received more feedback from both school and local community members. They prototyped their designs and shared their engineering designs in a showcase.

Other research focused on this unit provides impetus for the further study of CSA. In one other study, we explored what practices and discourses supported moments of rightful presence in classrooms. In another strand of inquiry, we explored how toolsets embedded in the curriculum supported students' recruitment and navigation of multiple epistemologies as well as students onto-epistemological developments in engineering. Across these studies, there was evidence of students using multiple forms of expertize to address issues of injustice. This study builds on this body of work highlight the tensions and possibilities for enacting CSA for students working in heterogeneous collaborative learning groups.

# 4 | DATA SOURCES AND ANALYSIS

The students, Mrs. K and we generated many data sources. Detailed field notes of classroom interactions were kept, along with video recordings of all lessons, and video-recorded whole class interactions with three focal groups. Field notes were kept daily. All student work was collected, and pictures were taken of both their sketch-up design posters and prototypes on a lesson-by-lesson basis to record the ways their engineering designs changed over time. Students shared their insight regularly on the curriculum and how to improve it. Mid-unit and end-of-unit "artifact interviews" with members of focal groups were conducted. Here, the "artifacts" are engineering designs students prototyped, which included their design sketches, actual prototypes, and written reflections about their prototypes. The interviews were conducted with the teacher and every student who opted into participating in interviews. In this study, two of the three students in each case opted into participating in interviews. Interviews lasted between 30-60 min, and covered four categories of questions: (a) Understanding the artifact (what it is, how it works, what problem it solves, etc., materials used and why, etc.); (b) Participation and engagement (behind the scenes, including a step-by-step description of the process, descriptions of interaction students had with peers, educators, and local community members, resources used); (c) Knowledge and practices (STEM knowledge and practice needed (prior and what was learned), and funds of knowledge); and (d) Meaning and value (what this project says about oneself, etc.). We also informally talked with Mrs. K to make sense of ongoing questions,

**TABLE 2** Curricular Sesquence

| No. | Lesson | Key focus | Community ethnography integration[a] |
|---|---|---|---|
| 1 | Introduction | Big ideas in engineering for sustainable communities | Examining and discussing how youths their age use community ethnography as a part of engineering design |
| | | Lesson 1: Engineering for Sustainable Communities Introduction | |
| 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 | Generating community narratives |
| | | Lesson 2: Designing Electric Art | |
| | | Lesson 3: Sustainable Electric Art | |
| 4–9 | Iterative Design Cycle 2 | Sustainable Classrooms: Defining Problems and Designing Solutions through Community Ethnography | Using community ethnography as a part of engineering design |
| | | Lesson 4: Engineering Design Challenge Intro | Surveys and observations of peers and community members |
| | | Lesson 5: Defining the problem: Using community ethnography to define engineering challenges | Dialogs with community on project ideas/design |
| | | Lesson 6: Initial Design | Observation |
| | | Lesson 7: Optimize design with community feedback | |
| | | Lesson 8: Prototyping | |
| | | Lesson 9: Refining Designs Through Technical Tests and Community Feedback | |
| 10 | Community Sharing | Lesson 10: Sharing Engineering Designs with the Community | Community Narratives |

*Key Next Generation Science Standard's Performance Expectations Fully or Partially Addressed:*

MS-PS3–5 Energy: Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

MS-ETS1–1 Engineering design: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1–2 Engineering design: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

[a]Community ethnography tools supported groups in eliciting expertize from classroom, school, and local community members.

concerns, and feel of the enactment, with a formal interview at the end of the unit. This study utilized data from 16 interviews, 35 days of field notes, student work and over 70 hr of video recordings.

Data analysis occurred through an iterative process. First, narratives for each group were written using the field notes. Particular attention was paid to the two groups' engineering work throughout the unit, and instances that seemed to shift groups' progress and/or impacted their groups' cohesion. These shifts were noticed when there were disruptions were noted when there were disruptions in the groups' participation patterns. For example, when McKenzie and Lucena began making design choices without asking to get Cory's approval or when Danny leveraged Isa and Amir's ideas. These moments often disrupted the classroom normal patterns of participation. Student work and interview data were integrated into these narratives. Katie and Angie then analyzed interactions in the videos by paying attention to discussions, resource accessing/sharing, body language, and movement. These videos were moments from the sticking points where participation patterns shifted or disrupted in the narratives. This bounded video analysis for this project. We then created a flowchart that investigated the interactions students had within and beyond their groups as they engaged with the engineering unit. Attention was paid to how students' roles changed within their groups throughout the unit. Then we explored why those roles changed by layering on key moments that impacted how power and roles shifted among group members. Considerable time was spent unpacking moments to make sense of how interactions played out and how those interactions were shaped by social/power hierarchies. Next, key interactions that impacted youths' CSA enactment beyond their group were then analyzed. These interactions were bounded to other students, Mrs. K, and adults who provided feedback on designs. Patterns that connected to larger systems of power including race, gender, linguistic diversity, and teacher authority were then identified. This approach aligns with social practice theory as it looked at how students' realities were shaped by their interactions with others within systems of power (Holland & Lave, 2009).

In the next phase of analysis, multiple themes were generated from organizing the codes in connection to our research questions. Themes included (a) classroom power hierarchies, (b) how/when student agency was impeded by interactions grounded in those hierarchies, (c) how/when enacting CSA disrupted power hierarchies, (d) changing student roles in connection to enacting CSA, (e) science knowledge and practice development, (f) community knowledge and practice development, and (g) resisting and disrupting what counts as being a good student and supporting the classroom community. We then produced a cross-case analysis table that highlighted those themes with multiple examples from the unit, supported with multiple forms of data.

This ongoing process and resultant codes/themes were discussed with students, Mrs. K and between Katie and Angie. Through member checking, our understanding of the students' and teachers' experiences became more specific and nuanced. Additionally, the analysis was shared with members of our larger research group who engage in similar work, but in different contexts, to seek feedback on coding and interpretations. This led to more contextualized coding themes and findings.

## 5 | FINDINGS

Analysis of Mrs. K, her students and our experiences highlight three main findings:

1. As the students enacted collective CSA, they were responding to unmet student needs grounded in systems of power operating within their classroom.
2. Throughout the engineering design process, student understandings of their defined issue of injustice was both refined and critical to their technical and social design considerations.
3. As the groups enacted CSA, power hierarchy disruptions, though incomplete, through recognition of students' expertize and the disruption of roles supported their efforts to address their classroom community concerns.

We develop these findings by highlighting the experiences of two focal groups. These cases were chosen as they are illustrative of the larger set of cases we have analyzed. The two focal groups were chosen because they highlight different issues of injustices through their engineering designs. Within each finding, we present the cases separately to draw out the nuances in how students enacted CSA through engineering design, and in particular, how sought to make visible and respond to power in their classroom communities toward more just ends.

## 6 | ENACTING CSA

Students enacted CSA by responding to the real and unmet embodied needs of their classmates in an engineering design challenge. Students engaged in the iterative refinement of their defined engineer problem. This supported the optimization of their project designs by leveraging multiple forms of evidence to understand issues that mattered to their classroom community. In doing so, they linked these unmet needs to enactments of dominant power hierarchies in their classroom, making the disruption of power a central criterion in their engineering design work. Students optimized their designs toward making an actual difference in their classroom community using their community and scientific knowledge to define problems and design solutions through engineering.

## 6.1 | The engineering design task and focal projects

The engineering task was to create an engineering design that would address classroom sustainability. In Mrs. K's classroom community, sustainability was defined as making their classroom happier, healthier, and better for the environment. The students surveyed their classroom and school community to learn more about their sustainability concerns. Drawing on her pedagogical stance supporting student choice, Mrs. K let her students design whatever they wanted as long as they could justify their design choice with data illustrating a community sustainability concern, and demonstrate through a sketch-up that they could actually build a working prototype with a light-up circuit with the available materials. We focus on two groups that sought to address injustices tied to normative power structures in classrooms through their engineering designs.

### 6.1.1 | McKenzie, Cory, Lucena, and the light-up Yardstick Limbo Stick

Lucena, McKenzie, and Cory engineered the light-up Limbo Stick. It is a yardstick adorned with 15 LED lights in a parallel circuit and powered by a hand crank generator. The lights are colored in a pattern and the light bulb wires are angled to avoid poking those limboing. Figure 1 shows the engineering design. Through the design and their classroom community's use of it, the group sought to make more fun and provide more physical movement throughout the day in their classroom.

By supporting more fun and movements, the students connected their efforts to making school fairer and an easier place to learn. For example, Mrs. K's class would take fun breaks, where Mrs. K would play music, two students would hold the Limbo Stick, another would crank the hand crank, and the rest of the class would limbo. Cory explained that by participating in limbo kids could better learn when he said, "After we do this [limbo], they can like, have their fun out. It's helping them to have more fun so they can learn."

The Limbo Stick supported the students in helping others have fun, and it supported the Limbo Stick group in being recognizing for their expertize. Remember how McKenzie predicted others' reactions when they discovered that she made the Limbo Stick with her group saying,

> *I think they would be probably surprised because I'm not like, I'm younger and I made this and it really does work. So, if they found out I made it they'd be like, "oh my gosh," because I made it with my group and it was actually pretty hard to do so I think they'd be surprised.*

The students were proud of their efforts to support their class in having fun through their engineering design work.

### 6.1.2 | Amir, Issa, and Danny and the "All the Way Up" accomplishment board

In the other focal group, Amir, Issa, and Danny created the "All the Way Up" Accomplishment Board. Through their engineering design, the boys sought to address the classroom community problem of their classmates not being recognized for their accomplishments. Figure 2 shows their final design. It is a poster for putting students' accomplishments on it with a border consisting of a hand crank generator powered, 17 LED lights in parallel circuit.

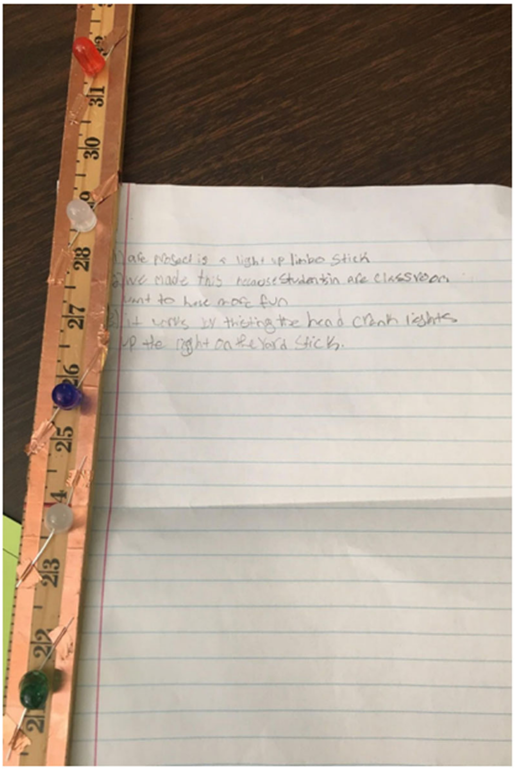

**FIGURE 1** Light-up Limbo Stick [Color figure can be viewed at wileyonlinelibrary.com]

Students and teachers would put students' accomplishments on a sticky note, and put it on the board. To further honor students' accomplishments, they would then crank the hand crank generator and light up the lights on the border.

Issa described the purpose of the board when he said, "Because like, because more kids need to get awarded and it makes them feel good because it will show everybody what they did." Through their engineering design, the boys worked to support their peers in both feeling good and being motivated to keep doing well.


**FIGURE 2** All the Way Up Accomplishment Board [Color figure can be viewed at wileyonlinelibrary.com]

## 6.2 | Defining sustainability problems within dominant schooling power hierarchies

Mrs. K's enactment of the curriculum supported the groups to iteratively integrate multiple types of knowledge to define sustainability problems that mattered to their classroom community. Students first identified patterns in school survey data on sustainability concerns to make visible the unmet needs of their classmates. They used these unmet needs as indicators of "unsustainable" dimensions of their classroom community. As they investigated these patterns further through interviews, observations and personal experiences, the students developed explanations and further motivation to address those issues.

### 6.2.1 | Understanding and addressing the lack of fun

The Limbo Stick group used their analysis of survey and interview data to build a rationale for why it was important to specifically address the injustices caused by the lack of fun in school. The students showed through their survey analysis that the majority of the students, teachers, and staff polled (68% surveyed) cared about this issue, too. Figure 3 shows their initial analysis. While many reasons were offered by their peers, one that stood out to the group initially was that they were only allowed one recess a day.

The students argued that a lack of fun leads to "negative cycles" for their peers and themselves, which have both disciplinary and academic ramifications. McKenzie explained when students were not having fun, they got bored, causing some to fall asleep in class. She worried if students slept, they would not finish their work, and receive bad grades, causing them to be tracked into lower-level classes in the seventh grades. This would impact their high school tracked class placements limiting college possibilities. McKenzie also got headaches when bored at school, making it hard for her to learn. For her, solving the problem of fun challenged the ways tracking that has long-term consequences for students and disproportionately impacts students of color (Taylor, 2006).

Cory suggested supporting fun through the Limbo Stick would disrupt the cyclical nature of discipline often found in schools. This was grounded in his own experiences and his understanding of his classmates' challenges:

> *Cory: Because if they're not having fun they're going to be bored and they'll [students] want to have fun, so they're going to get it out while they're learning, and when they're doing that they're not learning real stuff.*
>
> *Katie: When you're not having fun in school what do you do?*
>
> *Cory: Have fun.*

**1. Kids Results**

| What are the top 3 problems kids identified? | What percentage of kids cared about this problem? | Why do you think this is a problem? |
|---|---|---|
| needs to be more fun | 68.29% | I think this is a problem becuse we only go outside for ressess and that's it |
| more opportunities to celebrate accomplishments | 34.15% | I think this is a problem becuse if people get good grades they don't get to celebrate |
| need to do more things as a class to make a differnce | 31.71% | I think it is a problem becuse self managers get more privleges |

**FIGURE 3** Survey analysis student work

*Katie: Then what happens when you're having fun during those times?*

*Cory: You get in trouble.*

Cory was concerned that limited fun contributed to students not learning. Cory's connection between a lack of fun and learning highlights how aspects of schooling (e.g., curriculum, behavior policies) can make learning challenging. He knew from his own experience that he would make his own fun and then lose future fun opportunities. This made it harder for Cory to pay attention in class.

McKenzie, Cory, and Lucena's reasons to make school more fun pushed against how schools have historically been used to control and track students. Their efforts helped Mrs. K realize how the lack of fun impacted her students' learning opportunities, how students saw the purposes of school, and how students realized what ways of being (compliance and completing work) were necessary for school success. They leveraged upon these insights to design a light-up Limbo Stick that directly addressed this need.

### 6.2.2 | Understanding and addressing the need to recognize accomplishments

Similarly, the All the Way Up Board designers defined a problem that mattered to both their peers and themselves based on their experiences and community ethnography data. Issa, Amir, and Danny felt that their classmates needed more opportunities to celebrate each other's achievements. The students were concerned that 34.15% of survey respondents agreed that students needed more opportunities to celebrate accomplishments. Issa explained, "It's solving like how some kids feel like when they do good things they don't get rewarded. We have that board and they can get rewarded. Because more kids need to get rewarded and it makes them feel good. It will show everybody what they did." Issa highlights the importance of helping his peers "feel good" when they do good things at school. Issa, Amir, and Danny were trying to support their peers emotionally and motivate them to keep doing positive things.

When the students began to make their board, they initially focused on making a way to celebrate students' good grades. Amir described their solution by describing the group's initial idea on a hand-out: "Accomplishment board. It has a list of students' names like a grade sheet with lights." However, as students further drew upon their peers' and their own experiences, with Mrs. K's support, they refined their solution to honor students' multiple forms of success.

The group began to notice that only certain students were recognized because they did well on official academic tasks ("getting good grades"), but not other positive class contributions. They felt that this only made not honoring students' accomplishments in their class worse. They sought ways to make visible to the classroom community every students' contributions. For example, Issa explained that he knew that having accomplishments recognized was important for his peers. He stated that he noticed that his classmate Sean thrived when he was recognized for his positive contributions to class and hard work. However, if his efforts were not acknowledged he would get upset and stop trying. The group's collective motivation resisted what and who is recognized, and for what purposes.

## 6.3 | Disrupting power as epistemologically central to designing solutions

As students further investigated their identified injustices throughout the unit, those concerns became epistemologically central to the engineering design process. The disruption of power became a central criterion of their design solution. This was evident in how the students built new understandings of and arguments for how their design should work. Ensuring that their projects disrupted injustices was an impetus for engaging in multiple design iterations. Below we highlight how both groups refined the technical and social specifications of their solution throughout the engineering design challenge.

### 6.3.1 | Designing for more fun

Over the four-week period, McKenzie, Lucena, and Cory expanded their investigation. Mrs. K had them discuss with peers and adults about the lack of fun and what could be done about it at school. They discussed different theories about how and why a lack of fun impacted opportunities to learn and feel welcomed in school. They sketched-up their design solution—a light-up Limbo Stick, powered by a hand crank generator—and included both technical/disciplinary (e.g., how many lights [power load], type of circuit that would support the power load, how they would power their circuit using renewable energy, materials, size, and shape) and social specifications (colors, how it addressed the problem they identified, and when and how it would be used; see Figure 4). They received feedback on their sketch-up from peers and local community members, such as visiting engineers and parents. They then used this information to inform their design optmizing.

For example, the Limbo Stick group engaged in dialogue with their teacher on how they wished their design to function. In doing so, Mrs. K better understood the students' concerns. She shared that she had "teacher blinders-on" to students' needs for fun because she was focused on meeting all of the expectations of the school, district, and state. As the group worked on their design, they periodically tested it, which meant, putting on music, moving around, and limboing. At one point, Ms. K. paused the class and invited everyone to join a limbo line to engage the classroom community in testing how the stick works. This testing, supported by Mrs. K, led to new questions and design considerations for the group, which were taken up over several additional iterations, including: (a) developing a plan with their classroom community for when and how the stick might be used; (b) turning the lights to a diagonal angle so the LED lights' lead wires did not poke people; and (c) spreading out the lights across the yardstick so that they were more esthetically pleasing and visible.

The classroom community's use of the light-up Limbo Stick opened up opportunities for students and teachers to relate to each other in new, and more humanizing ways. For example, Cory, McKenzie, and Lucena put the Limbo Stick across the hallway the fourth-grade students needed to traverse to see the 6th grade engineering designs. Therefore, the students had to limbo to see the other engineering designs. When the fourth-grade teacher who often had a serious demeanor saw her students limboing, she walked over and asked Lucena, McKenzie, and Cory to lower the Limbo Stick and crank the hand crank for the lights. Almost everyone in the room stopped and watched. A sixth grader turned on the limbo music, and the girls with a light-up drum engineering design played in rhythm while the teacher limboed. We have never seen an adult limbo so low. The students cheered loudly.

The fourth-grade teacher's interactions with the Limbo Stick and its makers, at least temporarily, renegotiated the ways teachers and students could be around each other. Cory said that it was "cool" that he "learned something" about the teacher. He did not know she was so good at limboing. Her fourth-grade students also seemed surprised that she would limbo so well. As the teacher and her class used the Limbo Stick, they were able to learn new things about each other through new types of interactions.

### 6.3.2 | Designing to honor students' accomplishments

Amir, Issa, and Danny also iteratively engaged in the engineering disciplinary practices of defining problems and designing solutions as they sought to honor their peers' accomplishments. For example, through the engineering design process, Danny's perspective about the importance of celebrating students' accomplishments broadened and became more complex. Initially, Danny understood the goal as recognizing students for earning good grades, but by looking more closely at the survey and interview data and talking with his peers, he realized that his peers were doing lots of great things that should be recognized. He wanted to recognize classmates for being kind, for improving and doing well in sports, not just getting perfect scores (which he earned often). Danny moved from a self-focused definition to a broader understanding of success.

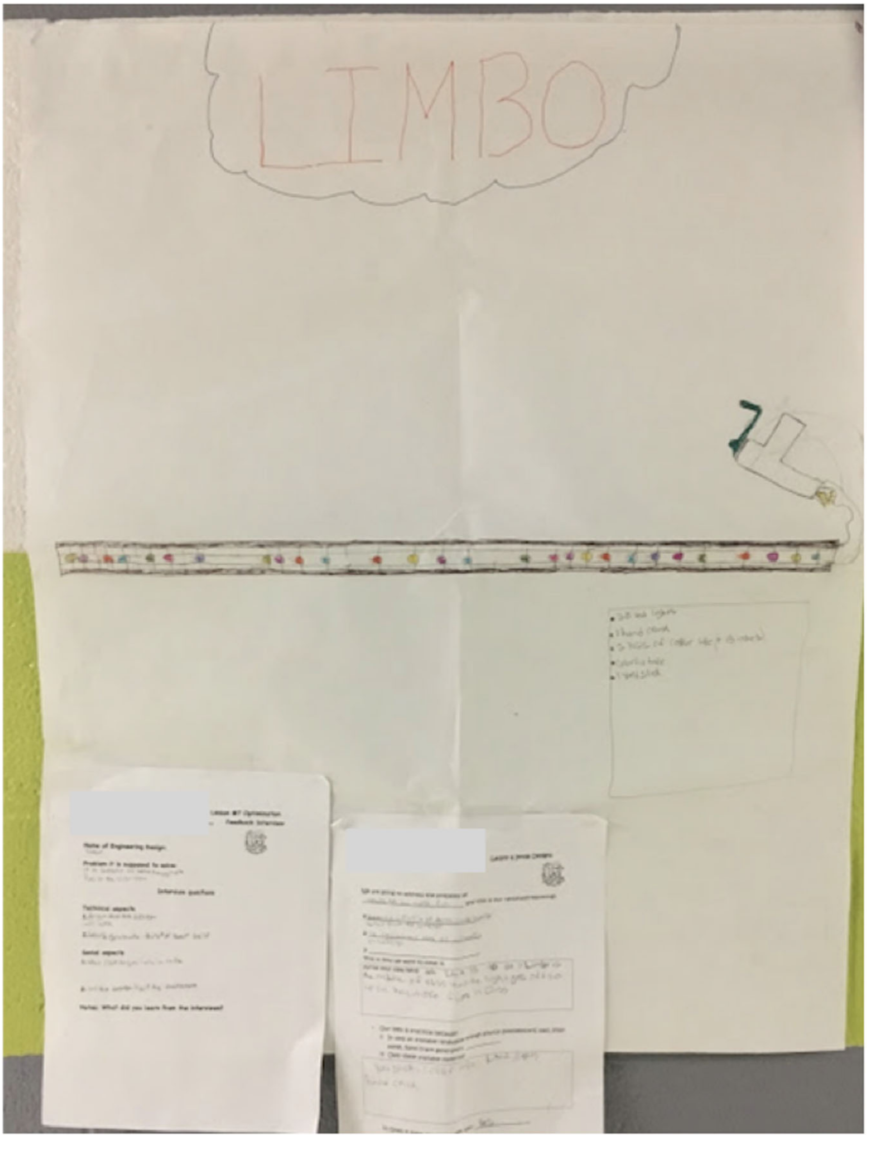


**FIGURE 4** Light-up Limbo Stick sketch-up [Color figure can be viewed at wileyonlinelibrary.com]

Danny's shift in recognizing his peers' success mattered as he previously benefitted from the power structure in his class that most often celebrated students with high grades. He explained to his mom that his classmates did "great things" that were ignored when he shared the Accomplishment Board's purpose, "Well I know that a lot of them have so many talents and they do stuff, but they don't really get recognized for that." His groups' efforts resisted how success is defined in schools at both an individual and class-wide level.

Issa, Danny, and Amir interviewed local community members to obtain technical and social feedback on their sketch-up designs before they prototyped. One community member, a former teacher, suggested that they should name their Accomplishment Board to better represent its goal. By the next day, Issa selected the name of the "All the Way Up" Accomplishment Board. This was inspired by the song "All the Way Up" by Fat Joe and Remy Ma. The lines that Issa repeated most were:

*I'm all the way up*

*I'm all the way up*

*I'm all the way up*

*I'm all the way up*

*Nothin' can stop me, I'm all the way up*

The group, however, often changed the words to "We're all the way up." Issa explained the "we" in the adapted lyrics represented "all the people" in his class, and Mrs. K was "in the middle of the 'we'." He saw his class working together to make sure everyone was recognized for their accomplishments, which worked to level who was able to celebrate students' success. He also disrupted what accomplishments counted in his classroom community. Naming the board helped the group better understand the classroom community's need to honor students' accomplishments.

Danny said that he thought Issa was the best person to name the board because of his creativity. Danny similarly connected the song to the purpose of the board when he explained the title, "Because you know, it's like, the main thing, you know, you're all the way up you know, all the way to the skies you know. Your accomplishments, it's kind of like all the way up to the skies."

The students challenged who could define, recognize, and encourage others to strive for accomplishments by creating a board that both students and teachers could use. This resisted the teacher–student power hierarchy often found in schools. This power disruption occurred because of and informed their iterative engagement in the engineering design cycle as they enacted CSA. They challenged what has been systematically and historically valued in schools (e.g., compliance and high test scores) and who has the authority to recognize accomplishments. While the school had formal measures in place to celebrate students' accomplishments, they had specific criteria that supported narrow ways of being a "successful" student. The boys expanded what counted as an accomplishment by thinking about students' progress and nonacademic achievements more while further supporting their peers in achieving more accomplishments. Through their light-up board, the students actively celebrated a wider range of achievements than what was recognized by the teachers in the school.

Throughout the engineering design cycle, the accomplishment group board also impacted the teacher–student hierarchies that existed in their school community. They challenged who gets to determine what is sanctioned as "school appropriate," what accomplishments are valued, and who gets to celebrate students' accomplishments. They not only saw the board as a way to celebrate accomplishments, but also as a way to encourage students to continue to strive to be their best. Issa explained how the Accomplishment Board worked, "When you know I get an accomplishment, that would help me, that would help me feel good about myself so I could do something else." By inviting their peers to add accomplishments to their engineering design, they further positioned their peers to support their classmates in achieving their goals. Table 3 highlights how, across both cases, the groups enacted CSA as they iteratively leverage multiple forms of disciplinary and social expertize to address their defined problems.

## 7 | MECHANISMS IMPACTING POWER HIERARCHIES OPERATING WITHIN GROUPS TO SUPPORT CSA

As groups enacted CSA, they addressed issues that mattered to their broader classroom community. We showed how both groups defined, refined and addressed students' needs not addressed through dominant school norms. However, as the groups engaged in the engineering process, their group interactions, at least initially, mirrored some oppressive norms operating within their classroom. These norms impacted students' opportunities to enact CSA. However, throughout the engineering process, the students restructured, in some ways, the power hierarchies

**TABLE 3** Enacting and expanding CSA while leveraging multiple forms of expertize

| Students enacting and expanding CSA | Expertize leveraged: Social | Expertize leveraged: Technical/disciplinary | Example-in-practice |
|---|---|---|---|
| • Identified oppressions that operate in the classrooms and naming them as critical problems they could solve | • Knew How to elicit, evaluate, balance and apply community members' input | • Applied energy transformation expertize to designing circuits | • The limbo stick group defined problem of lack of fun and not celebrating students' accomplishments based on community survey, observations, peer feedback and own lived experiences |
| • Worked more confidently on sketch up and building | • Insight from experiences, pop culture and peers to know what is fun/ appealing to students | • Analyzed the constraints/benefits of multiple green energy sources and circuit types | • Amir actively worked on troubleshooting his groups' circuit instead of watching his peers complete hand-outs |
| • Asked questions instead of deferring to others | • Artistic talent to design appealing and functional engineering designs | • Engaged in systematic troubleshooting | • The girls in the limbo stick group asked each other what they preferred instead of stalling their work when Cory was not in class |
| • Built and repaired designs when they were not working | | • Designed solutions based on defined problems | • McKenzie was able to fix the limbo stick when she was working by herself. |
| • Improved design based on deepened understanding of injustice operating | | | • All three members of the accomplishment board worked together to populate the board with a wide range of students' accomplishments |

operating within their groups. This occurred through both the recognition of students' broad expertize and distributing roles within groups. In doing so, the groups both defined their sustainability concerns grounded in power hierarchies and designed solutions more effectively.

Below, we delve into how the groups' enactment of CSA was impeded by and impacted power hierarchies. Students' experiences were impacted by the intersectional nature of oppression. However, we pay particular attention to the gendered dimensions of power hierarchies impacting and being impacted by the work of the light-up Limbo Group and how racial and linguistic hierarchies shaped the work of the All the Way Up group. We made this analytic decision given the salience of these forms of oppression operating within these specific groups. We then examine how recognition and role distribution supported moments of power disruption/restructuring, which further supported the groups' collective CSA enactment.

## 7.1 | Gender power hierarchies operating within the Light-up Limbo Stick

### 7.1.1 | Existing gendered power hierarchies

Power hierarchies operating within the classroom community had a gendered dimension. Considering how power hierarchies operate in ways that individuals are recognized and positioned with varying status and authority, the boys dominated the classroom in multiple ways. Across our long-term engagement with Mrs. K's class, we noticed how the boys had more opportunities to share their ideas. This was seen in group discussions. Boys much more than the girls would share answers in whole class discussion. Additionally, Mrs. K's attention was paid more to the boys than the girls as she was more likely to correct them and/or call on them to answer questions. This disproportionate attention was detrimental for all of the students in the class, but the girls had less access to the resource of their teacher's time or opportunities to leverage their expertize in the whole class setting.

This was visible in the Limbo Stick group's initial interactions. For example, during the sketch-up lesson, Cory was not in science class because he was in his reading pull-out class so only McKenzie and Lucena were working together. After working for about 5 minutes without sketching their Limbo Stick design, the girls indicated that they did not know what to sketch because the Limbo Stick was "Cory's idea" (even though the group settled upon the idea because it was a design idea submitted by a respondent on a community survey):

*McKenzie: [Katie], I don't really know how it is supposed to look because Cory came up with it.*

*Katie: Do you know what the idea was?*

*McKenzie: It was a limbo because we are trying to have more fun and there was going to be a circuit on it with the light, but I don't really know how it is going to look.*

*Katie: Did he talk to you about the ideas at all?*

*McKenzie: He was sort of talking about it and then we had to clean up so then we stopped.*

*Katie: Lucena you were there. What was he talking about?*

*Lucena: He was talking about how like how to grab the limbo, get the yardstick.*

*McKenzie: Yeah. He said there would be copper tape on it, it would be a circuit and it would have the light.*

*Katie: Cool and he was using a yardstick, right?*

*McKenzie and Lucena: Yeah.*

*Katie: So go ahead and write. Why don't you start [on the sketch-up] with the materials, right? You can fill in a lot of this, and it might make sense Lucena if you come sit on this side so you both can see it.*

The girls positioned themselves as unable to contribute to the design work without Cory. McKenzie noted that she did not "really know how it is going to look" and thus could not make design decisions. Additionally, Katie contributed to maintaining the power hierarchy when she asked the girls about his decisions rather than their preferences. However, when Katie asked the girls to work on the material section of the sketch-up, she leveraged their expert local knowledge of available classroom materials. This pedagogical support slightly disrupted the ways roles and power were distributed in their group. This led to the girls working together temporarily on the design instead of deferring to Cory.

A few minutes later, McKenzie called out to Katie asking to get Cory's input, further positioning him as the group's decision-maker:

*McKenzie (asking Katie): Can I go ask Cory what else we are using?*

*Jason (loudly): What is Cory your boss?*

*McKenzie (yelling back): Yeah, basically he came up with the idea.*

*Jason (slightly quieter): That still doesn't mean he is your boss.*

As Jason loudly told McKenzie that Cory was "not your boss," he interrupted her conversation. In doing so, Jason perpetuated the ways boys often talked over the girls within Mrs. K's classroom community. However, he also made visible the group's hierarchy that reflected these gendered dimensions.

McKenzie turned the conversation back to Katie to further seek help. This conversation further illustrates how power was maintained and disrupted through teacher and student dialogue:

*McKenzie: I wasn't there so I know we are doing yardstick limbo, but I don't know if it is a buzzer or?*

*Katie: You can only use lights so you know there are lights. So the good news is you are going to do it in pencil first so he can come help you make changes, and you are going to make changes over and over as you are doing this process so don't worry about it right now. I will definitely tell Cory that you really wanted his input and it will be nice for you all to be able to come back together.*

*McKenzie: I don't know if we are using a hand crank or solar panels?*

*Katie: What do you want? What do you want Lucena?*

*McKenzie: I want (pause) hand crank.*

*Katie: What about you Lucena?*

*Lucena: Yeah*

*Katie: I am giving you the power right now. Come up with, go crazy with your ideas. If he comes tomorrow, revisit the design.*

Katie reinforced normative classroom power hierarchies by saying she was *giving* the power to the girls which perpetuates the way that adults often dictate youths' actions in schools. When she told Lucena and McKenzie that Cory would be able to revise the plan when he returned, she was perpetuating the way that Cory was positioned as the ultimate decision-maker in the group.

Katie and the girls did, however, disrupt the ways the power hierarchy was operating as the girls were supported in making more decisions. As Katie supported the girls in making some of the technical design decisions, she recognized the girls' expertize, and leveraged upon that to further scaffold the new distribution of roles initiated earlier. McKenzie and Lucena began to work more confidently on their sketch-up and ask each other questions about both the technical and social dimensions of the design, instead of trying to defer to Cory. She also actively recognized the girls' rights and abilities to generate ideas for their engineering designs. By the end of class, the girls drafted most of the sketch-up.

### 7.1.2 | Recognizing expertize and distributing roles toward disrupting power

Throughout the engineering design iterative process, the Limbo Stick group challenged and slightly restructured the gendered power hierarchy operating initially within their group. This was supported through curricular and pedagogical interventions. Below we show how through actively supporting recognition and distributing roles the students restructured the gender power hierarchy, at times, in ways that supported their collective enactment of CSA. We also highlight ways that the dominant power hierarchies remained the same, and which impeded, to some extent, the group's enactments of CSA.

For example, watching the video of this short exchange, McKenzie shared how this moment helped her to see that she could take action and had ideas to contribute:

> *It was harder because we kept, we were talking about like we need Cory because it was Cory's idea, and but then we got used to it … I finally got the hang of it, and I knew how to draw it, and I knew what we were gonna do … And we did what we had to do instead of like saying we couldn't do it, and we needed Cory to do it. Because it was our idea too, like our group, so I finally got the hang of it, it was actually pretty easy.*

When McKenzie expressed "Because it was our idea too," she was recognizing Lucena's and her expertize. This was a disruption of how she previously saw Cory as the sole decision-maker. This shift supported her in enacting more agency. When she said, "We did what we had to do instead of saying we couldn't do it," McKenzie further recognized Lucena and her abilities to help direct the project. She was more aware of how they could better distribute roles across the engineering design process, which supported the group in optimizing their design when all three or only one group member was there. McKenzie later explained that Katie supported her in taking on new roles in the group by brainstorming ways to get started on the sketch-up. Additionally, she noticed Lucena showing how the parallel circuit should be built across the yardstick. Our conversation about distributing roles supported McKenzie in seeing herself as an important and capable group member.

McKenzie began to steadily apply her expertize throughout the project. By the end of the unit, she was confidently making choices about their engineering design. She had taken up new roles that she previously had not. Right before the community showcase, McKenzie was the only member of her group present because her peers were in their reading classes. She discovered that half of the Limbo Stick's lights were missing. McKenzie sat down, and quickly rearranged the circuit to equally space lightbulbs across the circuit. She worked quickly, calmly, and independently. While having developed circuitry knowledge across the unit supported her, McKenzie also needed to recognize her ability to use that knowledge and take on that fixing role. McKenzie described this moment as her *proudest moment* in the engineering unit.

McKenzie recognized her contributions to her groups efforts while reflecting with Katie when she shared, "I didn't leave, and I tried to finish it, and I did." She recognized her own abilities when she chose not to be frustrated and was focused "to get it done for the showcase." This highlights that her group's initial power hierarchy that was largely grounded in gendered interactions was transformed over the course of the unit as she moved from deferring to Cory about design details to completely repairing the Limbo Stick in the final moments before the showcase. McKenzie's self-recognition was connected to her technical knowledge of building circuits and finding solutions. This was supported by both the students and teachers recognizing each members' unique expertize and supporting a distribution of roles. As the group's power hierarchy was broken down, McKenzie supported her groups' collective enactment of CSA by fixing the design to support making school more fun.

Distributing roles by having each group member engage in both decision-making and design building was key to their efforts. The role distribution restructured their power hierarchy positively by supporting the girls in making decisions. This supported the whole group's efforts to collectively enact CSA. If the power distribution remained with only Cory making decisions about the Limbo Stick, the group would not have had the success they had. Together the group was able to effectively distribute the lights across their design, create a working parallel circuit and optimize their design for easy classroom use. McKenzie and Cory both explained that they could not make the Limbo Stick on their own because the help was necessary for figuring out how to make it.

Cory explained the light-up Limbo Stick showed not just how smart he was, but also his teammates' smartness:

> *Because of how like, well it's not just me that's smart. Our whole group, me and Lucena and McKenzie, when you start off people don't know what they're going to do, so you got to think about it. Think about it, think about it. [emphatically] And then you come up with an idea. That is time consuming, you put all the lights on, and decorate, and I just feel like it was a smart idea to do it. Everyone likes it, we finished it on time, and it was cool.*

Cory's explanation highlights how he recognized the whole group's "smartness." He highlighted together they were creative, persevered and made the circuits work. By recognizing each other's expertize, the students were more fully able to enact CSA.

However, the power disruption did not lead to a complete restructuring of the group hierarchy. Cory and Lucena seemed to maintain their positions in their group in a way that reflected the social hierarchies of their classroom and in enacting CSA. However, McKenzie took on more active and assertive roles to engineer to make school more fun. This disrupted the hierarchy that reflected the classroom's gendered hierarchy. She stopped relying on Cory as much, and began to see herself as capable, able and welcome to enact CSA. Her efforts were supported by interventions made by her teachers. Tensions, however, emerged in this group work. More teacher interventions could have supported Cory in seeing how he dominated his group, and for both McKenzie and Cory to better recognize Lucena's contributions. This case highlights how recognition and distributing roles can support restructuring power hierarchies for one student, but not another student.

## 7.2 | Racial and linguistic power hierarchies operating within the All the Way Up Board Group

### 7.2.1 | Existing racial and linguistic power hierarchies

Power hierarchies also operated within the Accomplishment Board group. The hierarchy within the accomplishment group often reflected the racialized and linguistic ways power was distributed within their class and among students. Enacted school-wide practices and pedagogical practices positioned certain socially constructed groups with more power within the classroom and within small groups. For example, the White and English-only speaking boys were more likely to rewarded and less likely to be disciplined than the Black boys through official school programs and teachers' actions. A disproportionately high number of White, English-only speaking boys were included in the student reward program and a disproportionately high number of Black, multilingual boys were included in the student behavioral support program.

The power hierarchy within the classroom community valued students' English speaking and writing skills over other forms of expertize. Mrs. K was overwhelmed by the linguistic diversity within the class, and she often cited her challenge in supporting six students who were "basic English language learners." Additionally, the class norms distributed power to the students who were not emergent multilingual students by pairing students as the tutors (the monolingual English speakers) and the tutees (the multilingual speakers). This strategy was meant to support emergent multilingual students. However, it positioned the students who were raised in the school's city as experts, and the students who recently immigrated as capable of only receiving help rather than being able to share their expertize. Additionally, the students born in the United States, and especially the White students, given the political rhetoric and actions against refugees and endemic racism in the United States, were positioned by current societal discourse to hold more likely institutionalized power in the classroom than the emerging multilingual students learning English.

The intersections of the group members' language and race impacted how the students enacted CSA and were positioned in their groups. White boys in both the light-up Limbo Stick and Accomplishment Board were initially positioned as the group leaders and experts. This was evident in how McKenzie and Lucena would defer to Cory's design decisions and not make them without him and how Danny initially ignored the contributions of his group members as they worked to define the problem they wanted to solve. Neither Cory nor Danny shared that they were aware of how they were dominating the design process at the beginning of the unit and neither did their teacher or the participant-researchers. This highlights how individuals positioned with power due to their socially constructed identities often do not see how they are wielding power and perpetuating oppression (Leonardo, 2009).

This linguicism was reflected in the Accomplishment Board group. Through his initial actions and comments, Danny saw himself as the expert in the group and believed that the other two students did not have much to contribute. When the students were analyzing the community survey data, Danny said, "I am basically working on this by myself." However, Danny and Amir's survey analysis hand-outs had some similar and different answers. This is just a glimpse into the evidence that Danny missed an opportunity to learn from and recognize Amir's contributions. This pattern mirrored the ways students who were emergent bilingual students were positioned in the classroom community throughout the year as needing help rather than being able to give help.

### 7.2.2 | Recognizing expertize and distributing roles toward disrupting power

The Accomplishment Board group challenged and slightly restructured the racial and linguistic power hierarchy operating initially within their group. Like in the Limbo Stick group's experience, pedagogical and curricular scaffolds supported the Accomplishment Board group in restructuring power hierarchies through recognition and distributing roles. These pedagogical and curricular tools supported Issa, Amir and Danny in restructuring their group's power hierarchy at times in ways that supported their enactment of collective CSA. In this section, we also highlight ways that the dominant power hierarchies remained intact, which limited the groups' enactments of collective CSA.

Initially, the boys worked independently. There was not much communication across the group. Danny tended to work on the design, while Amir would watch, and Issa would go interact with another group. As the unit progressed, many mechanisms supported the group in distributing roles more. Through small group and whole class pedagogical interventions, Mrs. K repeatedly emphasized that everyone should be doing something in their groups. The curriculum also supported more forms of participation as the students moved from writing activities to prototyping activities. In these different opportunities for participation, the students recognized and supported each other in utilizing their expertize in expanded ways, and thus disrupted the power hierarchy that existed within their group.

Issa's increased engagement further supported role disruption and recognition of each other's expertize. He explained to me that "It's really good" working with both Amir and Danny. He recognized his peers' expertize and distributed roles when he translanguaged across the group by speaking in English with Danny and Kirundi with Amir. Amir then took on a more active role in the circuit building, and Danny began to talk and joke with his group members. This pushed against the ways the three students were positioned at the beginning of the unit. Amir and Issa were supported in more actively contributing to the engineering design process, and Danny was supported in collaborating with others instead of taking over projects.

The curricular materials further supported the students in distributing roles when Issa began to work more with his group. After they finished sketching their design, the students completed a building plan that included the big steps that needed to be completed, considerations for that step, and who was in charge of the step. They stapled their building plan to their sketch-up. Issa was the leader of naming the board, Amir was the leader in making the circuit, Danny was in charge of determining the board size and putting it on the wall. As the students fulfilled their first "official" roles, they began to take on more technical and collaborative roles. For example, all of the students worked together when determining where breaks were occurring in their circuit.

The prototyping lesson further supported the students distributing roles because they could actively participate in engineering by building their design instead of participating mainly through required writing or speaking. The boys made their Accomplishment Board and built the circuit on it. This led to more opportunities for Amir and Issa to use their expertize in expanded ways. For example, Amir was often the lead expert of building and troubleshooting circuits. He would quickly troubleshoot the faulty circuit, making the connection stronger and reduce resistance.

Through recognizing expertize, the students' restructuring of who was recognized as experts in the group continued a month later when they were preparing for STEM night. The boys worked to make minor improvements to their Accomplishment Board. Katie encouraged them to brainstorm more accomplishments, in whatever language they preferred, to add to the board. This is an example of how students' actions are always mediated by norms about whose languages and expertize are welcomed within a space. Amir brainstormed accomplishments, shared them with Issa in Kirundi, and Issa wrote them down. They all tested that the lights were working before the event began.

By the end of the unit, the boys recognized how each other's roles expanded and were necessary toward enacting CSA. This recognition was evident both in their words and actions sharing engineering tasks. This disrupted their groups' power hierarchy that mirrored the ways that multilingual, Black boys were often positioned as needing help and the monolingual, White boys as being the class experts. Danny described the roles that each member of his group filled:

> *Amir, he kind of showed creative ideas, you know, he kind of showed like, you know, the lights he came up with that. He kind of put the tape on, he showed the best ideas to solve. Issa, he showed us to make it a little bit more cooler and nicer, so other kids can realize about this. And I showed like, kind of like experience, I am also the planner, I planned everything.*

Danny showed how he recognized the social and disciplinary contributions by citing individual things each member completed. However, when Danny said that he "planned everything" he minimized his peers' contribution. His comment perpetuates how Danny was often positioned as an expert in his class and the group. It also highlights the ways he struggled to recognize and restructure his groups' power dynamic. However, his words show how he was resisting the original hierarchy by better recognizing his peers' contributions than previously. This further supported the group's efforts to recognize students' multiple abilities and accomplishments, which was initially a challenge for him.

Restructuring the groups' power dynamic supported the students in enacting CSA by increasing their collaboration. Danny shared that the group was able to work together to address challenges better than if he was working alone. As he explained how his group would troubleshoot together, it was clear that the young people were collectively enacting CSA, which would not be possible if they had not distributed roles and recognized each other's expertize. Collaborating supported the students in both understanding the design problem and optimizing their solution.

> *Katie: Do you think there was anything that was special that came from you working with two other people on this?*
>
> *Danny: Well, it kind of helped. I know one thing is, you know, what is not working, two people on the board kind of crowds it. And if someone had a problem, that last person can come and help and then the next person can help. Then it would get done faster. And then we can test it all together.*

Danny's description of rotating who was troubleshooting highlights how he recognized and supported his group members' contributions in ways he previously had not. This distributed and collaborative effort supported the group enacting CSA as they optimized their design to better recognize their classmates' accomplishments.

Similarly, Amir and Issa further disrupted their groups' power hierarchy through recognizing everyone's expertize and distributing roles. Issa disrupted the language hierarchies among the group by using two languages to communicate with Amir and Danny. He noted that everyone in the class including Mrs. K worked together to make people feel good about their accomplishments. Amir led troubleshooting efforts when the circuit would stop working and the hand crank broke. This pushed against the ways he was often positioned as the one needing help in class. The group gradually began to recognize each other more for their talents and wide-range of expertize and distribute roles more, which disrupted the groups' power hierarchy and positioned them to further enact collective CSA.

Across both cases there was a restructuring of power hierarchies as the groups enacted CSA. Both the curricula and pedagogical interactions supported this restructuring. Table four highlights how curricular and pedagogical scaffolds supported restructuring power hierarchies through three different mechanisms: recognition of student's expertize, scaffolding the distribution of roles and making and using engineering designs that address injustice (Table 4).

## 8 | DISCUSSION

The Limbo Stick group and the Accomplishment Board group's experiences highlight three important characteristics of CSA. First, enacting collective CSA unfolds over time, through interactions and with scaffolding tools in classrooms. Second, students need to not just use multiple forms of expertize, but know that they those forms of expertize are critical in the enactment of collective CSA. Finally, power hierarchies impact and impede CSA enactment at the group level as the students address class-wide issues of injustice.

### 8.1 | Collective CSA over time

CSA can be a collective effort that unfolds, over time, as students have opportunities to learn with and from each other and members of their overlapping classroom, school and local community members as they refine, build, testing, and optimize their engineering designs. Each of these steps in the iterative design process created spaces for the students to contribute various forms of expertize in project development (technical knowledge of circuit design and power loading, creativity, art, scientific, and social explanation, etc.). As students contributed different forms of expertize, they also had to negotiate how these different pieces fit together toward a working design. Ensuring the designs would work in and for their classroom community was essential in this process. It not only made the experience more real, it was a constant point of negotiation as the students sought to solve the problems they identified. Mrs. K further supported these efforts by encouraging students to further test and get more feedback from their peers as they iteratively designed their solutions. As the engineering practices of defining problems and designing solutions continue to be incorporated into K12 education (NGSS Lead States, 2013), this study shows the importance of students being supported in engaging in those disciplinary practices with their classroom, school, and local community toward collective science agency.

Enacting collective critical agency also continued as an outcome of the students' final engineering designs. Both the light-up Limbo Stick and the All the Way Up Accomplishment Board address ways power was operating at the class level. As Mrs. K and the students used the final engineering designs throughout the rest of the school year, they were supporting students in having more fun and recognizing students' multifaceted accomplishments. Additionally, they were restructuring norms within the classroom by challenging how the classroom and school community members interacted and positioned students, not just teachers, as capable of recognizing each other's accomplishments. At an individual level, each group members' expertize was also publicly recognized as their engineering design was used. These cases highlight how pedagogical and curricular scaffolds are necessary to support students enacting collective CSA over time.

### 8.2 | Valuing multiple forms of expertize to support collective enactment of CSA

This study shows that students need to not only use multiple of expertize, but also know those forms of expertize are valued as they enact collective CSA. Both groups struggled to work in equity-oriented ways when writing was the main output (survey analysis hand-out, sketch-up's). Danny expressed that he was working by himself even though his peers were on task when they were completing their survey analysis hand-outs individually. Similarly,

**TABLE 4** Mechanisms supporting the restructuring power hierarchies within classrooms

| Mechanisms | Curricular scaffolds supporting power restructuring | Pedagogical scaffolds to support power restructuring: Teacher-initiated | Pedagogical scaffolds to support power restructuring: Student-initiated |
|---|---|---|---|
| Recognition of student's expertize | • By completing the building plan hand-out, the Accomplishment Board group recognized each other's expertize. | • Katie recognized McKenzie and Lucena's ideas and encouraged them to make decisions instead of deferring to Cory. | • McKenzie realized the Limbo Stick idea was not just Cory's idea, but their whole groups idea, and she could contribute her own |
| | • Mrs. K organized a showcase for the students' to share their engineering designs and new community and science expertize. | • Mrs. K recognized the assets of the students' community by encouraging them to get feedback from school and local community members. | • Cory described his whole group as "smart" because everyone's ideas were needed |
| Scaffolding the distribution of roles | • By completing the building plan hand-out, the Accomplishment Board group determined who would do what on their design. | • Katie listed design decisions that Lucena and McKenzie could make. | • Issa was the leader of naming the board, Amir was the leader in making the board, Danny was in charge of determining the board size and putting it on the wall. |
| | • Prototyping the designs required multiple forms of expertize. | • Mrs. K repeatedly that everyone in each group should be doing something.<br>• Katie encouraged students to talk and write in their preferred language. | • When they were brainstorming new accomplishments, Amir brainstormed them, shared them with Issa in Kirundi, and Issa wrote them down. |
| Making and Using Engineering Designs that Address Injustice | • The community surveys added salience to their understanding of community challenges. | • Mrs. K tried to program her phone for automatic class limbo breaks. At a STEM night, she organized a limbo game for both kids and adults. | • The Limbo Stick group had everyone (adults and kids) who was able limbo as they visited their class's design showcase. |
| | • As students were supported in defining the problem and designing their solution, students understanding of the injustice in their classroom deepened.<br>• Danny realized his peers' accomplishments were not celebrated by the current systems in his class.<br>• The Limbo Stick group understood that the lack of fun impacted students' learning opportunities. | • Both projects' goals supported Mrs. K in paying attention to the needs of her students. | • The Accomplishment Board group expanded what counted as an accomplishment by thinking about students' progress and nonacademic achievements more while further supporting their peers in achieving more accomplishments. |

Lucena and McKenzie felt like they could not make drawing decisions on their sketch-up without Cory. These groups dramatically shifted how they participated and recognized each other's expertize when the lessons required multiple tasks requiring varying expertize to be accomplished. Both groups began to recognize each others' potential when they were all able to work on completing their engineering designs in different ways. Using other forms of expertize was often a powerful entry point to deeper engineering engagement.

Creating spaces to value nontraditional forms of expertize in Mrs. K's class through recognition had a cascading effect. As students' various forms of expertize became legitimized, new spaces were opened for more types of expertize to be valued too. When Katie recognized McKenzie and Lucena's expertize and rights to make design decisions, they began to take on more design decisions. This supported Cory to also see their ability to contribute to the group, which was obvious as he referred to his whole group, not just as himself as "smart." Recognizing students for specific expertize led to more opportunities for that student's expertize to be recognized and then generatively leveraged by others. If Danny did not realize that Issa and Amir were able to contribute both social and technical expertize to their work, he would have continued to work on his own and reject their contributions. If McKenzie did not recognize her expertize, she would not have been able to fix the Limbo Stick on her own the day before the showcase. Conversely, when McKenzie and Cory did not recognize Lucena's expertize, the group did not leverage her talents in improving their design. Perhaps, more teacher recognition of Lucena's contributions would have supported more justice-oriented group work. Through this expansion of recognition, students and their peers noticed and further positioned each other to further develop and apply their expertize toward collective CSA enactment.

Curricular tasks that require multiple forms of expertize may support valuing and leveraging multiple forms of expertize as groups enact collective CSA. Other studies (Boaler, 2006) have highlighted how curricular designs that required multiple forms of expertize support students in using disciplinary knowledge in justice-oriented ways. This study further highlights the importance of curricular tasks requiring multiple forms of expertize to more effectively support students in reaching their group's goals, while also showing how this strategy may support a restructuring of power dynamics within the groups. Work in complex instruction in mathematics education has similarly shown that tasks that are designed to encourage the use of multiple abilities can support more equitable outcomes for learners (Boaler & Staples, 2008). This study highlights how researchers, teachers, and students can support students in enacting collective CSA using approaches that open up collaborative learning tasks and spaces for multiple types of expertize.

## 8.3 | The relationship between power hierarchies and collective CSA

Enacting collective CSA was limited by, but also impacted power hierarchies operating at both the classroom and group level. While students worked to address injustice at a classroom level, power hierarchies at their group level impacted their opportunity to do so. Much scholarship has investigated how students' efforts to enact critical agency was impacted by interactions with adults and within varying levels of power and institutions (Turner, 2012). For example, studies have focused on students' interactions with their physic teacher, and another study has highlighted how young people prepared to advocate successfully to their afterschool club's board for a new energy-efficient roof (Basu et al., 2009; Calabrese Barton & Tan, 2010). Turner (2012) highlights how high schoolers worked to convince the school district that overcrowding in their school should be addressed. However, this study adds another level of analysis of power and CSA by paying attention to the ways group dynamics impact students' opportunities to address injustice.

Power hierarchies operating within groups impacted students' efforts to enact collective CSA. As the students collectively sought to address injustice in their classroom community through defining problems and designing solutions, their actions and interactions were situated within their own groups' power hierarchies. As they restructured those power hierarchies, at times, through recognition and role distribution, the groups were better able to enact collective CSA. However, when those power hierarchies were not restructured, less student expertize was shared or leveraged. This process highlights the ways power operates at multiple levels and must be considered when supporting students and teachers in enacting collective CSA.

## 9 | CONCLUSION

Even as students sought to address injustice at a classroom level, enacting CSA is entwined within systems of power at the group level. This study highlights the importance of disrupting inequitable power distributions within groups and provides insight into ways to support students as they work to addresses injustice both within and beyond their group. Power hierarchies within the classroom impeded and were impacted by their CSA enactment. This study supports teachers in better understanding how to identify and disrupt power hierarchies found in classrooms. This study pushes science education researchers to better understand students' learning in conjunction with the ways power operates within classrooms. Finally, this study pushes education researchers to investigate how to design opportunities to enact CSA. This may lead to positioning students with more opportunities to develop and utilize multiple forms of community and science knowledge/practices in ways that matter to them. This may support more justice-oriented science learning.

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