PARTICIPATORY PLANNING AND TEACHING TO SUPPORT COLLECTIVE CRITICAL SCIENCE AGENCY IN A SIXTH GRADE SCIENCE CLASS

By

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ABSTRACT

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Despite calls to support more justice-oriented science learning, classroom interactions still often reflect the sociohistorical systems of power and oppression within which they are situated. Youth enacting critical science – using science and other forms of expertise to address issues of injustice – is an approach that has led to at least temporary restructuring of power hierarchies within and beyond their classrooms. However, there is a dearth of research highlighting the social dimensions of critical science agency. Also, the mechanisms supporting class communities' enactments of critical science agency are undertheorized.

Therefore, I explored the experiences of Mrs. B, her students and myself as we participatory planned and taught a family STEM night about engineering design, energy and electricity. Building on experiences engaging in an electric art engineering design challenge unit, the class community co-planned and co-enacted the event. The class disrupted power hierarchies traditionally operating within science classrooms and prepared an engaging learning opportunity connected to their families' lives. Throughout this process, Mrs. B's class community was enacting critical science agency.

Given the need for the field to better understand how to support critical science agency, I specifically explored with Mrs. B and her sixth-grade students: 1) What does critical science agency look like in Mrs. B's sixth-grade science classroom? *And 2)* How, if at all, does participatory planning and teaching support critical science agency?

Multiple data sources (interviews, field notes, student work, small and whole group interactions videos, conversation groups) were generated using critical ethnographic methods. Data was analyzed using a social practice theory lens with a power and consequential learning focus.

This dissertation builds on critical science agency research in two main ways. First, critical science agency is a collective act, involving a) using distributed and diverse forms of expertise, b) generatively building on and welcoming shared expertise over time through actions and discourse taken up by multiple community members and c) using that diverse and distributed expertise towards co-defined meaningful ends. This claim is highlighted through analytic vignettes of the participatory planning and teaching events that took place over the series of preparing and enacting STEM night. Second, the enactment of participatory planning and teaching practices supported collective critical science agency by: disrupting and amplifying class norms towards more just ends, supporting expanded authority, and allowing for addressing and co-defining outcomes of learning. This claim was highlighted by describing participatory planning and teaching practices that were enacted across the STEM night preparation. I also analyzed the relationships between those practices, amplifying/disrupting class norms and supporting expanded students' authority through an extended vignette of two students' experiences making a how-to, GIF-style electric art video. I conclude by presenting an analysis of the relationship between critical science agency and participatory planning and teaching.

These findings provide insight into powerful pedagogical and methodological approaches teachers, students and researchers can use to support more justice-oriented science learning within and beyond their classrooms. Implications include ways to analyze power within classrooms and a nuanced understanding of how to support enacting critical science agency.

To the students with whom I have learned,
thank you for teaching me.

To Ted, Maggie, Jane and Ben,
may your educations work for justice and be filled with joy.

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Chapter 1: Introduction

Like how people ask for help in stores, I felt like one of those people who help the people at the store.

-Cristina, 6th grade, participatory planner and teacher at STEM night

Cristina's quote highlights her feelings after teaching her grandmother and two sisters how to make electric art at STEM night. She felt "like one of those people who could help the people". This is particularly powerful as Cristina was helping her own family learn about energy and making circuits, which she learned how to do in school. It is even more powerful because Cristina taught her family by showing them a how-to electric art video she made to teach STEM night visitors. She and her classmate, Eric, created the video during recess. When her family successfully made their own electric art, they then took it home to share with the rest of Cristina's family. Cristina, her classmates, her teacher and I participatory planned and taught STEM night together. Throughout the process, the class community generatively and collectively leveraged multiple types of expertise to first co-define the goals of, prepare for and enact STEM night. This led to many powerful learning outcomes for Cristina and her class community.

Statement of Purpose

The purpose of this dissertation is to investigate ways students, teachers and researcher can support more critical justice within and beyond science classrooms. By critical justice, I mean identifying and addressing injustices grounded within sociohistorical contexts (Balibar, Mezzadra & Samaddar, 2012). This work is important because historicized injustice has long limited whose knowledge and for what ends counts within science education (Bang et al., 2016). Taking a critical justice stance recognizes the ways that interactions are situated within broader systems of power, and indeed science and engineering education can perpetuate those systems of injustice (Tan, Calabrese Barton & Benavides, 2019).

The participatory planning and teaching process was both a pedagogical and research methodological approach that aligned with the study's goal to support critical justice within and beyond the classroom community. This approach falls underneath a broader youth participatory action research umbrella (Cammarota & Fine, 2010). However, its enactment contributes new insights into how students teaching can at least temporally restructure power dynamics between teachers, students and researchers. A critical justice view of equity requires challenging, traditional patterns of participation to expand upon who and what areas of expertise are recognized and valued. This challenging can potentially disrupt participation boundaries and knowledge hierarchies (Jurow & Shea, 2015). Power is always operating within science classrooms and researcher-participant relationships. Therefore, as students, Mrs. B and I to tried to enact a critical justice approach to learning together, participatory planning and teaching was one way to challenge to disrupt hierarchies present within our relationships.

This study further explores how Mrs. B's class community engaging in participatory planning and teaching supported new norms of interacting both within and beyond the class community. Cristina and her class community were able to support critical justice as they participatory planned and taught STEM night together. They collectively transformed power relations within and beyond their class community. This was seen in the ways students expanded epistemic and positional authority to further participatory plan and teach. It was also seen in the meaningful learning outcomes they created for their families. These justice-oriented outcomes occurred as they collectively enacted critical science agency. By critical science agency, I mean using science and other forms of expertise to address issues of injustice (Basu et al., 2009).

Critical science agency is a form of consequential learning, which means it is a collective, relational and political process that supports meaningful action across temporal, spatial and relational scales (Jurow & Shea, 2015). Supporting consequential learning is one way to support more critical justice-oriented science learning.

Critical science agency has been shown to support consequential learning outcomes (e.g., Basu et al., 2009, Basu & Calabrese Barton, 2010) as youth leverage their expertise and act in meaningful ways. However, the field of science education's understanding of what critical science agency actually looks like within a classroom is limited. Similarly, there is a minimal understanding of how to design a class community to navigate the social dimension of enacting critical science agency. However, given the need to support more justice-oriented education, understanding how class communities enact critical science agency is motivating.

Research Questions

Given the powerful ways Mrs. B's class community's enactment of critical science agency supported more justice-oriented learning opportunities and the limited understanding of critical science in the literature, it is important to investigate what supported such transformational outcomes. Therefore, this study investigates:

1. What does critical science agency look like in Mrs. B's sixth-grade science classroom?
2. How, if at all, does participatory planning and teaching support critical science agency?

Most research in science education focuses on designing learning spaces to support students' development of science and engineering practices and knowledge for their own understanding. My study pushes the field to design ways to support consequential learning, in the form of critical science agency, for more justice-oriented science classrooms and broader communities. This work provides impetus for science and engineering education researchers and practitioners to consider in what ways heterogeneous (in terms of race, language and gender) class communities can use participatory planning and teaching practices to disrupt power hierarchies and support critical science agency.

I explored these questions with Mrs. B's sixth-grade classroom community using critical participatory ethnographic methods. This study took place at Wilkerson School, which is an urban school in a small, Midwest city. This site was chosen intentionally given my four-year relationship with the school, Mrs. B's interest in collaborating and the racial, linguistic and gender diversity of the student population. Throughout, Mrs. B, her students and I participatory planned and taught STEM night. By participatory planning and teaching, I mean students, Mrs. B and I co-defined the learning outcomes for STEM night and decided on how to support those learning outcomes through plans for particular activities and experiences. Then, the class community worked together to enact those plans by both preparing educative materials and teaching at STEM night.

The data sources generated in this study align with the critical ethnography methods (Thomas, 1993). They included interviews, field notes, participant observations, pictures of student work, video of small group and whole class conversations, conversation group recordings. I analyzed this data using a social practice theory lens with a focus on power and consequential learning.

Overview of Chapters

The remainder of this dissertation spans four chapters were I further explore the relationship between participatory planning and teaching, and Mrs. B’s class community’s collective enactment of critical science agency.

Chapter Two: Literature Review and Conceptual Framework

Chapter two contains the literature review and conceptual framework for this study. The literature review situates this study's enacted critical justice view of equity. Additionally, the literature review shows why supporting sixth graders in using engineering meaningfully, leveraging participatory planning and teaching methodologies and supporting the enactment of critical science agency may have strong implications for the field of science education. The rationale and components of the conceptual framework are then explained. The framework is social practice theory with a conceptual understanding of power and consequential learning.

Chapter Three: Contexts, Methods and Analysis

This chapter first describes the research site and the participants (Mrs. B, students, myself) of the study. Then it describes the methods used in this critical participatory ethnography. The data collection methods used in this study included participant observation, field notes, conversation groups, interviews and video of whole and small group interactions. I then highlight the analysis that took place and how it aligned with the conceptual framework.

Chapter Four: Findings

Findings are explored in two main sections. The first section explores, *What does critical science agency look like in Mrs. B's sixth-grade science classroom?*. I explore this question through an analytical narrative of the class community planning, preparing and enacting their STEM night. Claims show critical science agency is a collective act, involving: a) using distributed and diverse forms of expertise, b) generatively building on and welcoming shared expertise over time through actions and discourse taken up by multiple community members and c) using that hybrid expertise towards co-defined meaningful ends.

Then I explore, *How, if at all, does participatory planning and teaching support critical science agency?*. My claims show: The enactment of participatory planning and teaching practices supported collective critical science agency by: disrupting and amplifying class norms towards more just ends, supporting expanded authority, and allowing for addressing and co-defining outcomes of learning. I build this claim by describing participatory planning and teaching practices that were enacted across the STEM night preparation. Then, I further explore these practices through an extended vignette of Cristina and Eric's experiences making a how-to, GIF-style electric art video. I then zoom out to highlight how participatory planning and teaching practices supported amplification and disruption of norms towards more just ends and supported students' expanded authority. Then, I look across both claims to illustrate the relationships between participatory planning and teaching, norm disruption/amplification, expanded student authority and enacting critical science agency.

Chapter Five: Discussion

In the discussion, I connect the findings of this study to the field of educational research and share implications for teaching and learning. I highlight limitations of the study and paths for future research.

Chapter Two: Literature Review and Conceptual Framework

In this study, I worked to understand with Mrs. B and her students how participatory planning supported consequential learning, particularly critical science agency. In doing so, I paid particular attention to power operating within their classroom community. Within this chapter, I first share a literature review showing persistent equity concerns in STEM education to highlight where my view of equity is situated. Then, I highlight why participatory planning, engineering with middle school students and supporting class communities enacting critical science agency may be ways to support more justice-oriented learning opportunities. This argument, situated within the literature, supports both the conceptual framework and methodological choices made for this study.

Next, I unpack my conceptual framework. I first further define and highlight how consequential learning pushes on sociocultural theories of learning by valuing justice-oriented transformative outcomes and paying attention to how learning is always situated within systems of power. I define power, analyze how it operates at multiple scales within society and shapes learning opportunities within classrooms. I highlight how expanded authority can be used as a proxy for power. I conclude by explaining how social practice theory can be a helpful analytic tool to explore how participatory planning and teaching supports a class community enacting critical science agency. Throughout this chapter, I show how scholarship from and beyond the field of science education research supports this conceptual framework approach integrating consequential learning, power, and social practice theory.

Literature Review

Inequity in STEM

To establish the need for this study, I explored the ways in which inequity in STEM has been perpetuated in urban settings while critiquing the dominant equity narratives that have emerged to address it in the United States. I use the term STEM to refer to the integration of engineering and technology into science and math education, a major move in U.S.-based reforms, rather than the more traditional acronym of science, technology, engineering and math. This distinction highlights how engineering in middle school science education is one way to position youth to integrate the disciplines in meaningful ways (National Academy of Engineering, 2014). Through highlighting others' scholarship and exploring my own journey from being a teacher to also being an educational researcher, I then conceptualize a more justice-oriented view of equity and explore alternatives to build on and expand the conversation found in science and engineering education in ways that promote justice-oriented science education through participatory planning and teaching, expanding student authority and supporting collecting enactments of critical science agency.

Access. One major equity narrative centers on STEM career and education access. Certain groups of people have been historically underrepresented in STEM education programs and careers in the United States. In particular, women and many people of Color have been historically underrepresented in STEM careers and education for decades (National Science Foundation, National Center for Science and Engineering Statistics, 2015). National initiatives, serving the neoliberal agenda rather than individual and community empowerment, have been motivated by industrial and international competition to address this inequality with limited success (Holdren, Marrett, & Suresh, 2013). Labeling this as an achievement gap ignores the barriers, such as sexism and white supremacy, to access that members of groups historically underrepresented in STEM face. Rather, drawing on the language of an opportunity gap, an education debt more aptly describes the reason STEM education and careers are predominantly dominated by White and socioeconomically advantaged men (Ladson-Billings, 2006).

Students in urban school settings receive fewer STEM opportunities compared to students in suburban schools. Tate (2001) explained that schools in urban districts face much higher risks in standardized testing because of the need to maintain funding connected to test scores. Recent large scale studies show that youth from low-income communities, who historically have been under-represented in STEM fields, are more likely to attend schools with under-resourced STEM programs, which include, out-of-field teachers, inadequate materials/equipment, more text and less inquiry-focused instruction, greater focus on math/literacy limited STEM instructional time (Banilower, 2018). One decade later, Au (2011) noted the subjects that are assessed through high stakes testing (reading and mathematics) are taught even more as the financial consequences are even higher for schools at risk for failing to meet test benchmarks. Science is often completely absent in students' education experience at the K-8 level. As school funding is now tied even more to schools' standardized test results, science is taught less in schools that are under-resourced, as administrators are desperate to maintain the funding they do have. As an elementary science methods instructor in a teacher preparation program, I noticed the majority of the teacher candidates in my courses did not see science taught during their field placement. When I taught middle school in Chicago, most of my students did not have science class until they were in fifth grade. This reality (both my own experience and documented research) is at odds with not just national initiatives to address the opportunity gap in STEM, but also their rights of students to develop and use science expertise in ways that matter to them and their community.

Dominant discourse of science. While increasing access is one necessary step for fostering more equity in STEM education, it is not the only effort that needs to take place. The dominant discourse of science needs to be challenged and disrupted. Educators, scientists, and educational stakeholders have long promoted science as a universalist epistemology that is devoid of cultural bias or values, while advancing a narrow, Western way of knowing and doing science (Stanley & Brickhouse, 1994). As such, repeated calls to value the rich cultural ways of knowing of non-dominant groups have often been ignored in science education standards, policies and practice (Bang & Medin, 2010; Rodriguez, 1997). Historically, science has been used to justify gender, racial and ethnic oppression throughout the history of the United States through "scientific" testing of intelligence/development, and it also has been used to deny basic human rights of people of Color in order to further scientific research agendas (Kendi, 2017; Parsons, 2014).

Positioning developing science knowledge and practices as outlined by the Next Generation Science Standards (*NGSS*) as the primary path to promote equity in science education over other power imbalances shifts the focus to what students lack, rather than considering how science is serving neoliberal agendas (Philip & Azevedo, 2017; Rahm & Brandt, 2016; Richmond, Bartell & Dunn, 2016). This critique mirrors previous arguments pushing for more equity-oriented science standards (Calabrese Barton, 2003). The current access approach positions students as the problem needing to be fixed and diminishes the expertise students leverage while oversimplifying students consequential learning.

The dominant equity narrative in science education needs to focus on remediating the system rather than fixing the student (Tuck, 2009). Focusing on what youth "lack" in terms of legitimized knowledge and practices (e.g., predominantly white, predominately male, predominantly college-educated) fails to value the expertise many youth, especially youth of Color, bring to engaging meaningfully. When *Science for All*, an ideal promoted in the National Framework for Science Education is promoted as a beacon of equity, we need to question "Whose science?", "Science, for what end?", and "What expertise is needed to use science meaningful?" (Medin & Bang, 2014; NGSS Lead States, 2013).

Many researchers, teachers and students have resisted this dominant discourse and critically explore what is necessary for meaningful science. These efforts expand on what students need to know to use science in ways that matter to them. For example, Chinn's (2007) work draws on the language and place knowledge students have in order to robustly and meaningfully study ecosystems in their own lives. Calabrese Barton and Tan (2010) offered an example of the expertise necessary to address problems when considered how youth utilized their expertise navigating political interactions along with their science knowledge and ability to educate community members to successfully advocate for an environmentally sustainable roof for their afterschool club. Utilizing and drawing on students' expertise and language beyond those narrowly defined as the technical language of the dominant discourse can lead to transformational outcomes in science education (Gutiérrez, Baquedano-López, & Tejeda, 1999).

These three examples show how youth were supported in developing and leveraging hybridized expertise as they worked towards consequential learning outcomes. Additionally, they highlight the tension that exists between the dominant discourses of science and positioning youth to use science in ways meaningful to them. Not only did the youth in these studies need to learn science knowledge and practices with other forms of expertise, but they also needed to apply it collectively with others. Supporting students to use science with other powerful forms of expertise may support learning that is consequential.

"Consequential learning" (Jurow & Shea, 2015) demands a shift in the dominant discourses of equity in science education. It asks the field to shift from focusing on individual learning outcomes to community outcomes. Consequential learning occurs when members of a community collective enact new (and often hybrid) forms of practices as valuable towards advancing the goals of a community. These practices reflect hybrid forms of practice which bring together science disciplinary knowledge and practice along with community expertise. For example, Jurow and Shea (2015) examined a food justice movement in the western United States. Collaborating with a Mexican immigrant community in an urban food desert, they describe how food justice workers in a local community co-created contested practices in ways that shaped the political, social and cultural outcomes of food work. The authors described these practices as contested because they interrupted flows of "people, technologies, and practices" that made up the local food economy, and how it impacted residents (p. 298). Jurow and Shea suggested consequential learning happened as a result of the local cultural and social practices changing with regards to the food economy, precipitating changes in the world residents inhabited, allowing for new forms of success to emerge. People living in the community collaborating with community organizers identified critical leverage points in their unjust food system. They also co-created strategies for "remediating scale relations" to include the perspectives of "historically marginalized groups" (p. 300).

Thus, Jurow and Shea (2015) showed how consequential learning supports changes in how different people interact, are positioned and valued in a community. Critical science agency is a form of consequential learning and is the focus of my study. Critical science agency is using science and other forms of expertise to address injustice (Basu et al., 2009). I unpack both of these constructs more later in this chapter.

Critical Justice View of Equity. My understanding of equity in science education has changed over time. Beginning eight years ago, as a teacher in urban Catholic schools in New Orleans and later in Chicago, I became significantly more aware of the ways the dominant discourse of science education and how white supremacy impacted the students I worked with and my own learning experiences. Buying into the equity narrative of access, I was initially set on getting students excited about science. However, overtime I questioned who the science standards were written by, for whom and for what purposes. I realized what was tested, what I was taught as a student—and what I was trying to teach as a teacher—ignored who my students were and their communities' assets. Rather, the standards and curricula positioned students as needing to be remediated and pushed into a narrow idea of who scientists are and what they do. This led me to reconsider my teaching practices, and left me with many questions, such as how can middle school science be useful to students immediately, and how can teachers support students in using their community expertise in their science education. While I explore how my positionality impacted this study more in the methods section, working with other university scholars and the Wilkerson School community has helped me to further understand what equity could be in a classroom. In this study, I tried to work with Mrs. B and the students towards a critical justice view of equity.

As my own experiences as an educator show, equity can mean many different things. Within science education, equity has been taken up in many different ways over the last decades. However, among teachers and educational researchers, there is no consensus about the equity goals should be for the learning and teaching of science. Most often equity has been taken up to mean access to the dominant discourse of science. An access view of equity in science education has led to researchers to seek answers to questions focused on how to support students' opportunity to learn dominant science through access to materials, standard and development of all students science development.

Access and opportunity are always political. Sociological studies show this view of equity includes both access to resources *and* how access has been historically institutionalized. This can be considered in terms of whom has been granted access and *in what ways*. Not enough attention has been paid to how the distribution of resources is an artifact of institutionalized structures. Policy documents offer little attention to how the cultural resources for reform-minded science education are grounded in western ways of knowing/doing, or to the deep gaps in resources that exist across schools and school districts (Basile & Lopez, 2015).

Despite this dominant distributive view, more critically-oriented views of equity have gained ground in science education. These views of equity, which include “relational” views (Dawson, 2014), challenge the normative practices and power structures in science education. Rather than focusing on equal access and opportunity, individuals’ needs are considered in relation to who they are and what their lives are like.

Further, the relational view of equity calls attention to how current policy documents frame the outcomes of science education in assimilatory terms, often involving uncritical and unidirectional border crossing (Aikenhead & Jegede, 1999). Relational views of equity show how youths’ historicized experiences may not be a part of the standard curriculum. They also point out the risks individuals face when seeking to enter a potentially unwelcoming science education world. A relational view of equity reframes access and opportunity, situating the importance of promoting multiple points of entry and forms of movement through experiences.

However, even when both distribution and relation are valued, such views do not necessarily disrupt participation boundaries and knowledge hierarchies such that full participation in community is possible (Jurow & Shea, 2015). Therefore, I draw upon critical views of justice to reframe equity in science education (Balibar, Mezzadra & Samaddar, 2012). Critical justice views of equity address sources of injustice in addition to seeking the goals of distributive and relational views of equity. Power dynamics are always at play in science classrooms. A critical view of justice acknowledges the importance of access and opportunity, and of recognizing the many ways of knowing children bring to school. This view calls into question traditional patterns of participation in science to expand upon who and what areas of expertise are recognized and valued, potentially disrupting participation boundaries and knowledge hierarchies (Jurow & Shea, 2015). A critical justice view of equity challenges the conceptual and political underpinnings of equity in science education by putting attention on the need to re-shift relations of power and position within science education and its intersections with historicized injustice (Bang et al., 2016). This stance foregrounds attention to making visible and upending injustices located in current practice, but grounded in historical, social, and geographic histories (Balibar, Mezzadra & Samaddar, 2012).

In addition to critiquing dominant norms of participation in science education, a critical justice view of equity disrupts the expectations for learning outcomes by drawing attention to the importance of supporting outcomes that both include and expand beyond disciplinary learning to also include critical agency (e.g., using disciplinary and other knowledge to act on things one cares about) and social transformation (e.g., new patterns of participation). These more expansive perspectives legitimize meaningful outcomes for learners beyond those pre-determined by the writers of science curricula and standards. In this study, I sought to work with students and Mrs. B to disrupt the hierarchies that were operating within the students' science learning experiences to support more transformational learning opportunities.

Now I explore how participatory planning, critical science agency and engineering in middle school may have supported a critical justice view of equity in this study.

Participatory Planning

Given the ways that dominant science education has continued gendered, racialized and class oppression, one baseline step to disrupting that power hierarchy as a science educational researcher may have been to promote opportunities for students and teachers to participatory plan. Participatory approaches may disrupt who is positioned as an expert, distribute roles across the class community and support students in using science in consequential ways. Additionally, throughout this study, the students were positioned to develop hybrid practices to support their community to learn about energy in meaningful ways at STEM night. This supported students in using science in ways that matter to them.

This approach falls underneath a broader umbrella of critical youth participatory research methodologies. The field of critical youth participatory research methodologies encompasses a wide range of definitions, epistemologies, and approaches, ranging from the more widely discussed youth participatory action research to lesser used youth collaborative design-based research. These methodologies are focused on supporting young people to act towards socially just outcomes for themselves and their communities (Bautista et al., 2013). Another is the importance of preventing research from marginalizing youth and their communities (Cammarota & Fine, 2010).

Researchers have explored how participatory planning has supported consequential learning. Students as co-teachers is an approach that other studies have utilized when working to support critical science agency. For example, Donya, a high school student was positioned to teach physics to her peers as a way to support her own and her peers' critical science agency (Basu et al, 2009). Sixth-grade students, Mr. M and researchers worked collaboratively to plan a food and nutrition unit together, which better connected science to their daily lives (Calabrese Barton & Tan, 2009). Additionally, students, teachers and researchers using participatory approaches have highlighted ways students can leverage knowledge/practices in their daily lives that are often unsanctioned through official curriculum and norms of classrooms (Irizarry, 2017). This study builds on this research as it paid attention to effective ways the participants in this study co-planned and taught together, how that supported critical science agency enactment.

Critical Science Agency

Designing for classroom communities to enact critical science agency may support more justice-oriented science education. Critical science agency is a specific type of agency that is enacted when members of a community collectively develop and leverage science and other forms of expertise to address issues of injustice. Youth utilize critical science agency when they develop "robust understanding and practices of science, recognize themselves as experts for the skills and knowledge they have and use their expertise and community resources collectively to address issues of injustice" (Basu & Calabrese Barton, 2010, p. 75).

This is also seen in research on critical math agency, which informs critical science agency. Consider Turner's (2012) study that examines/closely follows youth's experiences of developing and leveraging different expertise in their efforts to address the inequitable overcrowding at their school. Students' math expertise was not enough to address the injustice.

The youth also had to grapple with how to best convince adults that their problem mattered, which required their unique community expertise and bridging that expertise with their mathematical knowledge. Similarly, the youth in Calabrese Barton and Tan's (2010) study developed new science expertise and used their multimedia skills to educate others in an effort to address the injustice and the dangers of urban heat islands. Youth being positioned to be experts in their community was necessary in both these cases of critical disciplinary agency.

While it is important for youth to develop science and engineering practices and knowledge promoted by access equity narratives – without such disciplinary expertise, students cannot enact critical science agency – this alone is insufficient and potentially oppressive. Having knowledge and practices alone, though, is not enough to support critical science agency. Rather, enacting critical science agency first requires identifying issues of injustice and then being supported in addressing those issues (Basu et al, 2009). To do so, students must be recognized by themselves and others as legitimate experts in both science and their community (Schenkel & Calabrese Barton, under review). While this is undertheorized, youth enacting critical science agency do not act on their own, but rather in collaboration with others in social contexts, which is a characteristic of consequential learning.

Opportunities in Integrated STEM: Engineering in the Middle Grades

Engaging students in the practices of engineering has become an important goal for science education in the middle grades. As the Next Generation Science Standards (*NGSS*) states, engineering design is the "systematic practice for solving problems, and technology as the result of that practice" (NGSS Lead States, 2013, p. 437). However, implementing the practices does not necessarily mean a critical justice view of equity is automatically supported.

At the same time, however, engineering curricula may be one way to push the science education community to support youth in enacting critical science agency. Engineering education is an emerging opportunity for educators to position youth to utilize their science and community experiences in critical and consequential ways as they focus on the engineering practices of defining problems and designing solutions as described in the *NGSS*. The *NGSS's* engineering practices (National Research Council, 2012) represents the first time engineering has been incorporated into national K12 science standards. While there is extensive research on engineering education programs in informal settings (Calabrese Barton & Tan, 2010; National Academy of Engineering, National Science Foundation, & American Society for Engineering Education, 2014), there is a dearth of scholarship on engineering education in formal, school settings that focuses on real-life community challenges. This study aims to contribute to understanding the best ways to engage students in engineering in ways that matter to them and their community.

Three themes emerged across my literature review investigating the outcomes of K-12 school-based, engineering. First, the majority of curricula accounted for only measured outcomes of the curriculum intervention through pre- and post-tests that measured content or reasoning skills (Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004; Kanter & Konstantopoulos, 2010; Mehalik, Doppelt, & Schuun, 2008; Silk, Schunn, & Cary, 2009). Second, there were mixed results in changes of attitudes toward engineering after the implementation of curriculum units (Cunningham & Lachapelle, 2014; Kanter & Konstantopoulos, 2010; Mooney & Laubach, 2002). Finally, no studies accounted for youth's community expertise or the impact the engineering had on their community. This highlights how this study pushed the field to consider critical justice views of equity by highlighting the collective and generative work of Mrs. B’s class community as they supported STEM night visitors in learning about and engineering with energy in meaningful ways.

Thus, there is a need for taking a critical justice view of equity in making sense of these new national expectations in science education, especially with respect to engineering education. It is my view that using participatory methods and designing for critical science agency may have supported Mrs. B's class community in having more justice-oriented learning opportunities. Now, I unpack the conceptual framework used in this study.

Conceptual Framework

This study attends to the ways students, teachers and researchers can collaboratively work to support consequential learning. Consequential learning is “meaningful actions that extends across temporal, social and spatial scales of practice.” (Jurow, Teeters, Shea, & Van Steenis, 2016, p. 210). This means consequential learning focuses on emerging practices that matter both now and for the future, has impacts across spaces and reshapes networks of both human and material relationships. Consequential learning requires restructuring the ways that forms of oppression operate at a local level. Birmingham et al. (2016) explain consequential learning occurs when "youth alter traditional patterns of participation in science (i.e., white men dominated) to expand upon who and what areas of expertise are recognized and valued within and across dynamic networks of practice" (Jurow & Shea, 2015, p. 819). Consequential learning particularly pays attention to opportunities to learn for those most marginalized within a learning community (Jurow & Shea, 2015).

Consequential learning is a collective and relational process. For learning to occur, students need to be able to see themselves as capable, able, and welcomed to use STEM in ways that matter to them and their communities. The students' work has to be supported through and by recognition by others as well as restructuring structures that are constrictive to dominant norms of being and doing that are often operating within in classrooms (Bang, Warren, Rosebery, & Medin, 2012; Calabrese Barton & Tan, 2010). Interactions and the take up of new hybrid practices geared towards students' social futures make consequential learning visible (Gutierrez, 2012). While consequential learning is concerned with the learning of those most marginalized members by other and structures within a community, I argue that to understand the process of consequential learning, it is critical to understand how community members positioned with more dominant forms of power understand and shift how they perpetuate oppression through their local actions. Consequential learning takes a critical step in the sociocultural understanding of learning by exploring how the relationships, norms and interactions are restructured across time and space as learners work to take meaningful action. This requires an analysis of how power is operating and learning is taking place at the same time.

Power and Consequential Learning Opportunities

Consequential learning is a political process as it foregrounds how learning is a sociopolitical process. As meaningful action takes place, actors are always situated within and impacted by broader systems of power being enacted at a local level. Consequential learning is influenced by and builds on sociocultural theories of learning to analyze how learning is occurring within systems of power. Using a sociocultural theory of learning allows us to understand how individuals' learning is context-specific, mediated by interactions and evident in emerging practices (Lave & Wenger, 1991). Learning occurs as individuals take up new practices and engage in the process of becoming through identity work (Nasir & Cooks, 2009). As individuals learn within communities of practice, they draw upon past experiences and histories, which leads to the enactment of hybrid practices (Calabrese Barton et al., 2013). In addition to their own histories, individuals draw upon artifacts, tools, and other knowledges, experiences, and expertise as they enact new practices (Nasir & Hand, 2006).

Consequential learning, with its roots in sociocultural theories of learning, allows for attention to be paid to the context within which individuals learn. This approach supports focusing on the interactions that support individuals' access to taking up new practices or not as well as the ways in which they are recognized. Consequential learning also focuses on situated interactions, recognition, and validation of students' new practices, and additionally the use of those new practices for transformation within the community (Birmingham et al., 2017).

While sociocultural theories of learning have been useful for analyzing learning opportunities through interactions within social contexts, this approach has been limited in how to analyze the ways local practices are impacted by broader systems of power and oppression. Scholars have begun to push for an understanding of how sociocultural theories of learning intersect with critical theories that examine systems of power (Esmonde & Booker, 2017; Lewis, Enciso & Moje, 2007; Nasir & Hand, 2006). Critical theories such as critical race theory or critical whiteness studies support understanding how racial oppression impacts students' learning opportunities at systematic levels (Leonardo, 2009; Taylor, Gillborn, & Ladson-Billings, 2016). However, they were not designed to understand how learning is occurring (Esmonde & Booker, 2017; Nasir & Hand, 2006; Lewis, Enciso & Moje, 2007). These scholars and many others have pushed for a more critical sociocultural theory approach to examine how power impacts the ways students learn. Consequential learning can support analysis of the ways and how students are positioned to (or not to) leverage resources as they take up new practices within a classroom and how interactions are situated in and impacted by broader sociohistorical systems of power.

Understanding Power

Understanding the characteristics of power is critical to being able to redress how it impacts consequential learning opportunities. Power is a complicated construct to define as it is enacted everywhere and how it operates is often rendered invisible especially for those who benefit from its enactments (Bell, 1992; Leonardo, 2016, Fendler, 2010). To define power, I draw predominantly on the work of Foucault (1977, 1980, 1984) and the scholarship that has analyzed and built on his work in the fields of education research (Moje & Lewis, 2007) and philosophy (Fendler, 2010). 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 person may be able to enact more power in one space and be subjected to power more in another space.

To highlight the construct of power operating within a school space, I share briefly how it operated within one student's experience in Mrs. B's class. Steph enacted power as he positioned himself as the fun and talented player and organizer of freeze-tag at recess. He would actively recruit others to play, make decisions about the boundaries of the game, and students would ask him even before going outside for recess if he wanted to play. But he wielded less power in the classroom space, as students who did not get into trouble often from within and beyond his class would define him as a "bad kid", and teachers and administrators would exclude him from classroom activities due to their enactment of disciplinary policies. During our interviews, Steph often described himself as a "bad" student. Not only did Steph's opportunity to access resources and participate differ in these two spaces, his identity was defined differently by himself, his peers, and teachers.

This dynamic, interactional view of power does not ignore the systematic ways power has served to position whole 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). This Foucauldian notion of power emphasizes that 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 members of different social groups 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, but is supported by larger systems and their policies and structures, such as capitalism, schooling and the criminal justice system (Bell, 1992; Sensoy & DiAngelo, 2012; Taylor et al., 2016). 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 privileges than people of color (Kendi, 2017; Rothstein, 2017). Even though individuals may not buy into the oppressive ideologies, through their actions they can be enacting 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, I pay attention to the intersectional nature of how power operates and impacts students' experiences (Crenshaw, 1991). For Steph, others perpetuated power on him not just as a black boy or a first-generation immigrant, but his unique experience as a black, first-generation immigrant boy. Due to the ways that power is enacted in complex ways, it is useful to pay attention to the textured lives and identities of classroom community members.

People enact power in multiple ways within the structure of schools. Sometimes power is easy to see within school systems, 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 (National Science Foundation's National Center for Science and Engineering Statistics, 2015; Tate, 2001). However, it is sometimes hard to see because power is always operating through multiple mechanisms. Fendler (2010,) drawing on Foucault's work, argues, "If we do not recognize power in its many different guises, then we become subject to the effects of power without knowing it" (p. 46). Power can be enacted in covert ways even though people often think of power as the overt, violent actions of those in charge to control others. While power does operate in this way at schools through administrators and teachers, many other modes of power are enacted as well that control students access to resources, agency enactment and ability to define themselves.

Alternative ways power operates may not seem controlling, violent or aggressive for those not being impacted directly, but they are always operating within a classroom space by shaping the types of interactions and practices occurring (Foucault, 1982). For example, students as young as kindergarten age have been already taught to evaluate their own and their peers' "smartness" by the degree of conforming to confining behavioral norms and expectations based on their socially constructed identities (Hatt, 2012). This process of control and expectations continues into students' experiences in middle school. For example, social interactions shape what students and ways of being are "cool" and are not in a sixth-grade classroom. These interactions happen both within the ways peers treat each other in person, but also through social media influencers and even the decisions that kids make before and after school in how they dress, what they do and how they represent themselves to each other. Students who are positioned as cool by their peers often may be unaware of the power that they are wielding. Those who are positioned with the most power are often unaware of the ways that they are benefiting from the structures that support their interactions (DiAngelo, 2018).

The Relationship between Consequential Learning and Power

Redressing power is integrally linked to consequential learning. Power and consequential learning are both enacted through interactions between people situated within sociohistorical contexts. Consequential learning focuses on transformational outcomes that redress relationships to be more justice-oriented. Additionally, power impacts opportunities to learn as learning occurs as individuals take up and are recognized for new practices by themselves and others (Wenger, 2008). Power also impacts knowledge formation in a classroom setting because it constrains and supports new forms of knowledge and expertise that can be developed (Parks & Schmeichel, 2012).

In this study, I pay particular attention to students' critical science agency and expanding authority in the classroom community. These are both forms of consequential learning because they both support and require meaningful action that restructure relations and moves beyond the individual actors. Esmonde (2017) explains, "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 how power is operating. Focusing on consequential learning may be a way to support more justice-oriented science education that values and supports students in developing and leveraging multiple forms of expertise towards community transformation.

Restructuring Power Hierarchies

To pay attention to the multiple forms of power impacting learning opportunities, I specifically focus on power hierarchies within classrooms. Power hierarchies are "the ways individuals are recognized, valued and positioned with status and authority" (Calabrese Barton & Tan, 2018, p. 21). The differential statuses that students maintain are a result of exertions of power. Therefore, I use both terms power and hierarchy in the construct of power hierarchy. These power hierarchies are shaped and formed over time and across space through the ways power is asserted and distributed through interactions. Like exerting power is a dynamic process, power hierarchies within classrooms are always in flux. However, power hierarchies within classroom often are relatively stable as the laminations of interactions have shaped expectations of being that often recognize, value, and position certain students with more opportunities than others (Holland & Leander, 2004; Leander, 2004). These past interactions that have occurred both within and beyond the classroom over time impact members of the classroom communities' views of themselves and others as well as their relationships with each other (Lave, 2012). Additionally, historical and broader interactions often position members of certain socially constructed groups (e.g., men, white people, wealthy people, teachers, English speakers) to have access to certain actions and resources over members of other groups (e.g., women, people of color, the working class, students, multiple language speakers) (Foucault, 1980). Power hierarchies operating within classrooms often reflect the ways that sexism, classism, racism and other forms of oppression operate throughout society (Esmonde, 2017; Schenkel & Calabrese Barton, under review).

This is a useful approach as this study examines how teachers and students can support critical science agency through participatory planning. Additionally, power hierarchies are a useful tool because they can often highlight how power operating within classrooms mirror, if at all, larger sociohistorical narratives in a way that looking at only individual exertions of power cannot. At the classroom level, power hierarchies are grounded in larger sociohistorical narratives connected to white supremacy, cis-hetero-patriarchy, and other forms of oppression (Fein, 2012; Leonardo, 2013). Paying attention to power hierarchies also can highlight how marginalized or dominant socially constructed identities intersect to compound students' opportunities to learn or not within the classroom (Bowleg, 2008; Crenshaw, 1991). Additionally, paying attention to power hierarchies allow for analysis of other consequential learning opportunities. Consequential learning requires a transformation of the community, not just learning opportunities for individuals (Jurow, Teeters, Shea, & Van Steenis, 2016). Paying attention to shifts, disruptions and restructuring of classroom power hierarchies is necessary to explore if, how and why consequential learning occurred.

This study is bound by analyzing shifts in power hierarchies made visible through students' expanded authority. I pay attention to both epistemic and positional authority. By epistemic authority in science classrooms, I refer to the ways of knowing (knowledge), talking (discourse), and doing (practices) matter in science, how and why, while still supporting more students in having access to the dominant forms of expertise being used within the space. Epistemic authority addresses *both* the nature of knowledge itself, as well as the social processes for achieving possible epistemic aims (Elby, Macrander, Hammer, 2016; Tan, Calabrese Barton

& Benavides, 2019). Expanded epistemic authority opens up space for students to share their expertise through generating new tools, understandings and practices.

By positional authority, I refer to the ways more actors within the classroom were able to make decisions about how spaces and resources were used to support learning goals. Authority can expand, for example, from teachers, parents and high academic status students to all students, disrupting dominant patterns of participation in science classrooms – patterns which reproduce inequalities along race, class and gender lines (Philip & Azevedo, 2017). Expanded positional authority supports students in having the resources necessary to leverage that expertise.

I bound analysis of power hierarchies in this way because these forms of power are made evident as students' knowledge are elicited, taken up by others and acted upon by themselves and others.

This conceptual framework builds on the work of other researchers, teachers, and students as it works to understand how power operating within classrooms can impact students learning opportunities. Math education has highlighted ways power hierarchies with gendered and racialized dimensions impact students' opportunities to participate and be recognized for their expertise while highlighting ways those power hierarchies can sometimes be restructured (Langer-Osuna, 2011). Esmonde and Langer-Osuna (2013) highlight how Dawn, an African American girl, was able to restructure interaction patterns within her small group to position herself as a mathematical expert. This also highlights how power is relational, fluid and situated within a sociohistorical context (Holland et. al., 2001). Shah and Crespo (2018) highlighted how students' statuses within classrooms often reflect cultural narratives that position certain student as math capable based on gendered and racialized systems of power. Power impacts students access and opportunities to develop and enact certain roles, which impacts their opportunities for certain consequential learning.

Social Practice Theory as an Analytical Tool

This study used social practice theory with a conceptual understanding of power and consequential learning as a tool to make visible how interactions within a classroom shape, disrupt, and possibly restructure power hierarchies and support students' consequential learning. Social practice theory is a sociocultural theory of learning that "emphasizes the historical production of persons in practice, and pays particular attention to differences among participant and to the ongoing struggles that develop across activities around those differences" (Holland & Lave, 2009, p. 5). Individual's learning, made visible through interactions and taking up new practices, are not separate from their personal histories nor broader sociohistorical narratives. Contentious local practices emerge when history-in-person interacts with history-in-institutionalized struggles. Holland and Lave (2009) explain: "If we recognize that the participants are historically related, partially united, partially divided, and surely always in conflict and tension through different political stances and relations of power, then a reasonable designation for this would be "contentious local practice" (p. 2-3) Local contentious practices emerge when discourse and action operating in the present are grounded in a person's history as well as the socio-political context of the interactions.

Social practice theory with a conceptual understanding of power and consequential learning is a useful analytical lens for this study as it pays attention to how local practices are shaped by one's person-in-history and the broader institutional and societal context. Past studies have shown how a social practice lens can support the analysis of power and learning by paying attention to the members of the classroom communities interactions without separating their choices from historical and systematic structures that have been built over time and space (Birmingham et al., 2017). This is useful as I sought to understand how participatory planning supported the consequential outcome of enacting critical science agency. Using a social practice lens, I paid attention to the ways authority, grounded in historical narratives, was made salient through interactions, and how expanding authority may impact a class community's consequential learning.

Social practice theory with a conceptual understanding of power and consequential learning provides insight into how Mrs. B’s class community restructured power hierarchies and enacted critical science agency as they drew upon their own history in person within a politicized context. Enacting critical science agency and power, both, rely on interactions that shape access to resources and recognition of individuals’ expertise and value (Basu, Calabrese Barton, Clairmont, & Locke, 2009; Moje & Lewis, 2007). Social practice theory emphasizes the ways that interactions operating at the local level, but are informed by sociohistorical events.

This conceptual framework supported my investigation of what critical science agency looks like in Mrs. B's sixth-grade science classroom and how, if at all, does participatory planning and teaching support critical science agency. First, interactions make critical science agency visible and social practice theory is attuned to those interactions. However, consequential learning is not situated in politically neutral spaces, and social practice theory takes into account sociohistorical narratives and systems of power that impact students' opportunities within classrooms (Holland & Lave, 2009). Additionally, consequential learning outcomes, including critical science agency, are influenced by one's history-in-person so a social practice lens helps account for how students' past experiences in and out of school impact how they and others position them within the science classroom.

Chapter Three: Contexts, Methods and Analysis

Using critical, participatory ethnographic methods aligned with the purpose of this study's research questions and conceptual framework. Critical ethnography is "rooted in the belief that exposing, critiquing, and transforming inequalities associated with social structures and labeling devices (i.e., gender, race, and class) are consequential and fundamental dimensions of research and analysis" (Calabrese Barton & Tan, 2010, p. 906). Additionally, participatory research methods aligned with this work as they may disrupt inequitable power dynamics commonly perpetuated by researchers on participants (Cammarota & Fine, 2010; Paris & Winn, 2014), and this study investigated how participatory planning and teaching supported the enactment of critical science agency.

Critical ethnography methods aim to redress issues of power, and are a form of a design experiment (Thomas, 1993). Using multiple critical ethnographic examples, Weis and Fine (2012) highlight that participants' interactions do not operate within a sealed environment, rather structural power impacts macro-level relations. Paying attention to and working with the class community to address the different actors and structures impacting classroom power dynamics and student learning was key for this study. Additionally, this approach aligned with a social practice theory with a conceptual understanding of power lens, because it highlighted that contentious local practices are situated within sociohistorical systems of power (Holland & Lave, 2009). While this study was bounded by the classroom community and its interactions with the larger school community, it was necessary to consider how sociohistorical contexts may have impacted the power operating within the classroom across the unit and planning, teaching and enactment of STEM night in this study.

As I work to support justice-oriented STEM learning opportunities, in making methodological decisions, I have tried to avoid the ways that STEM education and research has positioned students from non-dominate communities as being needing to be fixed (Tuck, 2009). Through this study, I sought to highlight Mrs. B and her students' experiences in a way that provides a counternarrative to the ways that youth and teachers attending urban schools have been positioned in damage-centered ways by researchers in the past (Yosso, 2005). I hope that my efforts to analyze and share the students and their teachers' experiences in participatory planning and teaching 6th grade STEM in my dissertation acknowledges the realities of oppression operating in young people's lives while highlighting the ways the class collectively worked towards social transformation.

While Mrs. B, students and I collaboratively worked to support consequential learning using participatory critical ethnography methods, we generated a rich data set. Data was generated from participant researcher fieldnotes, video recordings (whole class and focal groups), interviews, conversation groups, daily debrief conversations and student work. These data sources aligned with those typically utilized in critical ethnography methodologies (Calabrese Barton, 2001; Thomas, 1993). Table 1 provides an overview of the data sources. The generated data set provided insight into how authority was expanded, norms were disrupted and how students enact critical science agency. Additionally, data analysis highlighted the role of participatory planning and teaching in impacting the class community's consequential learning. Through analysis of this data, I paid particular attention to evidence of the shifts in authority, developing and leveraging expertise, and students' consequential learning opportunities.

Context

Local Context

This study took place in Great Lakes City. This urban city is a medium-sized metropolitan area located in the Midwest. The city has been impacted by the state's declining population and loss of industry to the area. However, Great Lakes City is filled with many community resources. For example, the community college and the nearby research university collaborate with the community often. Additionally, the city has been ranked highly for its refugee resettlement programs in the past, though the number of refugees has and will continue to decrease given new federal government policies. All of these assets and challenges impacted students' learning opportunities in their science class.

School Context

This study was situated at Wilkerson School, an urban elementary school. The selection of Wilkerson School as the study site was intentional. I developed relationships with the teachers at the school in a previous pilot of the I-Engineering curriculum and actively recruited these teachers due to the diverse make-up of their student body in terms of race, gender and religion. Over 72% of the student body are students of Color (4% American Indian, 7% Asian, 25% Black, 26% Latinx, 10% multiracial) and 28% of the student body are White students.[1] There is significant linguistic diversity, with students speaking Swahili, Farsi, Arabic, Spanish, English and over 10 other languages. Approximately 81% of the student body qualifies for free or

[1] The racial categories are limited in that they conflate race and ethnicity as well as essentialize groups. The gendered categories are limited as they further edify gender binaries. In this study, I try to present as comprehensive as possible representations of the participants, and share how the participants self-identify. For the school demographics, these limited demographics are useful for highlighting the racial diversity of the school community, and there are also material impacts of this categorization at the school and district level.

reduced lunch.[2] However, these demographic categories do not represent the nuance of the school's diversity, and the ways in which it impacts the school culture. In many ways, the school community rallies around supporting and welcoming all of their students, such as hallway displays celebrating the diversity of its student body, strategic partnering of students who are English language learners with their classmates, the hosting of culture nights, and teachers encouraging students to "help each other" often. In other ways, students' multiple identities are not supported by each other and the system within which the school operates.

The school's STEM magnet status also made Wilkerson School an ideal partner for this study. One of the benefits of the STEM designation is the increased amount of science and engineering education instructional time. High-stakes testing in urban districts has led to very limited instructional time for non-tested subjects like science and social studies (Au, 2007). Another issue the school was facing was student attrition to other districts. The school's magnet status was viewed as a potential way to slow the loss of students from the district to surrounding suburban school districts. The school is located in a school choice state, which provides opportunities for families to choose where to send their students. This has pushed the district away from a neighborhood school model to designating schools as magnets to meet students' different interests (e.g., STEM, language immersion, and performing arts). Still, the district has had a 36% net loss of students since district choice has become an option. The state's education funding is connected to students, which puts further strain on this under-resourced urban district as students' funding travels with them to suburban districts. The school district has lost financial resources and was trying to prevent further losses of students through initiatives like the magnet

[2] Free and reduced lunch status is often used as a proxy for better understanding students' economic resources and social class. This oversimplifies the students' financial situations, but it is the best representation available and impacts the material resources available at the school.

school. This is just one example of the political sphere in which the students and teacher were situated. This history is a reminder that student and teacher interactions are situated within a larger system of power that has material impacts on their schooling opportunities (Chambers & Huggins, 2014; Leonardo, 2013).

Focal Participants

Students. 23 of the 24 students in Mrs. B's class participated in this study. I initially identified a subset of nine students as focal students, and focused on gathering complete data sets with them over the semester. See Table 1. I selected these students because they were positioned by their teacher, peers and themselves with varying academic and social statuses in both their whole class and small group interactions (ex. high-achieving, popular, unpopular, etc.). These students were representative of the wide range of experiences of their peers and represented the racial, gender and linguistic diversity of the classroom as well.

Table 1. Focal students

Student	**Race/ethnicity**	**Spent younger years in:**	**Gender**
Abby	Latinx	USA	Girl
Chad	Black	USA	Boy
Cristina	Latinx	USA	Girl
Eric	Asian	USA	Boy
Molly	White	USA	Girl
Neymar	Asian	Thailand	Boy
Sophia	White	USA	Girl
Steph	Black	USA	Boy
Wan	Asian	Burma	Boy

Mrs. B. Mrs. B was the lead teacher in this study. Mrs. B has been a teacher for five years, and has taught sixth grade at Wilkerson School for three years. She teaches her students in a self-contained classroom for all core classes. She has positive relationships with most of her students and knows them all well. For this study, the core unit study was I-Engineering (described below), and Mrs. B has participated in multiple I-Engineering professional development sessions (approx. 30 hours.) This was the second time she has implemented the I-Engineering unit. Mrs. B identifies as a Latinx woman and mother of five. She bridged her lives across home and school often. This was evident in her children helping her after school, bringing students to events with her children, and decorating her classroom with pictures of her family and even her parents' plants.

Mrs. B sought out ways to holistically care for her students. For example, she brings her water cooler and ice into school on hot days and makes sure students have their basic needs met. Sometimes this meant making home visits and getting to know her students' families. She sought out opportunities for her students to learn through community resources, such as recruiting community members with various careers (teachers, carpenters, school board members) to provide feedback on engineering designs or making plans to have invasive species experts support students' learning in future units. Mrs. B also sought ways to support her students' learning by paying attention to what she wanted to improve on as a teacher and seeking help often from me (as a participant researcher) to do so. Mrs. B's asset-centered view of students and her commitment to improving her pedagogy to better support her students made her an ideal research-practice partner.

Myself. I have worked with the Wilkerson School community for three years. I initially developed relationships with the teachers through professional development sessions and visits to the preservice teachers in my science methods course placed in their classrooms. I also developed relationships with the teachers and students by supporting two I-Engineering implementations and one ecology unit. When we were not implementing the I-Engineering unit, I visited Mrs. B's classroom usually on a weekly basis. Mrs. B introduced me to her class as "This is Ms. Katie. She is my very good friend and she will be spending a lot of time with us throughout the year, and will help us do some cool science stuff, too. Just like you can ask me for help, you can ask her." During these visits, I joined the class community in many different ways, such as participating in problem-based learning lessons, engaging in one-on-one tutoring, providing feedback on writing and going on field trips. I developed relationships with other members of the school community, and have taken part in both academic, extracurricular and social activities at the school. These relationships have been developed both in and out of the school context. These relationships and time with the community have supported me in understanding some aspects of the school culture. Table 2 highlights my engagement with the school. Even with this long-term relationship, I was a visitor to this community.

Table 2. Katie's engagement with the Wilkerson School community

Summer 2016	Fall 2016	Spring 2017	Summer 2017	Fall 2017	Spring 2018	Summer 2018	Fall 2018	Spring 2019
Hosted a four day I-Engineering Professional Development with Wilkerson School Teachers	Weekly school visits, 403 students field placements at Wilkerson School	Weekly school visits, I-Engineering unit enactment over 7 weeks	Revised I-Engineering Unit with Wilkerson School teachers	Weekly school visits, hosted a one day I-Engineering professional development session	Weekly school visits, five week I-Engineering unit enactment, three week ecology unit enactment, participated in daily routines and special events during the last quarter of the school year, soccer coach	Revised ecology unit with Mrs. B	Weekly school visits, collaboratively writing practitioner piece with Mrs. B, soccer coach	I-Engineering unit enactment
~12 hours	~30 hours	~240 hours	~10 hours	~40 hours	~350 hours	~10 hours	~50 hours	~200 hours

As I analyzed my work with Mrs. B and her students, it was critical that I also paid attention to the ways that I have been impacted and implicated within systems of power and how that has impacted my own consequential learning. This matters in how I came into this work and shapes how I see the world. Below, I outline some key ways that I have been positioned within systems of power especially through interactions, as well as how that shaped my own identity work and shifted my perspectives.

Growing up in a family of six, I was the third child of four and the only girl. The repeated family priorities that were routinely repeated especially when I was avoiding doing my homework assigned at my Catholic grade school were: *faith, family, school and friends*. This value set pushed me to be very good at playing the dominant game of school as it was mostly brought up when my brothers and I were not meeting my parents' expectations for our schooling experiences. Success in school was measured by grades and not getting into trouble rather than what I learned or how I used that learning. While I love being in nature, designing things and understanding the world around me, the emphasis was often on following directions and getting good test scores. This led me to see school as a means to an end, and what I was learning as not that relevant to the things that I loved like playing sports, being in nature, my family, friends and broader Fort Wayne community. My family's expectations about schooling and my performance in it though aligned very much with a social mobility view of schooling, which positions schools as commodities that are necessary for reaching or maintaining desirable societal positions (Labaree, 1997). This shaped my initial views of school as being useful for opening up opportunities like getting into the University of Notre Dame (a common goal for many Catholic, Midwestern kids especially when their parents and two older brothers attended like mine did) and getting a job with which I could support myself.

The insular community in which I grew up perpetuated a myth of meritocracy that positioned my success in school as having to do with my hard work without interrogating the ways in which the schooling was designed to support white, upper middle-class students like myself (Frankenburg, 1993). I did not just participate in the school community Monday through

Friday, but also at Mass on Sundays, at friends' houses on the weekends and in sporting events and other extracurricular throughout the weeknights. This community was predominantly White, almost all Catholic, and middle to upper-middle class. Through my community's and societal narratives about meritocracy, I was socialized to believe that my success was determined mostly by my effort alone rather than the resources and policies that positioned me to succeed in school. Additionally, my teachers, classmates and family rarely discussed how we were positioned with power through white supremacy and classism. This perpetuated why I did not always see how I was often benefiting from systems of power (Sensoy & DiAngelo, 2017).

As I got older, engaging in the dominant epistemology of science further positioned me with additional social and intellectual capital (Lipsitz, 2005). For example, as the only sibling of four who pursued a degree in STEM, I was positioned by my members of our family and friends as the Schenkel kid who studied a "difficult" subject. It was an expectation in my family that my brothers and I all obtain college degrees which supported social reproduction as both my parents are college educated. While all of my brothers obtained college degrees, I am often deferred to and named as the "science person" when friends and family are trying to understand things that may or may not have a scientific explanation. Though sometimes, I am also questioned and teased if I do not know something because I am a "science person". These experiences further support my desire to pay attention to identity work as consequential learning. Identity work pays attention to the dynamic nature of identities and provides more opportunities for people to develop and be recognized for hybrid practices that allow for using science in the moment instead of just getting an answer right or pursuing a science career (Calabrese Barton et al., 2013). Identity work can support expanding narrow descriptions of what science is and who can do it.

While I have always liked science, I did not always recognize the different ways I could use it both in the present and the future. This was impacted by multiple interactions with others as well as narratives about who can do what. For example, even though I was the only kid in my family expressing interest pursuing any STEM degree, I never had a conversation about pursuing a possible career working with my dad as a general contractor, which my brother is now doing. However, my parents enthusiastically supported me in becoming a teacher when four years earlier they discouraged my brother from doing so. While I strongly identify as a teacher and am grateful for the opportunity to continue in the field of education, I am left wondering in what ways have I been socialized to enter into education over other fields. For this study, my experiences support me in considering in what ways girls have access to and are welcomed to use STEM, and how science classrooms perpetuate patterns of participation.

When I began teaching, I knew how science degrees and careers had strong social role valorization, and in some ways that motivated me to get students excited about pursuing a science degree. However, that narrow focus and my own experiences with a focus on schooling for the purposes of social mobility ignored the ways that science can be used powerfully within communities in the moment rather than being used to prepare students for long-term career goals. Additionally, I ignored barriers that I did not experience given my positionality that many of the students with whom I worked would face as they pursued science degrees (Mutegi, 2011). Through my work with students, teachers and other university researchers in New Orleans, Chicago and in Michigan, I have learned more about the value of using science in consequential ways. Being able to use science now rather than just in the future matters. Additionally, inviting youth into the planning of how they want to use science and disrupt barriers to doing so may help transform the oppressive nature of much science education.

Given my positionality, I do not always notice how power is operating within dominant science education and in classrooms. Therefore, I tried to commit to learning with instead of working for students, their teacher and the community in this study. Additionally, in my work, I sought to disrupt hierarchies with Mrs. B who has been positioned with power through her official role and students who have positioned with various amounts of power than others due to a combination of their social status, gender, language(s) and race. Often science education scholarship focuses only on those who are oppressed versus those who are perpetuating oppression. In this work, I sought to see how all members of a classroom community can work towards justice in science education and support consequential learning.

Unit Context

The study was embedded with the I-Engineering unit (NSF DRL #1502755). This unit is an energy engineering unit. In this study, the students and Mrs. B worked together to adapt the energy engineering curriculum to meet their context. This participatory approach was grounded both in pedagogical and research stances that value students and teachers as experts of their communities and seek to disrupt power hierarchies across the class community by leveraging individuals' expertise and distributing roles (Calabrese Barton & Tan, 2008; Irizarry, 2017; San Pedro, 2015). This may support a disruption of power hierarchies and support consequential learning in science education.

The five-week pilot implementation of the energy engineering unit focused on designing solutions that make school communities more sustainable. Other research team members, teachers and I developed the unit and then co-revised it with youth and teachers over the last three years. Mrs. B helped to revise the unit. Mrs. B taught this unit during science and engineering class periods. Table 3 shows the unit flow. As a participant researcher, I assisted by co-teaching lessons as needed, but Mrs. B dictated how much support she wanted. According to both students and my estimation, Mrs. B was the lead teacher about 75% of the time, and I was the lead teacher about 25% of the time. Students participated in whole group, conversation groups and one-on-one conversations to plan events throughout the unit including STEM night, community feedback day, and the engineering design showcase. Students took on leadership roles for these events as well. Throughout the unit, youth learned about energy (transfers, sources, circuits), used community ethnography techniques to define problems connected to sustainability at their school, and designed solutions that utilized a green energy source and LED light bulbs.

STEM Night

This study focused particularly on Mrs. B's class community participatory planning and teaching STEM night. STEM night occurred and built on the first unit's iterative design cycle of making sustainable electric art. Students drew on their experiences in the first design cycle to plan and host a STEM night for their families. Throughout the findings, I highlight the history, context and outcomes of STEM night.

Table 3. I-Engineering unit curricular sequence

#	Lesson	Key Focus	Community Ethnography Integration
1	Introduction	Big Ideas in Engineering for Sustainable Communities Lesson 1: Engineering for Sustainable Communities Introduction	Examining & discussing how youth their age use community ethnography as a part of engineering design
2-3	Iterative Design Cycle 1	Sustainable Electric Art: Using iterative design cycles to make electric art cards for family/friends, powered with green energy sources Lesson 2: Designing Electric Art Lesson 3: Sustainable Electric Art STEM Night	Generating Community Narratives
4-9	Iterative Design Cycle 2	Sustainable Classrooms: Defining Problems & Designing Solutions through Community Ethnography Lesson 4: Engineering Design Challenge Intro **Lesson 5**: Defining the problem: Using community ethnography to define engineering challenges **Lesson 6**: Initial Design **Lesson 7**: Optimize design with community feedback **Lesson 8:** Prototyping **Lesson 9**: Refining Designs Through Technical Tests and Community Feedback	Using community ethnography as a part of engineering design Surveys & observations of peers & community members Dialogs with the community on project ideas/design Observation
10	Community Sharing	Lesson 10: Sharing Engineering Designs with the Community	Community Narratives
Key NGSS 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.			

Sustained Engagement

While I focused on the energy unit and STEM night enacted with the students and Mrs. B in this study, my relationships with students, faculties and families, experiences and understanding of the school and Mrs. B's classroom culture were developed over time. This impacted both how the students, Mrs. B and I planned, enacted and experienced the units. Additionally, I drew on these experiences as I paid attention to the classroom and school culture in this study. This aligns with my methodological commitments of critical participatory ethnography because understanding culture is a key aspect of it (Calabrese Barton, 2001). My sustained engagement with the school community supported my analysis and provided weekly opportunities to member-check my findings with Mrs. B, and occasionally focal students who come back to visit the school regularly.

Data Generation

Fieldnotes

I wrote fieldnotes after each lesson and unit event (e.g., planning sessions, showcases, STEM night). The fieldnotes centered on the whole group instruction, experiences of small focal groups and student participants' efforts in the planning and enacting of STEM night. I described interactions supporting participatory planning and teaching. I paid attention to observable aspects of power hierarchies and consequential learning as well as actions and curriculum enactment that seemed to impact them. In order to pay attention to changes in power dynamics, I tracked the following: patterns in the take up (or not) of individual ideas in interactions, ways that students' expertise and participation personas are recognized as positively or negatively contributing to the class community, role distribution, decision making, variations in student positioning, resource access, and punishment and reward behaviors (who was targeted).

Students' input, as well as other scholarship (Esmonde & Langer-Osuna, 2013; Langer-Osuna, 2011), shaped how I described the observable aspects of power in my fieldnotes. Paying attention to how the students understood power operating is important as my positionality in the classroom impacts how I see, wield and am impacted by power (Milner, 2007). In particular, the students encouraged me to pay attention more to who is rewarded and punished. The observable dimensions of agency also informed by my theoretical framework and previous studies. To pay attention to critical science agency enactment I observed how students and teachers were using knowledge/practices with other resources to address issues that matter, including optimizing and improving designs, defining problems and designing solutions that use multiple forms of expertise. Paying attention to the observable aspects of power hierarchies and consequential learning provided insight into how these two constructs are intrinsically linked.

Video

Video recordings were valuable for analysis of students' interactions. I videotaped whole class instruction with a fixed camera that captured the teacher's interactions with all students. I used GoPro cameras to video record focal groups during group work and the GoPro cameras to videotape the class community working together to participatory plan and prepare their plans for STEM night. GoPro cameras worked well for this because they have a wide-view lens that can capture all students' actions and what they are working on together.

This approach is similar to other studies focused on group dynamics within a whole classroom (Langer-Osuna, 2011). Additionally, this approach aligns with Derry et al.'s (2007) work that urges video collection methods to align with research questions and theoretical frameworks. The video of the whole and small groups allowed for interaction analysis, which is important when using a social practice theory lens and investigating authority expanding.

Occasionally, the students angled the cameras to show what they thought was important. Students brought the GoPro camera with them as they moved around the classroom and school building. This was important because there often was much student movement in Mrs. B's class, and students were positioned differently in various spaces. Conversation groups were also video recorded.

Conversation groups

I met weekly with students for conversation groups. All students in Mrs. B's class were invited to join the group, and we met during lunchtime. The students insisted that we did not split into two smaller conversation groups, and emphasized that everyone should have a chance to share their thoughts. For example, Steph would ask his peers, "What do you think?" Nine students participated in at least half of the conversations. Students always had the choice to attend. However, most students chose to come to the conversation groups when they were able to attend. School absences, other lunchtime opportunities and being in trouble impacted some students' attendance. The fluidity and open welcome to participate led to many students contributing to our understanding of power and the planning I-Engineering and STEM night. Table 4 shows the number of students that participated in the conversation groups.

Table 4. Students participating in conversation groups

Total students participating in only one conversation group	2
Total students participating in only two conversation groups	0
Total students participating in only three conversation groups	2
Total students participating in only four conversation groups	5
Total students participating in five conversation groups	2
Total Students participating in conversation groups.	13

Conversation group participants (the students and I) discussed participatory planning, participation patterns students noticed within their classroom, status hierarchies and their ideal classroom and group dynamics. Participation patterns and power hierarchies matter in science learning because they impact students' opportunities to take on roles that support them in trying out and developing new knowledge and practices. Together, we discussed what to pay attention to when working to address issues of power within the class and groups. This informed pedagogical choices, fieldnotes observation protocol, debrief conversations and other interview protocols. In the next four conversation groups, we revisited the ways the students defined power, and we also co-created solutions and adjusted lesson plans to be responsive to issues they noticed in the class. The conversation group planned aspects of the next steps in the units. See Appendix B. for conversation group protocol.

Planning Meeting and Activities Recordings

There were multiple planning and preparation meetings for STEM night. Mrs. B, the students and I planned STEM night as a whole class, small groups and one-on-one. Students then prepared for STEM night as a whole class, in small groups and by themselves. This preparation occurred during class time, lunch and recess. I video and/or audio recorded the preparation activities and conversations depending on the context as much as possible. In data analysis, these recordings provided insight into the interactions that supported STEM night, the role of participatory planning and critical science agency.

Interviews

I interviewed students and Mrs. B in multiple formats throughout the unit. Most interviews were both audio and video recorded. The interviews were connected to the study's research questions and as well as curriculum planning and revisions that aimed to restructure power hierarchies to better support consequential learning. Throughout this unit, I conducted 23 formal interviews and multiple informal debriefings with Mrs. B and the students.

Student Interviews. Student interviews were centered on student-produced "artifacts." The two "artifact" interviews focused on students' 1) electric art and 2) the engineering designs students prototyped. In this study, I aimed to interview each focal student in each round as well as members of their groups. Six focal students participated in both interviews, and two focal students who participated in one interview Steph was suspended during that interviewing timeline, and Abby chose to start participating in interviews beginning with the post-I-Engineering interview. Eric was a focal student in this study, but chose not to participate in interviews. Table 5 highlights focal participants’ participation in the interviews and conversation groups, and Table 6 shows how the number of students participating increased with each round of interviews.

Table 5. Focal students' participation in interviews and conversation groups

Focal Student	Electric art Interview	Post-I-Eng Interview	Conversation Group				
			4/27/18	5/7/18	5/14/18	5/31/18	6/6/18
Abby		x	x	x	x	x	x
Chad	x	x	x	x	x		x
Cristina	x	x	x	x	x		x
Eric							
Molly	x	x		x			
Neymar	x	x		x	x		x
Sophia	x	x		x			
Steph		x	x		x	x	x
Wan	x	x		x	x		x

Table 6. Interviews completed across the study

Electric Art Interviews	7
Post-I-Engineering Interview	13
Teacher Interviews	3
Total Interviews	23

Mid-Unit I-Engineering Interviews. I interviewed students after they completed the electric art design challenge and the STEM showcase. This interview was centered around students' electric art artifacts, which students created to give as a present to a loved one. All of the electric art had a working simple or parallel circuit powered with a 3V battery and lighting a 10 mm LED light bulb. The interview was broken into three parts: understanding students' statuses (academic, social and other) in the classroom, the electric art artifact and their vision for their ideal classroom community. Questions first prompted students to provide insight into how they saw themselves, their perceived social and academic status in the class and what it meant to be successful in their classroom. These questions provided insight into both power hierarchies within the classroom by paying attention to relationships across the community and varying definitions of success. The next set of questions prompted insight into a) understanding the artifact (what is it, how it works, what problem it solves, materials used and why, etc.); b) participation and engagement (behind the scenes, including a step-by-step description of the process, descriptions of interactions/support youth received from peers, educators, and 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). These sections of questions were adapted from I-Engineering interview protocols that build on previous Calabrese Barton and Tan's (2012; 2018) critical ethnographic artifact interview protocols. The final questions in the interview protocol asked students to share what they liked and also hoped for their ideal classroom community. If students attended STEM night, I asked them about their experiences. See Appendix D for Mid-Unit (Electric Art) Interview Protocol.

Post-Unit I-Engineering Student Interviews. I interviewed each focal participant and five of their classmates at the end of the I-Engineering unit. The interview was structured around their engineering designs artifacts. Each group created their engineering design to help make their classroom community more sustainable. Each design used a green energy source and powered one or more LED light bulbs. The questions explored a) the problem space and group's solution, b) knowledge and practices (STEM knowledge and practice needed, and funds of knowledge), c) group dynamics, d) meaning and value (what this project says about oneself), and e) participatory planning preferences. This interview provided insight power and learning operating within and beyond the students' groups. See Appendix E for Post-Unit Student Interview Protocol.

Teacher Interviews.

Beginning of I-Engineering Teacher Interview. I interviewed Mrs. B near the beginning of the I-Engineering Unit. During this meeting, questions prompted Mrs. B to share the participation patterns she noticed in her class, and share what success meant to her in the class in general and in science class. We also talked about students she saw as having varying levels of success and possible explanations to why. Mrs. B also shared hopes she had to better support the class community.

Post-lesson Teacher Debriefing Conversations. Throughout each week, I had multiple informal conversations with Mrs. B about how the I-Engineering was going and to coordinate future lessons as well as STEM night planning and enacting. These conversations provided insight into her immediate perceptions of STEM night, the lessons and unit. These conversations were unstructured, but provided insight into how she noticed participation patterns and learning outcomes playing out across the curricula enactment.

Post-unit I-Engineering Interview. I interviewed Mrs. B at the end of I-Engineering. The interview centered on groups' engineering designs that stood out to her. The interview paid attention to a) the processes groups engaged in to make their engineering designs, b) the knowledge and practices they knew and also developed, c) and the overall impact on the classroom community. This interview protocol has been revised throughout multiple pilots of I-Engineering. It provided insight on the consequential learning for students and the ways the participation patterns in the classroom were impacted through participatory planning. See Appendix H. Post-I-Engineering Interview Protocol.

Data Analysis

I engaged in multiple iterative cycles of data analysis for this study. This led to changes in research questions as well as the scope of the study. Below I describe the analysis that led to my findings highlighting what critical science agency looked like in Mrs. B's sixth-grade science classroom and how, if at all, does participatory planning and teaching support critical science agency.

I first analyzed data using categories reflecting dimensions of power hierarchies' maintenance, disruptions and consequential learning. Given my social practice theory lens, I paid particular attention to how different themes operated through interactions. These categories were reflected in the observable dimensions of my original research questions (see table 6). These categories used the students' observations about the characteristics of power and learning operating in their class as well as the analytic frameworks that have paid attention to power dynamics in group work (Esmonde & Langer-Osuna, 2012, Langer-Osuna, 2011; Schenkel & Calabrese Barton, under review), identity work (Calabrese Barton et al., 2013) and student agency (Ballard & Belsky, 2010; Schenkel et al, accepted). I coded focal students' interviews and then coded my field notes. After an initial coding of the field notes, I took a step back to find themes across the codes. My initial codes provided insight into Mrs. B's class culture and possible themes connected to power disruptions.

Table 7. Initial analysis

Research Questions	Observable Dimensions (Fieldnotes, video recordings)
1. How do power dynamics across gender, language and race in a 6th-grade classroom impact students' science learning and engagement?	• Whose and what ideas are taken up or not • What students, expertise and ways of being are recognized as positively or negatively contributing to the class community • What and who fills different roles • How and what decisions are made • How are students are positioned and by whom • Who has access to what resources • Interaction patterns that highlight different experiences for members of different minoritized/dominant groups
2. When and how are these power dynamics disrupted/restructured? What roles do participatory curriculum planning, student interactions, pedagogical moves and curriculum play in disrupting/restructuring power hierarchies?	• Changes to the observable dimensions of power hierarchies indicate restructuring of power hierarchies • Tracking changes between the original curriculum and youth revised curriculum highlight salient aspects of participatory curriculum planning and enacting • The roles of different stakeholders enact in planning sessions • Patterns in how various interactions maintain or disrupt group participation patterns • Patterns in how various pedagogical moves allow or not allow for different forms of recognition and participation • Patterns in how different curricular features do open up space or not for different forms of recognition and participation
3. How does restructuring power hierarchies through student, teacher and curricular practices support consequential learning in a science classroom?	• Knowledge and practices use and developing • Using knowledge/practices with other resources to address issues that matter • Recognition by others and oneself for expertise • Enacting agency • Optimizing and improving designs • Defining problems • Designing solutions that use multiple forms of expertise • Emerging new patterns of interactions and discourse

Next, I combined codes, and re-coded my fieldnotes. In doing so, I highlighted moments that seemed to disrupt or amplify the way power was distributed within the space by paying attention to shifts in ways students had chances to have their ideas taken up and be used. Examples included Mrs. B hosting a whole class discussion about what the class wanted to plan for STEM night, Cristina teaching her family how to make electric art, Steph choosing to finish his electric art during recess. These moments were connected to students having access to use spaces as needed and the role participatory planning and teaching played disrupting power hierarchies.

I bounded my analysis to the participatory planning and teaching events connected to STEM night because I wanted to be able to thoroughly analyze over eight separate small participatory planning events leading to the STEM night. Through this choice, I was able to delve deeply into multiple grain-size of participatory planning and teaching events. Additionally, these events provided significant insight into critical science agency and the role of participatory planning and teaching practices.

I then zoomed into the participatory planning and teaching events for further analysis. For STEM night, there were multiple participatory planning events like a whole class planning conversation, students preparing a GIF-style, how-to, electric art video, and students teaching their families how to make electric art. For each event, I mapped onto it what supported the event in happening, what were the outcomes of the planning event and how did it seem to resist or amplify the way power was operating through class norms in the space. I then layered in more aspects of consequential learning by paying attention to what types of knowledge and whose knowledge supported those events and outcomes in happening. Table 8 highlights the questions and example codes investigating these questions.

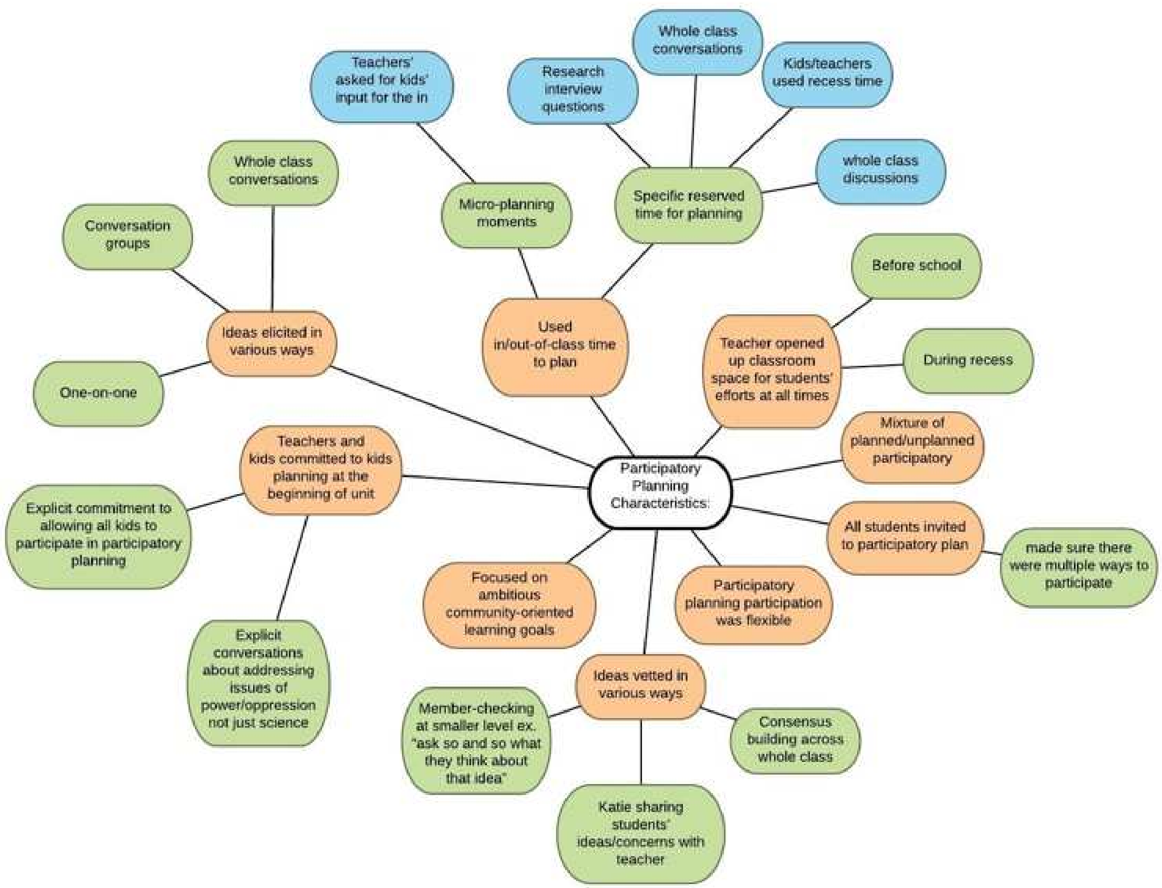
For each event, I then layered in more data. If video recordings were available of the event, I then analyzed the video for both dialogue and actions to make sense of the interactions that took place. Additionally, I used students' interviews and small group conversations to have them explain their experiences enacting the participatory planning and teaching event to privilege their interpretation of their practices over mine. For example, after Cristina taught at STEM night, I asked her about the experience and she told me more about her interactions with her family and how she felt happy and proud of the event.

Table 8. Questions and codes used to further analyze the participatory planning event

Question	Example codes
What supported each participatory planning event?	• Whole group conversation allowed for multiple ideas to be shared. • Students were able to use the classroom community as needed • Ideas shared across multiple groups were contributed to the video plan
What were the outcomes?	• Refined the goal of STEM night • Students were supported in leveraging their expertise to make how-to video • Supported students in then making educative posters • Moved expertise developed within class conversations to the greater community through STEM night
How did the event shift power hierarchies at all?	• Disrupted/shifted authority to make decisions from teachers to students • Disrupted/shifted authority to use resources from teachers to students • Opportunities to contribute expertise and participate • Students not disciplined as much • Multiple students shared their ideas • Students took action
In what ways if at all did the event support consequential learning?	• STEM night plan was grounded in the curriculum in youth-centered and community-centered ways • Students recognized their own unique expertise • Students taught others new knowledge • Expertise was shared across spaces • Expertise built on past experiences

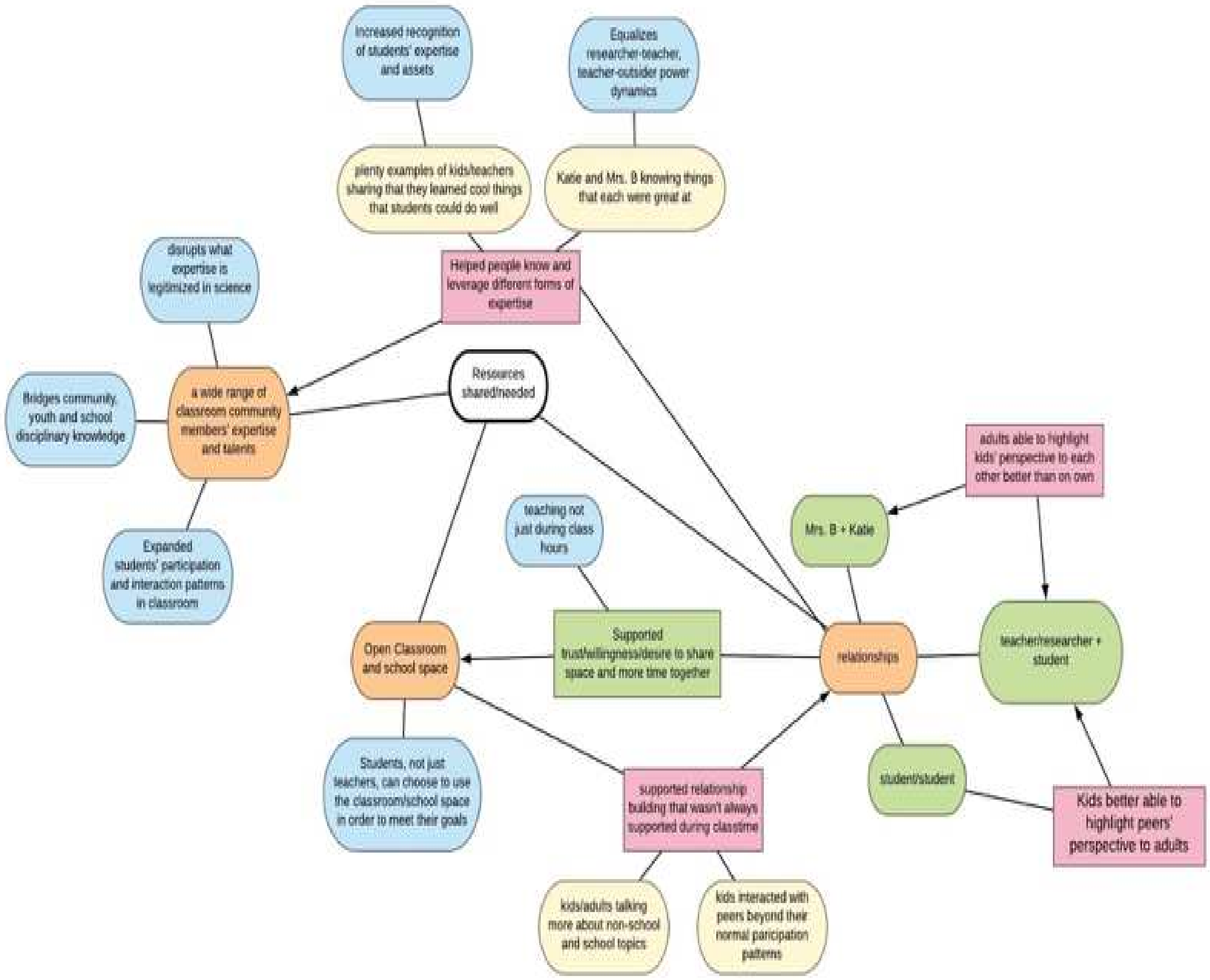
Then I looked across each event to find patterns of practices that seemed to support the class community participatory plan. Figure 1. shares an initial analysis of patterns of practices supporting the participatory planning events.

Figure 1. Initial analysis of patterns of practices seeming to support the participatory planning events



Then I analyzed what ways the identified participatory practices seemed to support students in having more opportunities to share, develop and put their ideas into action. Figure 2. Highlights initial mapping of those themes.

Figure 2. Connections between participatory practices and power operating within the class



In addition to analyzing for power disruptions and expertise leveraging towards meaningful ends happening in the moment, I also analyzed the data set to make better sense of the norms operating that supported differing levels of authority for different people within the classroom. I paid particular attention to things like the ways students were included/excluded from the class community, how success in the classroom was described, patterns in social and academic relationships. I then compared those patterns to sociohistorical patterns operating within the school. Then I looked to see if those patterns were ever disrupted throughout the process participatory planning and teaching of STEM night. While I bounded my analysis to participatory planning and teaching events of STEM night, I drew upon my long-term engagement as I worked to analyze norms that were disrupted and amplified through the class community's interactions. For example, I looked across school-wide programs (self manager program, special education program) to see if students from differently socially constructed groups were proportionally represented in the programs or not. Then I paid attention to patterns in how students within and not a part of those programs had access to contribute and participate in the broader class community. I analyzed how students and Mrs. B defined school success to find patterns in what it meant to be a member of Mrs. B's class community. I analyzed who was chosen to work with others and who was not. Using these modes of analysis and others, I was able to highlight norms operating within the classroom impacting students' epistemic and positional authority. Additional data sources included conversation group recordings and my field notes and observations over the three years of the school community.

Chapter Four: Findings

It was really cool watching the families explore the different stations. Kids and adults made electric art templates, and they helped each other. We had the videos loaded on iPads, and we saw people watching the videos in order to figure out how to make the templates. Unlike last year, there were alot of families working together rather than mostly groups of 6th graders working on making circuits together.

-Fieldnotes, 4/18/18

This brief field note reveals my initial reflection on Wilkerson School's 2018 STEM night. In my fieldnotes, I described a glimpse into what I felt was a powerful learning experience for sixth-grade students, their families and other visitors. I noted how both youth and adults moved between stations trying out the electric art that the sixth grade produced, creating their own electric art, and testing green energy sources on their art. At each station, families and sixth graders collaborated to experience different aspects of what the sixth graders learned and made in their engineering exploration of electric art. In this moment, families used materials designed by sixth graders to support their learning and making. Families passed around iPads playing student-produced electric art "how-to videos" as they were learning how to create circuits that they could take home. They also looked at prompting questions, such as "What energy source do you like the most?", and "What would be better to power a house, a crank or solar panel?", on a student-made poster as they decided on their favorite green energy source. During the STEM night event, it was noteworthy how adults were learning with their sixth-grade students as they collaboratively tried out and learned about circuitry, rather than having a more supervisory role over the students like I observed they had had during the previous school year's STEM night.

The families were also interacting and learning together in ways that Mrs. B's sixth-grade students hoped would be responsive to their families and their own rich cultural knowledge and wisdom. Drawing on their experience learning electric art and knowledge about how and what they wanted their families and community to learn, the sixth graders participatory planned, enacted and taught this STEM night. By leveraging their STEM and community expertise, the students provided families with opportunities to experience energy and circuits together and to have fun while doing so. The class community also supported a more justice-oriented learning experience for families that shifted interactions between students, teachers and their families from one where teachers were the directors of learning with the emphasis on STEM expertise, to one where student, families and teachers as co-teachers and co-explorers in ways that not only valued both community and STEM experience but required these different kinds of knowledge to be central in their learning. Throughout the designing and enacting of STEM night, the class community shifted what expertise mattered and created new learning opportunities with hybrid knowledge.

In the following section, I show how Mrs. B's sixth-grade students' participatory planning and teaching was a collective act of critical science agency.

Specifically, I asked:

1. What does critical science agency look like in Mrs. B's sixth-grade science classroom?
2. How, if at all, does participatory planning and teaching support critical science agency?

The main findings show:

1. Critical science agency is a collective act, involving:
    a) using distributed and diverse forms of expertise,

b) generatively building on and welcoming shared expertise over time through actions and discourse taken up by multiple community members

c) using that hybrid expertise towards co-defined meaningful ends.

2. The enactment of participatory planning and teaching practices supported collective critical science agency by: disrupting and amplifying class norms towards more just ends, supporting expanded authority, and allowing for addressing and co-defining outcomes of learning.

STEM Night a Collective Act of Critical Science Agency

Wilkerson School STEM Night: Connecting Students' Learning and Families

Mrs. B's class community participatory planned and taught the second annual Wilkerson School STEM night. The STEM night was an evening event for the students and their families to attend. The teachers of each grade level (fourth, fifth and sixth) were in charge of facilitating an activity connected to science, technology, engineering and math. STEM night, along with "culture night" and "family reading night," were events for students and their whole families to attend in the evening. There was always food such as pizza and juice, and activities all around the school connected to the theme of the night. During the STEM night, the fourth grade teachers did a forensic activity in the STEM lab, the fifth grade teachers showed the robots that their students made in the 5th grade hallway, and the sixth grade teachers had students working together to make large circuits on bulletin boards in the school gym to eventually display around the school.

STEM night was the newest event of the family learning nights. The school principal instituted the event as another way to support family engagement with the school, which was a strong commitment of hers. For example, she often asked students how their parents were, thanked families for coming into the school and celebrated them at the sixth-grade recognition event by having the sixth graders applaud their families for their support. STEM night was also a way to promote the school's STEM magnet status. The principal encouraged teachers to use STEM night to highlight what students were learning that connected to STEM subjects.

Preparing for STEM Night

Mrs. B was invested in supporting an engaging STEM night. For example, Mrs. B began planning for STEM night before the school year even started. During an I-Engineering professional development session in August of 2016, Mrs. B asked my research team if we could help with the spring 2017 STEM night. Similarly, during the 2017 August professional development session, she asked if we could help support the 2018 STEM night. Through recruiting collaborators to help and plan early, Mrs. B's dedication to the event was obvious.

Mrs. B was further dedicated to improving the sixth grade's contributions to the event. For example, Mrs. B shared with me that she wanted the sixth grade part of STEM night to be more engaging than the previous year. While Mrs. B expressed that she liked the large circuit making activity shared during the first STEM night, she wished for the experience to involve family members more than it had. I had also noted in my field notes from the previous year's STEM night that "At the night, there were alot of kids who made things, and less adults who joined in the work"(Fieldnotes, 5/7/17). What we both were noticing was that not everyone was engaging with the activity, and we agreed that we wanted to create a more family-centered STEM night.

During the same conversation, we agreed that we wanted to involve students more in the planning and teaching of the two classroom-based units than we had in the past. This built on our shared desire to support more equity-oriented participation within the classroom as well as connect science topics more directly to students' lives. By planning to have students contribute to participatory planning and teaching the I-Engineering unit and ecology unit, we also opened up space for students to collaboratively design and enact the sixth-grade portion of STEM night.

The sixth grade STEM night contribution was directly linked to the students' experiences in the first I-Engineering design challenge of making electric art. This challenge took place across three lessons (six instructional hours) that introduced students to engineering for sustainable communities, energy transformations and circuits, and sustainable energy sources. The driving question for the challenge centered the students' families: How can I make an original light-up card or gift for my friend or someone in my family? Students learn to apply principles of engineering for sustainable communities to creating electric art. These principles include 1) Using community members' ideas in engineering, 2) Helping the community solve their problems through engineering, 3) Caring about the environment, and 4) Design solutions for now and in the future.

Further, all of these lessons and their educative materials were previously co-designed with youth from the area. Students at Wilkerson School helped to refine these lessons based on their experiences with the unit in the previous year. As students completed the first lesson, they designed an electric art card for a loved one using copper tape, a LED light bulb and a three-volt battery. See Figure 3. for the prompt and constraints of the challenge. The students prototyped simple, series, and parallel circuits using templates in order to evaluate the constraints and advantages of each circuit type. Then, they balanced social and technical considerations as they designed electric art for a loved one. In the second lesson, the students evaluated the constraints and advantages of various green energy sources to optimize their sustainable electric art.

Figure 3. The electric art design challenge prompt

As the engineering design challenge of making sustainable electric art was wrapping up, Mrs. B and I worked together to start involving students in the participatory planning and teaching of STEM night. First, we shared with the other sixth grade teachers the desire to involve sixth graders in planning and teaching at the event. After a short meeting, the sixth-grade teachers agreed to allow all of Mrs. B's sixth-grade students to engage in planning and teaching at the event even though it was initially suggested by one of the teaches that students in a special award and leadership programs should be the helpers. Once the other teachers agreed to the plan, Mrs. B and I worked to involve her sixth-grade class in planning the event.

Mrs. B’s classroom community’s participatory planning and teaching took place across three main phases. First, the students and we collaboratively defined our goals for STEM night. Second, we collaboratively enacted their plans by preparing educative materials to support STEM night visitors in meeting their learning goals. Finally, the students taught at STEM night. Students engaged in this planning and teaching process over the course of two weeks through one-on-one, small group and whole class efforts both during and outside of science class time.

As the class community planned and enacted their STEM night plan, students drew on their experiences completing the sustainable electric art challenge and their community expertise to best support their families in learning about engineering design and electric art. Students used their engineering, circuitry and energy expertise to plan for and enact STEM night. Students also drew upon their social and emotional experiences as they engaged in the electric art design challenge to tailor the STEM night to be more supportive of families in having positive learning experiences. They also thought about what would make the engineering design task meaningful for family members. For example, students from their experiences knew of their great frustration of having to troubleshoot their electric art cards and the pride they felt when they found success in making a working circuit.

The conversation group excerpt below occurred immediately after the students were discussing how they liked to make things like electric art:

Katie: What are some ways that you all have made—tell me about the process of making your card. How did it go?

Deedee: Oh, it went horrible.

Katie: Okay.

Cristina: I got mad a lot.

Steph: As soon as I started it, I had no clue what I was doing.

Katie: Yeah?

Steph: No clue.

Wan: Me too.

Katie: Yeah? Fahima, you said it was really frustrating. Was it frustrating the whole time?

Fahima: No, it was like the beginning, and then when it started working it was better.

Katie: Oh, okay. When was it hard for you? Tell me a little bit more about that.

Fahima: The beginning, when we started making our card, the part that was frustrating was when I put in my lights and then the battery wouldn't work, and it wasn't working, and then I kept on redoing it and it still wasn't working.

As noted in the transcript above, the students expressed frustration in learning how to make electric art when Deedee said, "Oh, it went horrible,"; when Cristina expressed, "I got mad a lot."; and when Wan agreed with Steph about having "No clue." as to how to make circuits.

However, even though the experience was initially frustrating when the students were able to design electric art that worked they were filled with excitement and pride. For example, when I asked Fahima if the process was frustrating the whole time to me, she explained that "when it started working it was better." Similarly, her classmate, Abby explained, "It's hard at first, and you have to keep on working, keep on trying and you have to just get there. Try different things."

The students' frustration was relieved when they got their cards to light up. Throughout the electric art challenge, I saw students light up as their cards did for the first time and then show their peers, teachers and myself their working cards. Additionally, the whole class celebrated their success when Mrs. B had all the students who made electric art using a simple series stand up and the class applauded. The class repeated this process when all the students who made a parallel circuit for their electric art card stood up and were applauded. The students learned about the emotional experiences of failing multiple times and finding success in electric art.

Throughout the planning and teaching process, which I will go further into later in this chapter, students leveraged these multiple forms of expertise and emotional experiences to support STEM night visitors in learning. For example, they leveraged their wide range of technical and social expertise developed across the electric art challenge. I will show how students designed tools, like a video, to support visitors in learning how to make circuits works. Students needed to know circuitry expertise as well as how to make electric art in less frustrating ways to make the video supportive. Additionally, students used their community expertise to design a meaningful STEM night experience for visitors.

Enacting Critical Science Agency through Planning and Teaching STEM Night

Mrs. B's class community participatory planning and teaching STEM night was a collective act of critical science agency. The students focused on creating and enacting learning goals focused on real experiences that matter in schools and communities. Through participatory planning, Mrs. B's class community used multiple forms of expertise as they defined the STEM night learning goals. The class defined an issue of justice – providing their families meaningful access to collaboratively engaging in engineering design to make something meaningful. At the same time, they would have the opportunity to learn about energy transformation and circuitry, where they were actively welcomed and positioned as community experts. In doing so, the students drew on their own experiences making electric art versus completing energy tasks that did not maintain space for creativity or exploring on their own. Consider how Sophia described her experience in the electric art unit.

Sophia: It's fun. I missed the first week to do it, but it's still really fun, and I learned a lot about circuitry, not including last year because last year we had somebody hook it up for us. Then we just had to imagine something; it would work.

Katie: Really?

Sophia: Yeah. It's like if I put this here…'cause I got to make a funny card for my grandparents.

Katie: Nice. That's awesome. All right. Sophia, what does it mean that you were able to do something that—you said that they hooked up the battery or the lights for you, or was that—

Sophia: Yeah. The wire. We had wire last year instead of copper tape, the tape. They did the wiring for us. Using the copper tape by ourselves and making our hands—all of them by ourselves was really cool.

As Sophia described how in fifth grade, the teachers "did the wiring for us" and then during I-Engineering she got to "imagine something" and "make a funny card for my grandparents", she was highlighting her developing and leveraging expertise about circuits, and also her family while her creativity supported her in having a really "cool" experience.

The class wanted to support STEM night visitors in doing the same. They addressed wanting visitors to explore energy in ways that mattered to them through the application of science and community expertise. The students, Mrs. B and I planned to support STEM night visitors to experience, learn in enjoyable community-connected ways, and take home new circuitry and energy expertise.

Below I unpack a series of participatory planning events to highlight how Mrs. B's class community enacted critical science agency. Specifically, I show how the class community's enactment of critical science agency used distributed and diverse forms of expertise, generatively built on and welcomed shared expertise over time through actions and discourses taken up by multiple community members, and used that diverse expertise towards co-defining meaningful ends. As the class community enacted critical science agency, they addressed broader systemic injustices in local practice in humanizing ways across planning, enacting the plan, and teaching at STEM night. I highlight these aspects of critical science agency through the class' planning process, prepping of materials and enacting of STEM night.

Participatory Planning and Teaching Events Supporting Critical Science Agency

In what follows, I share narratives from across three key aspects of the participatory planning and teaching process: 1) initial planning events, 2) the preparation of educative materials, and 3) enacting of STEM night. Within each event I share, I unpack how the class was enacting critical science agency as they were leveraging multiple forms of expertise and building on that expertise through action and/or discourse to open up space for more forms of expertise and to support learning towards meaningful ends.

Initial Planning for STEM Night

Preparing for student participatory planning and teaching. Multiple factors contributed to Mrs. B's class community participatory planning and teaching of STEM night. As I described above, STEM night was a schoolwide event and each grade level teaching team was expected to contribute and facilitate an activity. Mrs. B and I first agreed to have her students' participatory plan and teach STEM night as a way to make STEM night more student and family focused with the other sixth grade teachers. During a short lunchtime STEM night logistics planning meeting, the other three sixth grade teachers agreed to have Mrs. B's class community collaboratively plan and teach the event. Through this conversation, the sixth-grade teachers shifted their ideas that they would plan STEM night to supporting Mrs. B's sixth-grade students planning it. In addition to getting the other sixth grade teachers permission to have students plan and teach STEM night, Mrs. B prepared her class to participatory plan and teach STEM night through supporting them in completing the electric art design challenge.

Collaboratively planning.

Mrs. B, the students and I collaboratively defined the goals for STEM night through one-on-one conversations, whole class discussions and in conversation groups where students' shared their expertise.

These goals included the following. First, they wanted to support visitors in actually experiencing what they had learned while making circuits in science class. Second, they wanted to connect STEM night to whom they knew the visitors to be. To do so, they chose to design STEM night to be fun and accessible to both young and old engineering and circuitry novices. Finally, the class community wanted to design ways for STEM night visitors to take their learning with them in a form they would value. Below I further highlight each of the characteristics of the class's learning goals for STEM night.

Consider how during the whole class planning conversation, the students ensured that adult and youth visitors would have chances to experience the art at the sixth-grade electric art exhibition. When the class had finished the electric art design engineering challenge, Mrs. B hosted a whole class community conversation focused on what they learned. She used this conversation to open up the question of what they would want their families and other visitors to learn and do at

STEM night. Through this discussion, the class community planned to both keep their electric art working and support visitors in trying their art out. Mrs. B began the conversation by saying:

> Think of a way, sixth graders, of how we are gonna display our cards. Think right now, and don’t be afraid to raise your hand. Chad and I brought up the point that we don’t really want them on the table because they can get broken. How else could we display our cards?

Through this introduction to the topic of displaying the electric art cards, Mrs. B established an opportunity for students to share their ideas. Mrs. B worked to elicit students’ ideas when she said, “Think of a way, sixth graders, of how we are gonna display our cards. Think right now, and don't be afraid to raise your hand." She positioned the sixth-grade students in her class to think of and share ideas openly even while sharing her own concerns that the electric art might be broken by visitors.

Students then quickly shared multiple ideas and Mrs. B facilitated the conversation:

Abby: Maybe we could put them on the wall for parents, kind of, or like—

Mrs. B: So parents can see ‘em, but not like Bobby (Mrs. B’s toddler son) size? Okay, I like that idea. Sophia?

Sophia: I really think that you’d wanna have these little sides so only if you went around and wanted to pick up that card and get it.

Mrs. B: Okay. Chad?

Chad: Then I’d want someone standing there to make sure they’re not breaking anything.

Mrs. B: We could, so we could still keep them on the table? (Students shake heads in agreement) Okay. I'm trying to think if we have a couple of trifolds to put them up.

Katie: With trifolds with the batteries and switches, they might not stay in standing up.

Mrs. B: We could have a table with, then like Chad said, somebody standing there.

Katie: Yeah, a couple of kids, maybe a couple of adults and teachers standing there.

Sophia: Then we could maybe shift.

Mrs. B: What do you think, sweetheart?

Zoe: We could just put a sign there that says, "Do not touch."

Throughout this conversation, students initially used their expertise to plan ways to protect the electric art, rather than support visitors in experiencing the electric art. Students ideas reflected their concerns that their work should be widely visible and still accessible for visitors to learn from. For example, as Sophia noted, "you'd wanna have these little sides so only if you went around and wanted to pick that card and get it." While Zoe worried about visitors touching the cards, "We could just put a sign there that says "do not touch", Mrs. B used that moment to raise questions about the role of their electric art, and the value of interacting with it, in visitors' learning:

Mrs. B: We could, but we kinda want like parents to touch?

Zoe: Yeah.

Adam: Parents only! (Sounds dismayed)

Zoe: I think put a sign that says only parents can touch.

Douglas: Yeah.

Teacher: We could. We could.

Dennis and other students: We want the kids be able to touch… (voices become inaudible)

Teacher: Okay. What do you guys think over here on this side? Do we have any ideas on how we want to display them?

Dennis raises his hand and quietly says something, but the idea is not taken up by Mrs. B.

Mrs. B: Okay. Steph?

Steph: Like they said, I guess, they can't touch it.

Mrs. B: Okay, but we kind of want them to touch it. We want the right people to touch it. We don't want kids coming around and just pushing stuff. That's also one of the reasons why, for STEM night, we invite the whole family to come, Douglas?

Douglas: Write "be careful with it."

Teacher: Be careful with it? Sophia, did you have your hand up?

Sophia: Yeah. That's one reason to put something around it, like maybe that clear wrap stuff that sticks. It's sticky, yeah, but that it's wrapped around it like that.

Mrs. B: Wow, you are fancy. [Laughter] I like your idea.

Sophia: It's not like we're buying a bunch of plastic to put on there. It's just clear around it.

Teacher: Right. Okay?

Dennis: Do a table.

Mrs. B: We could do a table. Can you say a little bit more about what you're thinking about having the experience table?

Dennis: If someone, if they try to come and mess with it, if they're not using it how it's supposed to be used, they can tell them how to use it.

Katie: Having people there to show you how to use it, and then maybe having a student there, or maybe an adult sitting there, too. Would that help?

Dennis and other students: Yeah.

The above transcript reveals how the class discourse shifted as they considered how their goals for STEM night could support visitor's learning. First, Mrs. B shared that she wanted more people to experience the electric art by saying, "We could, but we kinda want like parents to touch?" when Zoe suggested that a sign should say, "Do not touch." However, expanding access to trying out the cards to parents only was not enough for Adam who in a quietly and disappointedly way said, "Parents only!" which was backed up by Zoe. However, when Dennis and several other students simultaneously voiced that they wanted children to be able to touch the cards, Mrs. B turned it back to the class to ask what they thought, echoing the value of being interactive with the cards. This opened up a negotiation where her students collaboratively struggled with and brainstormed ideas for increasing access to the cards, with ideas ranging from cover the art in clear wrap (Sophia) to a "be careful" sign (Douglas).

Finally, when Dennis' idea was discussed about having an "experience table," the class decided that everyone could touch the electric art. Dennis' idea both planned for supporting visitors to learn how to turn on the electric art, but also for ensuring that the electric art the sixth graders had made would not accidentally be broken.

Through valuing multiple and different (often contradictory) students' ideas and helping students to listen and respond to each other's ideas, Mrs. B supported her students in collaboratively deciding that all STEM night visitors should be able to experience, not just look at, the sixth-grade electric art. As the class decided if visitors should be able to use the switches to illuminate the electric art cards, Douglas, Dennis, Adam and Sophia all shared ideas to support more visitors in touching and experiencing the electric art. Even though some students and Mrs. B were initially concerned that visitors would break the electric art, the class community collectively leveraged their expertise to address this concern. By students leveraging their expertise, they defined an important STEM night outcome: That every STEM night visitor, no matter their age, would be able to experience the sixth grade made electric art. In looking more closely at Dennis' explanation of the experience table and my interactions with him, it is also important to note that the class' decision-making regarding touching the electric art was tied to supporting visitors' deeper engagement and learning. Dennis was concerned not that people would break the cards when "messing with them," but that they would not know how to light them. My suggestion of having a person to help visitors if they needed it supported planning to help the visitors' learning.

Throughout small group and whole class planning conversations, it became clear that the students' discourse focused on their desire for family visitors to "experience" what they had experienced in learning about engineering, energy and circuits, instead of just seeing it. This goal of designing for STEM night visitors to experience what the sixth graders had learned during the electric art design challenge was evident in students' sharing their expertise while discussing the plans for each of the STEM night stations: the sixth grade electric art exhibition, the make-your-own electric art station and the green energy exploration station. For each station, students wanted visitors to have opportunities to engage with the materials as a way to enjoy learning about circuits, electricity and green energy sources. Below, I highlight how the class collaboratively decided on and then designed to reach those goals.

Continuing to leverage students' expertise to make opportunities for others to learn about circuits

The class community further connected the STEM night learning goals to students' and their STEM night visitors' lives as they elicited and leveraged students' expertise through multiple planning conversations. In particular, students collaboratively decided that they wanted STEM night visitors to experience making electric art. Mrs. B, the students and I leveraged our expertise to address concerns and come to a consensus about if and how it was possible to support visitors in enjoying making electric art during a short STEM night visit. The students leveraged their insights regarding what challenges visitors may have in learning to do electric art (e.g., what they would need to learn, and the associated frustrations), as well as what kind of learning scaffolds would be engaging for the visitors. Below I highlight the ways that students' expertise leveraged their past experience and knowledge of their community. Additionally, I share ways the students, Mrs. B and I built on each other's expertise to plan a way to support visitors in experiencing making their own electric art.

Mrs. B continued to elicit ideas from students' expertise after they decided on the plan to display the sixth grade made card display. She prompted the students to continue collaboratively defining their STEM night goals when she asked:

> What do we think would be cool to display for parents? This is for parents and then fourth and fifth graders that will see what we're doing in sixth grade. What, in I-Engineering, in the past two weeks that we've been doing with energy and

batteries and circuits, what do you think would be cool to share that they think would be cool? Think about it. What has been cool the past couple of weeks?

With this prompt, she oriented the students both towards her goal of sharing cool things with parents and younger students as well opened up an opportunity for the students to decide what they thought was most important to teach. This led to sharing ideas that Mrs. B previously had not considered and was unsure of their possibility. Chad answered her question about what he wanted families to do:

Chad: We could just let them make their own cards, maybe.

Mrs. B: Okay. Chad, do you think it would be simple enough to show somebody in like 15 or 20 minutes though?

Chad: Step-by-step.

Mrs. B: The step-by-step tutorials?

Chad: How the iPad shows it as these little slides for each little area, so that it tells you how to do it.

Mrs. B: Oh. What were you saying?

Chad: You could load up, also, things that you could watch.

This exchange highlights how Mrs. B elicited more ideas from Chad when she voiced her specific concern that visitors would only have ten to twenty minutes to make their electric art. He then leveraged his love for technology (often he and others would call him the class "tech guy") and his experience watching a youth-produced electric art video at the beginning of the electric art design challenge, when he suggested the class use step-by-step tutorial on iPads to help visitors learn how to make electric art quickly as a way to address Mrs. B's time concern. Building on his expertise and bring in the expertise of other students who had similar ideas, I shared ideas I learned from Cristina to use electric art templates and Rachel's idea to make shorter how-to videos.

Katie: Yeah. I've heard that before, too, from Cristina. Rachel has been there, too. You know the templates that we use? We have some templates that are like that, too. Maybe, I don't know if they work on their own templates cuz I think those templates are pretty fast to do once you watch a video. Right?

Mrs. B: Yeah, and if there's a couple of kids there.

During this continued exchange leveraging students' expertise to address her concerns, Mrs. B was convinced. Mrs. B further contributed to making sure visitors were supported by recommending students as expert helpers. I continued to help the class in being prepared to support visitors in experience electric art when I shared Rachel's idea further when I asked the class:

> Do you think it'd be useful to use the video that the kids make, or would it be better if we just had somebody—or would you like it so we had it so somebody had—so we make a video where I just time-lapse it and show you how to—

Before I could finish sharing Rachel's idea, students responded with emphatic "yeah's!". Mrs. B first elicited students' ideas, expressed concerns and openness to those ideas, and then further elicited more students' expertise. In doing so, students' ideas built on each others' in a way that supported them in planning for making electric art making more accessible to STEM night visitors.

For example, consider how Rachel shared an idea about using a GIF-style video to teach visitors about making electric art after she heard Abby, Cristina and me talking during recess when I asked them, “So like if you are going to STEM night, what would you want people to do?”. I shared that in the previous year, students helped make larger circuits together, but there were many options for what visitors could do at STEM night. Cristina suggested that each person should make their own circuit using templates, and later at recess, when I asked her for ideas, Rachel suggested that we share short GIF-like videos to help others learn.

Through sharing this idea with Cristina, Abby and me, Rachel was applying her expertise about youth enjoying GIFs through multiple social media outlets. She also knew that a characteristic of GIFs is that they repeat, which would be helpful for electric art newcomers who might need to watch the videos more than once for extra help. Finally, she also knew that the families visiting STEM night would have limited time to spend at the school, so her idea about using short how-to videos would be important to support them in quickly learning how to make their own electric art template. Her expertise and ideas were then leveraged in the larger class discussion to support the class in figuring out how to help visitors make electric art. Incorporating this expertise in a whole class planning conversation helped to make her idea a reality.

Another example of the class community planning to connect STEM night experience to what they knew about their community was how they planned fun into the event. Consider how the students prepared for the green energy exploration station. During the whole class planning conversation, multiple students suggested that STEM night visitors should have chances to explore the green energy sources (piezoelectric pads, solar panels and hand crank generators). When I asked: “Yeah, so what kind of questions would you want people to think? What would you want people to do with these materials on the table? Just play around with them?” Deedee responded, “Play with them.” Then, when Mrs. B asked the class if they had the three green energy sources at the stations, "What would you wanna do if you had all that in front of you? Douglas responded, "I wanna do that." Both students' responses highlighted how they wanted STEM night visitors to both experience the green energy sources and also have fun while doing so. Similarly, Dominic and Steph suggested challenges for people to attempt, such as seeing if they could light up a parallel or series circuit of lights using the different green energy sources. Students wanted visitors to be able to have fun and explore with the green energy sources.

Students leveraged each other's pedagogical expertise to connect STEM night to their community by designing ways for visitors to connect their learning to their lives outside of the school. In particular, this was evident in their plans for both the green energy station and the make your own electric art card. As the students drew on their expertise about the advantages and constraints of different green energy sources and wrote exploration questions, they were designing ways for families to think about how they can conserve energy and mitigate their impact on the environment. As the students designed ways for visitors to make their own electric art in fun and enjoyable ways, they were also designing a project that visitors could physically take with them to their homes.

Throughout the planning conversations, the students, Mrs. B and I used distributed and diverse forms of expertise shared by the class community. For example, the students, Mrs. B and I shared technical expertise about engineering, electric art, energy and circuits. Students also drew upon expertise that they developed throughout an electric art engineering unit to make STEM night accessible. The students leveraged their own experiences, built on each other's ideas and made space for new expertise to be shared as they moved forward to enact their plan to make STEM night welcoming, fun and engaging for their community. In doing so, they generatively built on and welcome shared expertise over time through actions and discourse taken up by multiple community members and used that hybrid expertise towards co-defined meaningful ends.

Critical reflections about participatory planning. Across the participatory planning conversations, the class community developed a plan to support visitors in having a positive, meaningful and engaging experience. Students were able to prioritize both knowledge and experiences that Mrs. B and I had not previously considered, which led them to design a STEM night that we could not have developed without their input. In an interview the day after the planning session, we each expressed that students shared ideas that we could not have imagined on our own.

Katie: What did you think of yesterday's planning session?

Mrs. B: Okay, so not everybody was on board, and it was so totally impromptu, but I feel like they came up with ideas that we would not have come up with.

Katie: Oh, there were so many ideas. I did not imagine there being two stations.

Mrs. B: No.

Katie: Yeah, or, actually, they came up with, it's like three stations.

In our conversation, Mrs. B and I both acknowledge the expertise that students leveraged when they came up with ideas for three different stations, when we thought there probably would have been one. When I said, "Oh, there were so many ideas," I was noticing the multiple ways students leveraged expertise to not just determine the number of stations, but also to define and support the experiences they wanted visitors to have.

As our conversation continued, we also were able to reflect on the ways expanding opportunities for students to make decisions supported the class community in addition to supporting planning a meaningful STEM night for visitors.

Mrs. B: It is a good idea because they [students] do come up with really good ideas, and then that makes it seem more—if I look at my classroom as a community, but now, it's more so the community because now they have an input.

Katie: Right. They have an input. Thinking about how we can get as much input as possible into the I-Engineering [energy engineering unit] is something I'm really interested in, too, and I think even if we think about looking ahead at, okay, these are things that are coming up. Let's ask kids. See, I think that could be something that could be helpful.

Mrs. B: Yeah, and something that I totally need to do more of, instead of being the dominating teacher, but more like, hey, what do you guys think.

During this reflection, Mrs. B highlighted how she saw the power of generatively building on and welcoming shared expertise from multiple students for two reasons. First, when she said, "they do come up with really good ideas", Mrs. B was highlighting how when students have the opportunity, they are able to leverage their expertise to support the broader class community. Second, Mrs. B highlighted how welcoming multiple forms of expertise within the space supported fostering a stronger class community. Mrs. B recognized that when students had opportunities to "have an input," the class was a stronger community than when she felt like a "dominating teacher." She saw co-planning as a way to make space for students to contribute their ideas, and then actually using them instead of her being the only decider in the classroom.

Students also expressed that students helping plan events like STEM night supported new ideas to be leveraged to reach their goals. Consider the ideas exchanged at the end of the whole class planning conversation group:

Katie: Do you think it matters that kids help plan events like this?

Multiple Students: Yes. (emphatically)

Katie: Okay. Can some people raise their hands and explain why?

Molly: I think it's important because we're kids and we know what other kids our age want, versus like what adults think.

Katie: Okay. Yeah. How about you, Sophia?

Sophia: A kid's point of view, like deciding for other kids, because an adult doesn't exactly know what it is. I had tried to imagine and be like, 'What do your parents like? What do they want?' Ummm so it's better to have a kid's point of view sometimes.

As most of the students responded with a loud, "yes" when I asked them if it mattered to have students plan events like STEM night, it was clear that there was a consensus that students thought sharing authority in planning learning opportunities mattered. The students shared highlighted that students have expertise that adults do not always share. Mrs. B and I agreed with that assessment when we later discussed that the students had way more ideas than us for STEM night. Engaging students in the planning supported there to be more community and science expertise leveraged to meet the class' STEM night goals.

Prepping Materials for STEM Night

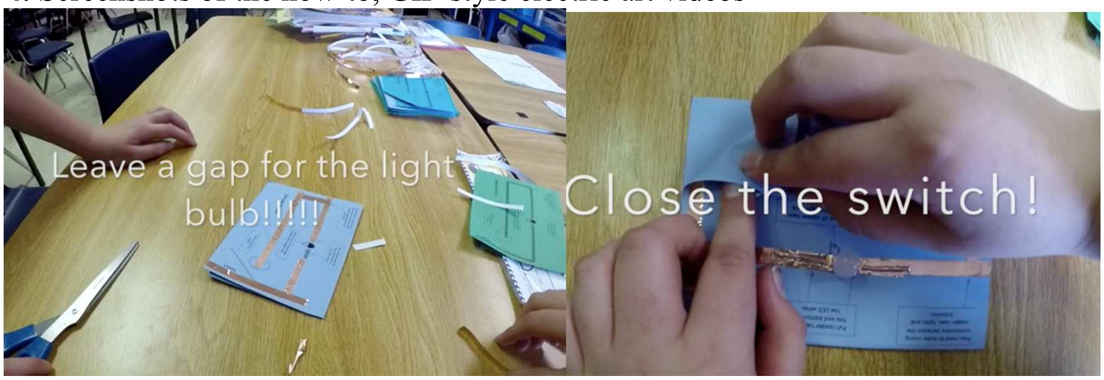
Students were invited to help prepare the educative materials at the end of the whole class STEM night planning discussion. Mrs. B planned for students to prepare the necessary materials for STEM night across different times and spaces. These included during recess, after recess and during science class during the afternoon before STEM night. By offering many different preparation periods, Mrs. B was providing students flexibility to use their expertise to support the class in completing the task necessary for their planned STEM night. Students volunteered for what posters they wanted to make for the event (welcome signs, renewable and non-renewable resources and circuit tips). By choosing what they wanted to help work on, students were able to leverage their expertise in ways that aligned most with their interests as they helped their class community work towards their STEM night goals.

Below I describe how students used their expertise to support their class in reaching their goals of a STEM night that provided visitors access to learning about energy and circuits while being responsive to who their community was. In particular, I focus on students developing the how-to, GIF-style electric art video, making a welcome sign and designing educative posters. Then I look across all examples to highlight how these efforts supported the class community in using distributed and diverse forms of expertise, generatively building on and welcoming shared expertise over time through actions and discourse taken up by multiple community members using that hybrid expertise towards co-defined meaningful ends.

Making a video

Cristina, Abby and Eric worked on making the two how-to, GIF-style electric art videos during recess. The students built on the ideas of Chad and Rachel as they worked to make videos that were short, repeatable and showed step-by-step how to make the electric art work. Cristina and Eric made a time-lapsed video showing how to make a complete simple circuit while Abby worked on creating a complete parallel circuit. Neither video team was able to get their circuits to work immediately. However, unlike when they first made electric art templates and cards, the three students were able to troubleshoot much more independently of the adults in the classroom. In doing so, they were leveraging their expertise that they developed when they engaged in the electric art unit.

Figure 4. Screenshots of the how-to, GIF-style electric art videos



Additionally, the students knew making electric art could be frustrating for novices if they keep making mistakes. For example, when Cristina described her first initial experiences making electric art, she said, "I got mad a lot." Therefore, students used both their emotional experiences and the new circuitry expertise they developed making electric art to better design a less frustrating experience for visitors. Similar to the youth-produced videos that they previously watched, Eric and Cristina's video included tips to avoid common mistakes that they experienced when they made electric art. Tips included, "Leave a gap for the light bulb" and "Close the switch". (See Figure 4). The students wanted to make sure the STEM night visitors would find success in making their own electric art so they had specific tips to add. Tips included, "Sandwich the light wires between the copper tape", and "Pay attention to +/- side of battery sides."

As the students made the electric art videos, they were building on their peers' expertise that led to a class community consensus to make how-to, GIF-style electric art videos. When the class decided that they wanted the videos at STEM night, they actually opened up an opportunity for Cristina, Abby and Eric to both use and further develop their circuitry expertise as they troubleshot how to complete the circuits. The students making the video would later support STEM night visitors in having an easily accessible tool to use as they made their own electric art.

Later in this dissertation, I delve more deeply into the making of videos to highlight how participatory planning and teaching practices supported Cristina and Eric in having expanded authority. For now, I use this brief description of the event to highlight how students were building on the expertise of others and their own experiences as they enacted their class goal to support visitors in learning and enjoying the process of electric art.

Making a welcome sign: Designing for STEM night to be truly welcome

One material students felt was important was designing what they considered to be a "truly welcoming" sign. Christina and her friend Abby chose to come to the classroom during recess to support the class community's STEM night prepping. Cristina and Abby decided to make welcome signs for STEM night so that everyone would feel welcome at the event. Therefore they wrote, “Welcome to STEM Night.” However, Cristina and Abby, both students with multilingual families, knew that writing “welcome” in one language would not truly welcome all families.

Cristina came and asked me if she could also write “Welcome to STEM Night” in Spanish on the poster. We both tried to remember how to spell *bienvenidos* and eventually she went to ask the English Language Learner teacher for help. She came back with it written down, and then I recommended that she ask how to write the welcome in Swahili, too. She went and asked a teacher who spoke Swahili for help. Beyond English, Swahili was the most common language spoken within the school community. However, Cristina decided it was not enough to have the sign written in three languages because one student in her class spoke Pashtu so she wanted to make her feel welcomed too. Even though Abby did not want to go ask their English

Language Learner teacher for more help, Cristina persisted and went to ask him on her own. During this moment Cristina leveraged many people's linguistic expertise to better support her community in engaging in STEM night.

When I asked Cristina why she wanted to write "Welcome to STEM night" in Spanish she told me that both of her parents spoke and wrote in Spanish at home, and that "It would be really cool if they could come to school and see a sign that they can immediately read and understand." As the designer of the Welcome Sign, Cristina drew upon her knowledge of what languages were spoken among the families at her school, and what it meant to be able to be greeted with a familiar language, in what has been a typically English-only (or English-dominant) space. Leveraging multiple resources (multilingual speakers, different school spaces, poster making materials) supported Cristina and Abby in designing a way to make the school more approachable for their own and many other multilingual families. This supported her class enacting critical science agency as they prepared to make STEM night an enjoyable opportunity to experience circuitry and energy sources for families that reflected who they are.

Cristina and Abby's work on the Welcome Sign challenged the English-dominance in the Wilkerson school space. Personally, Cristina's idea to write bienvenidos alerted me to the ways that we were not being as welcoming as possible to all of the students and their family. Additionally, through including multiple languages on the welcome sign, the girls were actively pushing against practices operating across the United States that position English as the language for schooling. Scholarship has shown that while the United State does not have an official language, the dominant use of English and exclusion of other languages has been a form of oppression operating (Cobas & Feagin, 2008).

This case also highlights how the girls disrupted both the linguicism and racism operating within their school. As they wrote welcome in multiple languages, they were choosing languages that were spoken predominantly by families of color. The intersectional experiences of multilingual students of Color in English-dominant schooling impact their learning opportunities in multiple ways (Pérez Huber, 2010). Cristina and Abby's efforts supported their class community in resisting that oppression.

Making Educative Posters

During their free time, students came with me into the STEM lab to create the educative posters that their class designed. The students worked collaboratively to enact their class's plan to have educative posters at both the make-your-own electric art station and the green energy exploration station. As students prepared the posters, they built on their own experiences as well as the expertise shared during the class planning discussion. Additionally, they co-developed their expertise as they brainstormed and refined their posters.

For example, in the following exchange, the three youth brainstormed common errors that people make when creating circuits. This conversation supported the students in building on each other's ideas to make sure newcomers to electric art would have success.

Katie: What tips do we have for electric art? Cut the copper tape with scissors right?

Mike: Make sure all of the copper tape is lined up.

Sophia: And pushed down.

Cristina: Yeah!

Katie: Alright push down the copper tape. Mike, you mean overlap the copper tape.

Mike: Yeah.

Cristina: Make a sandwich instead.

Sophia: Yeah!

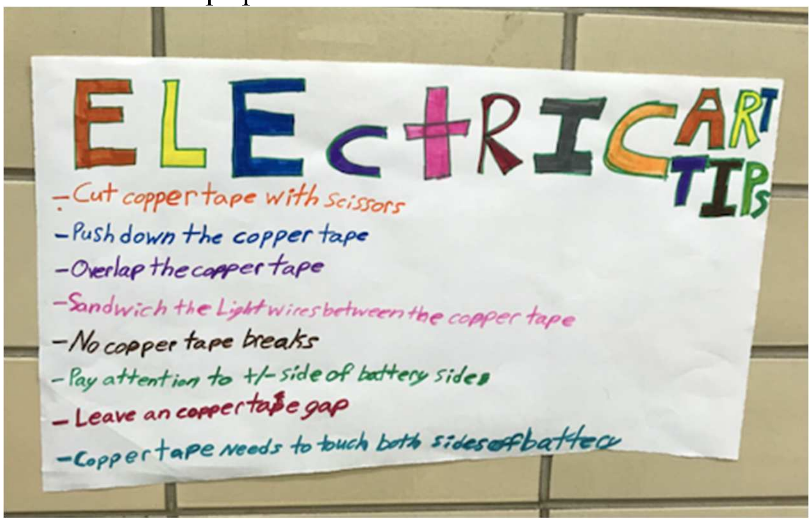
Katie: So sandwich the light wires so they are between the copper tape…

Cristina: Then you should put, push hard. No make sure there are no breaks.

As students built on each other's answers, they were drawing upon their own expertise and developing new expertise as a result. When Sophia and Cristina both emphasized pushing down on the copper tape, they were refining Mike's idea that all the copper tape must be lined up. The girls were pointing out that the copper tape must be strongly connected or the electricity would not flow. They clarified each other's ideas and used what they discovered making electric art to help others learn how to do so too.

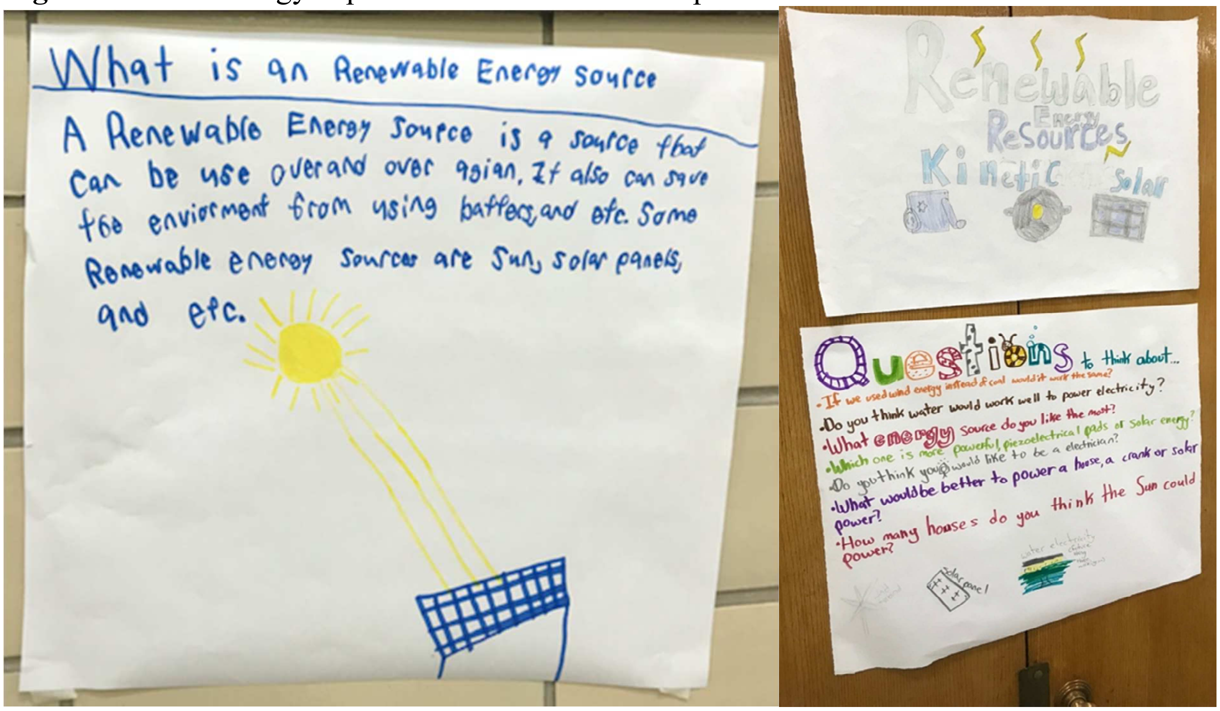
Figure 5 is the resulting poster highlighting the brainstormed list of tips created by the students. Students generated a total of eight tips to support the STEM night visitors to leverage as they created their own electric art. In addition to the brainstormed tips, the students chose to use multiple colors and block letters to appeal to visitors. Their level to aesthetic detail is reflected in how each tip was written in a different color and the block letters were outlined in one color and filled with a different color.

Figure 5. Electric art tips poster



Additionally, the students generated questions for STEM night visitors to explore with the green energy sources. This approach addressed their class' goal to have visitors explore the green energy sources. Questions included, "Do you think you would like to be an electrician?", "Which one do you think is more powerful, piezoelectric pads or solar energy?", and "What do you think would be better to power a house, a crank or solar panel?" Consider how Sophia's dad was an electrician, as she and her peers asked, "Do you think you would like to be an electrician?" She was connecting STEM night directly to her family's life. These questions pushed on both the technical and social dimensions of the energy sources, which supported the students using their expertise to help visitors to think about how green energy could be utilized in the community. As students created these posters they were helping their class community to enact critical science agency by working to support STEM visitors to "explore", "try" and "play with the green energy sources in meaningful ways. See Figure 6.

Figure 6. Green energy exploration station educative posters



Enacting STEM night

Mrs. B had students work together and with me to complete the final steps of STEM preparing for STEM night. Together, students and I prepared circuit making materials (batteries, templates, copper tape, scissors, clear tape) and then collaboratively set up the STEM night materials in the gym to best support visitors positively experiencing STEM night.

During the final preparation activities, students used their expertise about how they wanted visitors to access the STEM night materials. They made decisions on where to locate the different tables/stations as well as how to set up each of the activities on the tables, re-arranging things multiple times. For example, as Dominic, Eric and Eli collaboratively worked to get the materials ready for the make-your-own electric art station, they engaged in a decision-making process that leveraged what they knew about circuits and learning to make it a smoother experience for visitors. Dominic asked me if I wanted the batteries separated but kept in their packages. While his question showed how he viewed me as the expert, he was making a helpful material preparation step that I had not thought of previously. His question prompted me to draw upon his expertise to ask the boys if they thought it was better to keep the copper tape in rolls or strips. Dominic, Eli and Eric all wanted the copper tape to be in strips. They indicated that the strips would make it easier for community members to get materials quickly, and it would lead to much less copper tape wasting. By asking students to make the choice of how to prepare the materials, the boys' collaborative expertise on supporting families in accessing materials further shaped the STEM night.

The students also used what they knew about how to support others in how they arranged the educative posters at STEM night. They chose to hang the circuit troubleshooting tips posters near the electric art station table. They then put the green energy questions above the green energy station. They re-arranged the posters' locations to make sure that families would be able to see them clearly as they sat at the stations, so that they could actually use them as a learning tool when they learned about green energy sources and worked on electric art. They also helped brainstorm where to put materials so everyone could access them – and know they could access them – and also where to put the markers and colored pencils so there was enough space on the make-your-own electric art table. I saw Dominic and Eric walk around the table multiple times to see if the materials were spread out well enough. They then decided where to place the iPads with the electric art GIF videos so everyone who needed additional help could see them. During this time, I helped students to move the cafeteria tables safely and asked prompting questions to help facilitate decision-making processes like, "Where do you think the green energy station should go?" and "What do you like best?". As student collaboratively enacted their expertise about the best way to design the physical space of the gym for STEM night, they were using hybrid expertise towards co-defined meaningful ends of supporting visitors in having access to the resources necessary to enjoy and explore energy at STEM night.

Stem night teaching. At the end of the whole class planning discussion, Mrs. B invited students to help enact the plans at STEM night. She said:

> We need to make sure that we have kids there to be the experts and talk to— (Abby raises her hand) Okay, so Abby is definitely coming. Who else is definitely coming tomorrow? We totally need and want your help.

By encouraging students to be experts and saying, "We totally need and want your help," Mrs. B was highlighting how the members of the class community had important expertise to share with STEM night visitors. As students raised their hands, Mrs. B asked them to think out logistical questions to make sure that they could make it.

Mrs. B: Okay. You've talked to Mom? She's good? You've talked to Mom and Dad, and they're good? Chad, you talked to Ma?

Chad: Yeah, kind of.

Mrs. B: Do we need to call Mom?

Dennis: My mom don't—

Mrs. B: That's okay. Doesn't she work on Wednesdays?

Dennis: No, but I think you could tell her.

Mrs. B: Okay. Sophia, you're definite? JJ, can you get here?

JJ: My mom said she called my sister, Natalie.

Mrs. B: The one that lives in Detroit?

JJ: No, she lives here.

Mrs. B: Abby is coming. I know specifically that she's coming. Mom is dropping her off, and she is gonna specifically stand there to be an expert.

As Mrs. B interacted with the students asking questions specific to their families' STEM night attendance plans like "Doesn't she work on Wednesdays" or "The one that lives in Detroit," she was first connecting directly to what she knew about the students' families. She also was offering specific tools and was willing to take action, like "Chad, you talked to Ma" and "Do we need to call Mom?", to make sure the students were able to coordinate attending STEM night. She was supporting them in being able to attend STEM night and leverage their expertise to support others experience making electric art and green energy sources in meaningful ways.

Cristina like many of her peers attended and taught her family at STEM night. Now, I zoom into Cristina's experiences teaching STEM night to highlight how she supported her class community's goal to support STEM night visitors in having positive experiences. Cristina attended STEM night with her grandmother and two sisters. This was the first time ever that her family attended an afterschool academic enrichment event. Cristina explained that she asked her family repeatedly to attend. Her parents had to work so they arranged for her grandma to bring the three granddaughters. By getting to the event with her family, Cristina was able to teach them about engineering, energy and electricity through showing them her electric art, making their own electric art and exploring the green energy sources.

Immediately, Cristina brought her family to the make-your-own electric art station. Cristina explained, "We went to make a card thing for them, and they didn't understand it." Given the alignment between their uncertainty and the video Cristina produced, she chose to show the video to them. Her grandma and sisters immediately complimented Cristina for the video. Her grandma told Cristina that she could become a "millionaire" who manufactures things that needed circuits. Cristina laughed and smiled about that when she recounted the conversation to me the next day. By sharing the electric art video, Cristina supported her family in being able to leverage new expertise about circuits. She was also sharing her own expertise about circuits.

As her family worked on the electric art cards, Cristina initially helped her older sister and grandma troubleshoot when their electric art cards did not work initially. Cristina explained the steps she took: "I put on the lights for her [older sister], and I told her to put the battery on the negative side and stuff. Then she did it and it worked." At this moment she drew upon what she learned in the electric art design challenge in class, and also what she and her peers discussed as tips for making electric art. After her grandma created a working electric art circuit, Cristina encouraged her grandma to help her younger sister complete her circuit. Cristina supported her family in creating working circuits by looking at others' working circuits to figure out why theirs were not working. By looking at examples of working electric art, she was able to use expert tips that she helped to create to avoid getting frustrating and help her family make working electric art. Additionally, in this example, Cristina drew upon the video she made, me, and the electric art materials to teach her grandmother and two sisters how to effectively complete electric art templates. This shows the ways that Mrs. B’s class community’s expertise built on itself across time to support families in learning happily about electric art.

Cristina's family also brought home materials to make together another working electric art card to give to Cristina. As her family left the sixth-grade station, Cristina showed her family the electric art card she made for her mom. Her sisters agreed that her parents were going to really like it. Taking home the electric art materials with them and their new expertise of how to make electric art templates provides a glimpse into Mrs. B’s class community’s success of planning and enacting STEM night in a way that provided access to energy learning while being responsive to who the visitors were.

Cristina deemed STEM night a success because how many people engaged in the activities and seemed to be having a good time at the same time. She explained, “Lots of people showed up and it was fun." There were over 250 visitors to STEM night, which was significantly more than the year before. Many of her classmates also brought loved ones to the electric art stations, and taught them about energy and circuits. When new families would join the table, they would both watch the how-to, GIF-style electric art videos as well as look at the cards that other STEM night visitors had made. This shows how STEM night further supported an expansion of expertise within the space as electric art novices used resources to learn new skills. At the end of the event, teachers had to make multiple announcements that STEM night was over. As students and their families reluctantly left when STEM night ended, they took extra supplies home with them to complete their electric art.

Returning to STEM night as Critical Science Agency

Across the participatory planning and teaching events described, Mrs. B’s class community collectively enacted critical science agency [CSA]. I noted in Chapter 2 that the literature describes CSA as a specific type of agency that is enacted when members of a community collectively develop and leverage science and other forms of expertise to address issues of injustice. However, this literature does not adequately address how students are supported in leveraging their various forms of expertise in ways that generatively build on and welcome shared expertise through actions and discourse taken up by multiple community members. The literature also addresses CSA as an individual action. What I show in this section is that CSA can be viewed as a collective act, and in so doing opens up new insights into how communities collaboratively use distributed and diverse expertise towards co-defining meaningful ends.

Mrs. B's class community's STEM night planning incorporated – indeed, needed – multiple types of expertise. As students' cultural and disciplinary expertise was shared and leveraged, the goals of the STEM night evolved to be more community responsive and equity-oriented (Bang, Warren, Rosebery & Medin, 2012). The students emphasized the importance of, and made plans for, more fun. Noting that the outcomes of learning are not just the new knowledge itself, the students also provided ways for community members to design, build and take artifacts of their learning home with them. Consider how Cristina's family took home materials for them to finish another electric art template together.

Further, the collaboratively developed green energy station was designed to prompt family and community visitors to think about how their energy choices impacted the environment. This approach may have impacted their energy choices at home. Additionally, the students used multiple and culturally relevant scaffolds (e.g., educative posters, example electric art displayed, how-to electric art videos) to support STEM night visitors' in learning about energy and circuits on their own, and in ways connected to their lives. This supported visitors' rights to experience learning opportunities by providing multiple tools with which to approach their learning experiences. See examples of the multiple types of expertise leveraged in Table 9. The class resisted incorporating only dominant science education expertise and connected the STEM night learning experiences to community, which is a matter of justice (Tan, Calabrese Barton & Benavides, 2019).

Table 9. Examples of expertise used participatory planning and teaching of STEM night

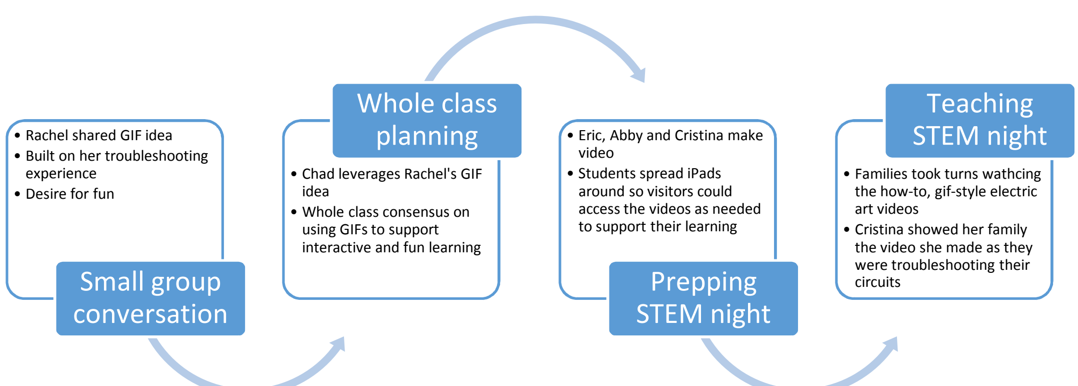
Types of Expertise	Examples of expertise leveraged
Disciplinary content knowledge	Energy sources constraints and advantages
	Circuitry
	Circuit troubleshooting
	The connection between energy sources and the environment
	Engineering design
Pedagogical Expertise	Own experiences feeling frustration and then pride completing electric art
	Scaffolds needed to support visitors in both effectively and enjoyably learning at each station
	Access to materials supported learning
	Authentic design activity
Community expertise	Visitors would probably want to explore the materials at each station, not just adults or youth
	Fun made learning better
	Being able to design, build and then take learning activities home supported engaged learning at school and later
	Connected green energy sources to families' energy sources and jobs
	Signs in multiple languages
Creativity	GIFs
	Need for aesthetically-pleasing educative posters

There was a generatively building on and welcoming shared expertise over time across the planning, preparing for and enacting of STEM night. This collaborative and generative leveraging and development supported Mrs. B's class community in first defining, then refining and enacting a STEM night plan that opened up opportunities for the broader school community to access and engage with STEM in meaningful ways.

To show the generative leveraging of expertise towards co-defined ends, consider the ways Rachel's idea for the how-to, GIF-style electric art videos supported Mrs. B's class community in collaboratively planning and enacting the make-your-own electric art station. (See Figure 7.) Rachel first shared her idea for making a how-to, GIF-style electric art video to support electric art making with Cristina, Abby and I. This built on both her experiences and expertise being frustrated and then happy as she troubleshot her own electric artwork during the

I-Engineering unit. Additionally, as she shared her idea she was leveraging her expertise about GIFs and what community members thought was fun. During the whole class conversation, this how-to, GIF-style electric art video idea supported Chad and later the whole class reach a consensus that they wanted visitors to experience making electric art in a way that was fun and supported learning. As the class prepped for STEM night, Eric, Abby and Cristina used their expertise and developed new expertise as they troubleshot the circuits used in the how-to, GIF-style electric art videos they made. They made these videos to support the class community's goals to support circuitry novices in making their own working circuits. Then as the students prepared the gym, they used their expertise about resource availability to spread the iPads around the make-your-own electric art station to ensure access to the how-to, GIF-style electric art videos to everyone who needed it. During STEM night, Cristina leveraged the how-to, GIF-style electric art video she made to show her family how to make electric art. Similarly, multiple families took turns watching the videos and passing them around to support newcomers to the make-your-own electric art station.

Figure 7. Electric art video-making process highlighting the generative nature of building and leveraging hybrid expertise towards co-defined meaningful ends



From the inception of Rachel's make-your-own electric art station to visitors watching the videos at STEM night, there was generative leveraging of expertise that built on her idea. In each of the events above, you can see how multiple students, Mrs. B and I used the idea and built on it to co-define, refine and address their STEM night goals. In doing so, the students also developed more expertise like Cristina, Eric and Abby discovering new ways to troubleshoot circuits as they filmed the videos. In addition to supporting the students who were participatory planning and teaching leverage new forms of expertise, the how-to, GIF-style electric art video ideas as it evolved across the planning and teaching process opened up an opportunity for visitors to access STEM expertise in a way that was responsive to the community. It was fun, informative and supported electric art making that could be taken home.

As Mrs. B's classroom community planned STEM night, they positioned each other as co-experts and co-teachers of meaningful learning to each other, their families and teachers. This is important because it speaks to how and why they sought to provide access to develop and leverage new expertise towards co-defined meaningful ends. As Mrs. B's class community enacted critical science agency, they positioned students as teachers of meaningful learning to each other, their families and teachers. They designed for STEM night visitors to have more access to develop and leverage expertise for their own and the broader community's learning. For example, the class community, after some discussion, agreed that visitors should be able to experience lighting up the sixth-grade students' electric art, making their own electric art and trying out each green energy source. This resisted common ways I have seen that students' work and scientific tools often are on display to be seen but not used when families interact in schools, especially in schools serving low-income populations.

Mrs. B's class community participatory planning and teaching STEM night push on understandings of critical science agency. Mrs. B's class community enacted critical science agency as they used multiple forms of expertise to address issues of injustice. However, this chapter highlights how as Mrs. B's class community enacted critical science agency there was a generative leveraging, building on and expanding of expertise across time, people and space. Through this process, access to leveraging multiple types of expertise was opened up and co-defined issues of injustice were addressed both through the process of enacting critical science agency and as an outcome of critical science agency.

Exploring How Participatory Planning Supports Critical Science Agency

As the class community participatory planned and taught STEM night, students and then the visitors to STEM night leveraged multiple forms of expertise. They also collectively disrupted and/or amplified classroom norms towards must just opportunities for learning and interacting. The generative leveraging of expertise was critical to enacting critical science agency as it opened up meaningful STEM learning opportunities while reshaping norms and interactions. Understanding what supported students' expanded authority and disrupted/amplified norms to generatively use resources and their knowledge to collectively take action is key to understanding how, if at all, does participatory planning and teaching support critical science agency. My main claim is: *The enactment of participatory planning and teaching practices supported collective critical science agency by: Disrupting and amplifying class norms towards more just ends, supporting expanded authority, and allowing for addressing and co-defining outcomes of learning*.

To build my second major claim, I first describe five main co-produced participatory planning practices that interacted to amplify and/or disrupt different classroom norms towards expanding epistemic and positional authority. After walking through each of the co-produced practices in order to describe them and offer brief contextualizing examples, I offered an in-depth vignette (how-to, GIF-style electric art videos). With this vignette, I examine more closely how these participatory planning and teaching practices interact, and how they support expanded authority by amplifying and disrupting class norms. After this vignette, I then elaborate on how the participatory planning and teaching practices interact to amplify and disrupt norms operating within Mrs. B's classroom, and highlight students' expanded authority.

I conclude this section by examining the dynamic relationship between the participatory planning and teaching practices, norms amplification/disruption and expanded authority. I highlight the connection between the collective enactment of critical science agency and authority, noting the role that participatory planning and teaching practices play in this process. As I noted in the previous section, critical science agency is a collective act, involving using distributed and diverse forms of expertise, generatively building on and welcoming shared expertise over time through actions and discourse taken up by multiple community members, and using that hybrid expertise towards co-defined meaningful ends.

As I show throughout the rest of this chapter, students need to have authority within the classroom community to share and leverage their expertise. Epistemic authority opens up space for students to share their expertise through generating new tools, understandings and practices. Positional authority supports students in having the resources necessary to leverage that expertise. If students do not have authority within the school space to share and use their expertise, the class community cannot leverage hybrid practice towards co-defined meaningful ends.

Co-Production and Participatory Planning and Teaching Practices

Mrs. B's class community co-produced participatory planning and teaching practices as they prepared for and enacted STEM night.

I illustrate five co-developed practices, which include:

1. Valuing and leveraging students' different expertise and interests
2. Allowing flexibility in participatory planning and teaching of the curriculum
3. Consensus building between all classroom community members
4. Planning for more equity-oriented participation (e.g. providing multiple ways to participate and learn) as well as science learning.
5. Planning for community-oriented outcomes that matter.

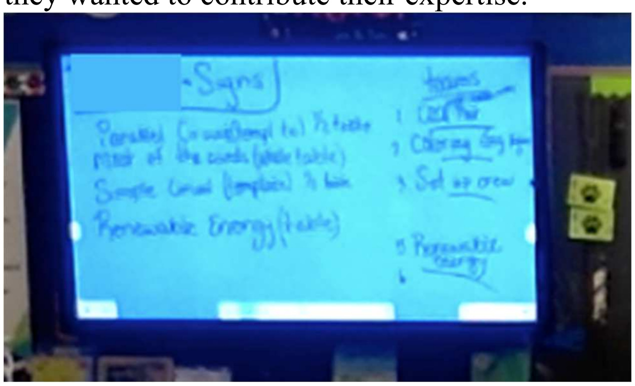
I now share descriptions of each co-produced practices. I describe some of the multiple ways they were enacted and share brief contextualizing examples that occurred throughout the participatory planning and teaching process.

Valuing and Leveraging Students' Different Expertise and Interests

Valuing and leveraging students' different expertise and interests meant Mrs. B, her students and I invited others to share their multiple types of expertise as the class community worked towards co-defining and plan for the experiences they wanted STEM night visitors to have. This practice emphasized an open invitation for all students to participate. Mrs. B would often ask students questions about both the content they wanted visitors to learn and how they wanted visitors to experience it. For example, during the whole class planning conversation, she asked, "What it's gonna look like, what it's gonna feel like, what we're gonna have on the tables." By asking multiple "What" questions, she was encouraging students to share multiple types of expertise about what they knew. She would also keep track of students' ideas on the Smartboard and would write to-do lists. Then she would ask students who wanted to do each task. See Figures 8 and 9 to see how Mrs. B writing down ideas and the resulting STEM night plan. It was also common for Mrs. B to elicit students expertise by re-stating students ideas to get more students input instead of evaluating them herself.

Figure 8. Mrs. B recorded students' ideas.

Figure 9. Mrs. B then organized tasks into to-do lists before inviting students to choose what they wanted to contribute their expertise.



Additionally, this practice was enacted when students were invited repeatedly to prep for the STEM night. Another strategy was for me to host conversation groups with small groups of students. These opportunities enabled students to share their ideas in an environment where they may have felt less risk for speaking out. Another strategy was when Mrs. B led a whole class conversation to review and refine the STEM night plans. In this whole class conversation, she centered the students' ideas as the main focus, and encouraged students to build on what was already there. In so doing she legitimized the students plans as valuable, and directly complemented the importance, quality and value of the student-led plans. She also used talk moves to encourage students to ask each other what they thought. For example, Mrs. B would re-state students ideas and pause. In doing so, students had chances to add their knowledge to the discussion. Additionally, she would use moves to expand the conversation to the whole class. Consider, how she said, "Okay. What do you guys think over here on this side? Do we have any ideas on how we want to display them?". Through this move, Mrs. B expanded the conversation to include students on the right side of the room who had not shared their ideas about how and what they wanted STEM night visitors to learn.

The co-produced practice of valuing and leveraging students' expertise and interests shifted the way the class community shared their knowledge. It led to more students contributing ideas, and a wider range of expertise being shared. Instead of telling students what to do when we were setting up the gymnasium for STEM night, I asked prompting questions and students' collaboratively made decisions. For example, Dominic, Eric and Eli were three students who rarely contributed to whole class conversations. However, during the set-up period, they talked and took steps together to make sure that there were materials spread across the make-your-own electric art station so families could easily access the materials as they learned together. This is important because the students collectively used their expertise to contribute technical, social and pedagogical expertise to the design and enactment of STEM night.

Allowing Flexibility in Participatory Planning and Teaching of the Curriculum

The second co-produced practice was the practice of allowing flexibility in participatory planning and teaching of the curriculum. This looked like the class community maintaining on-going openness to changes in both a) what the class' learning goals were, and b) how the planning process for obtaining those learning goal was conducted. Being flexible in planning seemed primarily to be in response to the efforts on both the teachers and students' parts to find a way to authentically incorporate the wide range of interests and expertise shared by students (see previous practice)., Mrs. B and other teachers first enacted this practice when they shared the STEM night planning opportunity with Mrs. B's sixth-grade students. In doing so, the adults usually in charge of planning became more flexible to the enactment of students' expertise.

Mrs. B further enacted being flexible, when she opened up the whole class conversation for the STEM night planning by asking, "What do you think would be cool to share that they think would be cool?". While in this example she was also leveraging students' expertise, she was being flexible to how the STEM night planning and teaching of STEM night would change based on the students' answers. Recall Mrs. B and my reflection conversation after the whole class STEM night when we shared with each other that we did not conceive of three different energy stations. However, as students introduced multiple ideas about supporting visitors making electric art and explore green energy sources, we were open to the plan and supported the students in enacting three energy stations tailored to support the STEM night visitors learning.

When students raised ideas that did not "align" with the plan, Mrs. B would essentially slow the process down so that the classroom community could adapt the plan as needed. Mrs. B would ask clarifying questions, and engage in a brainstorming process with the students to figure out how the class could adapt the class plan to incorporate new ideas.

Another strategy for enacting this practice involved adapting the actual planning process to meet student needs. For example, Mrs. B and I planned for me to host conversations during lunchtime. Students were encouraged to attend as many or as few as they wished. We developed this plan in collaboration with the students who voiced the idea that students should have the power to decide when and how many planning meetings they attended. We wished to make the meetings accessible during the school day, which is why we scheduled them during lunch. However, lunch was an important social time and valuing students' needs along these lines helped. For example, Sophia told me that she wanted to come, but had not had enough time with her friends recently so she chose to go to recess some weeks and other weeks she participated in the conversation groups. Mrs. B also made time during recess, and in her regular class periods for planning work to happen.

This approach led to the opportunity for more students to participate than if participation was mandatory. A total of eleven students participated in the conversation groups, but attendance ranged from attending one conversation group to all five conversation groups. See Table 10. This flexibility allowed for more students to engage in the conversation group form of participatory planning.

Table 10. Students participating in Conversation Groups

Total students participating in only one conversation group	2
Total students participating in only two conversation groups	0
Total students participating in only three conversation groups	2
Total students participating in only four conversation groups	5
Total students participating in five conversation groups	2
Total Students participating in conversation groups.	11

As a researcher-participant, I was challenged to be flexible in the ways that participatory planning and teaching occurred. After the second conversation group when students were rushing out to recess, I informally suggested that we split the conversation group in half and have two weekly conversation groups instead of one so everyone had more chances to share their ideas. However, Steph quickly disagreed because he explained that even if everyone was not sharing, they still were participating.

Being flexible also meant being open to where STEM night preparations took place. Consider the different places students were supported in preparing for STEM night. The whole class planning conversation took place in the classroom. Cristina and Eric started making their how-to, GIF-style electric art video in the classroom during recess and finished it after recess in the library. Dominic, Eric, Sophia, Cristina, Mike and other students worked first in the STEM lab and then the gym as they completed final STEM night preparation.

Consensus Building between All Classroom Community Members

Consensus building between all classroom community members is the third co-produced practice. Members of the class community enacted this practice as they worked towards agreements about different decisions connected to STEM night planning and enacting. Students and teachers would elicit multiple ideas from students through multiple formats and then get more feedback from the broader class community. Members of the class community would then discuss the plan and adjust it until there was agreement on how to proceed. This practice was often enacted at the same time when students' expertise was leveraged.

I enacted consensus building when I shared Rachel's how-to, GIF-style electric art video for supporting electric art with the whole class. Cristina, Abby and I all thought it was a great idea, but to consensus build, I then brought the idea to the whole class. When I shared her idea in the whole class planning discussion, I asked the class what they thought about it and if they thought it would help visitors make electric art. Consensus building sometimes included sharing the idea first in a small group and then with another group of students or the whole class.

Consensus building supported multiple students sharing their expertise about one topic. For example, consider how the class community decided that STEM night visitors would be able to try to light up the sixth graders' electric art. Mrs. B, students and I all shared ideas and concerns when Mrs. B asked students for ideas about what the class wanted visitors to experience. We enacted the practices of consensus building as we collaboratively addressed those tensions until the class had agreed not just that visitors would be able to interact with the electric art, but also the plan to have class community members at the station to support visitors in testing the electric art switches in case they needed help. Through these ongoing conversations, students and teachers would elicit and evaluate multiple forms of knowledge and agree on a plan.

Planning for More Equity-Oriented Participation (e.g., Providing Multiple Ways to Participate and Learn) as Well as Science Learning.

Planning for more equity-oriented participation and science learning was the fourth practice. Mrs. B's class community enacted this practice by planning and enacting learning opportunities that supported STEM night visitors in participating in many different ways that connected specifically to who they are. Additionally, enacting this practice also meant that the class community worked to support opportunities for all students to participate in meaningful ways as they supported the class in leveraging hybrid expertise towards co-defined meaningful ends. This means that the class supported students in having chances to share and develop new expertise throughout the planning process rather than just having select students and/or the teachers making all the decisions.

Consider how students enacted the practice of planning for more equity-oriented participation when Cristina and Abby created the Welcome to STEM night sign in multiple languages. The students knew that many families, including their own, spoke many languages beyond English. They wanted to make sure that more people felt welcomed to engage with the STEM learning that night.

This practice was evident in the various learning tools students designed to ensure that each STEM visitor could learn how to make circuits. Consider how the class community prepared four different educative resources to support electric art making: electric art tips poster, a parallel circuit how-to video, a simple circuit how-to video and templates. Recall how students discussed how frustrating making electric art could be so they chose to make it easier for their community with these learning tools.

Encouraging students to consider what types of experiences they wanted families to have instead of just what they wanted to learn supported the class community in enacting this practice. Similarly, the students worked to make sure STEM night was fun, which reflected how they wanted their community not to just learn, but enjoy doing so. Throughout many planning moments, the students planned to make sure that it was fun. When the students planned to have questions for visitors to use as they explored the green energy sources, they were choosing to support visitors in participating in more fun ways.

The practice of planning for more equity-oriented participation applied to the process of planning not just the outcome of STEM night. This practice was enacted when the class community repeatedly invited every student to contribute and develop their expertise to support the STEM night effort. Consider for example, even though the conversation groups were sometimes very large, no student was excluded. Additionally, remember when Mrs. B told the students, "We totally need and want your help" when she asked for students to volunteer to help teach at STEM night. In doing so, she was opening up space for all students to have a chance to share their expertise and contribute to the class' goal. She re-enforced this point when Sophia told her, "I'm not so much of an expert, so that's maybe that I have to be an expert." by responding, "You will be an expert. You are fine!” Through this brief exchange, Mrs. B was supporting Sophia in seeing herself as capable, able and welcome to join the class's STEM night efforts. Sophia showed her dad, sisters and sister's friend her electric art and supported them in making electric art at STEM night.

Planning for Community-Oriented Outcomes that Matter

The final practice was planning for community-oriented outcomes that matter. Mrs. B's class community enacted this practice as they designed learning opportunities that supported community members in using new expertise in ways that they valued. Enacting this practice also meant that the class community planned for STEM night visitors in taking and applying newly developed expertise beyond STEM night and into the community. This practice was enacted in planning by deciding what outcomes would matter most to community members and in preparing the necessary tools and resources to meet those outcomes.

There were multiple examples of the class community enacting this practice. First, the students and teachers planned an event that mattered to their community as over 200 visitors attended. Mrs. B's class community's planned community outcomes that mattered when they designed the make-your-own electric art station to allow families to learn together at school and then take their learning artifact home. For example, Cristina's family took extra materials home when they ran out of time so they could finish their last template. Additionally, they enacted the practice of planning for community-oriented outcomes that matter by providing an opportunity for the whole sixth grade to be recognized for their electric art expertise through the electric art exhibit. The exhibit making also supported the STEM night visitors in making their own electric art as they used the sixth-grade electric art cards as models.

Students enacted this practice as they provided ways for families to choose how they would engage with the STEM energy stations. Students planned for students to go to any station and in any order. When they got to the stations, there were tools that students produced to help families learn in engaging ways. However, there were also choices that families got to make, like what questions did they want to explore with the green energy sources, what type of electric art circuit (simple or parallel) would they make or what sixth-grade card did they want to try and light up. Through providing these choices and openness, Mrs. B's class community was positioning STEM night visitors to engage in learning that mattered to them. They also were enacting the practice of being flexible in the planning and enacting of the curriculum.

The five participatory planning and teaching practices were co-produced and leveraged by Mrs. B, students and I across the class's collaborative STEM night efforts. Table 11. offers a summary of these practices with multiple illustrative examples from each of the STEM night phases discussed earlier (planning, preparing, enacting).

Table 11. Examples of participatory planning and teaching practices

Participatory Teaching and Planning Practices	Participatory Teaching and Planning Practices Examples
Valuing and leveraging students’ different expertise and interests	• All students were invited to talk • Incorporate GIF-style making skills • Incorporated youth-centered ideas about what, why and how people should learn about green energy sources, circuit-making and electric art • Incorporated the languages of the community into the event
Allowing flexibility in participatory planning and teaching of the curriculum	• All students were invited to share ideas and take action in multiple formats • Varying levels of involvement of students was encouraged • Refining STEM night goals and plan allowed
Consensus building between all classroom community members	• Multiple opportunities for students to share, debate and agree to ideas • One-on-one conversations led by teachers and students to get multiple students’ input
Planning for more equity-oriented participation (e.g. providing multiple ways to participate and learn) as well as science learning.	• All students invited to develop and contribute their expertise to the STEM night planning and teaching • All students and visitors invited to participate in STEM night • Provided multiple tools (GIF-videos, troubleshooting tips, electric art templates, model electric art cards) for families to learn how to make electric art
Planning for community-oriented outcomes that matter	• Taught over 200 visitors about green energy sources, energy, the environment and supported them in making their take-home electric art • Supported the broader school community in recognizing the sixth-grade students' expertise in creating and teaching others on how to make electric art.

Participatory Planning and Teaching Practices Interact towards Disrupting and Amplifying Norms towards Expanding Authority: An illustrative Vignette

The iterative enactment of the five participatory teaching and planning practices supported Mrs. B's class to disrupt/amplify class norms towards more just ends and expand students' authority. Below I first highlight the enactment of the participatory planning practices together. Then, I show how the enactment of the practices led to the amplification and/or disruption of classroom community norms further supporting the expansion of students' epistemic and positional authority. I highlight this mechanism by revisiting, in detail, the how-to, GIF-style electric art video planning, making and teaching process.

Rachel first shared her ideas about making a GIF-style electric art video when I asked Rachel and Cristina for ideas for teaching others about circuitry at STEM night. By asking students for ideas, I was enacting the practice of leveraging and valuing students' expertise. Rachel shared her idea of making a short electric art DIY video like the one they had previously seen, except she wanted the video to be shorter so everyone could watch it faster. The idea was then discussed in a whole class planning discussion, which was focused on planning for community-oriented learning outcomes that made a difference and supported equity-oriented participation at STEM night. A consensus was reached to use that idea when Mrs. B asked the class if they liked the idea. Many students responded audibly with yes's and yeah's.

The practice of consensus building supported the practice of valuing and leveraging students' different expertise and interests. As consensus was being established, more students shared their ideas and were also invited to contribute their expertise. Mrs. B and I invited everyone in the class to help with the video preparation during recess. Mrs. B wrote down every volunteer's name and gave it to the students to take to lunch so they could use it as a hall pass to come down and work to make the videos. Cristina, Abby, Steph, Deedee, Chad and Eric all volunteered to help. Through the consensus building and leveraging students' expertise and interests, the video preparation responsibilities expanded from just one student's ideas to six different students volunteering to help make the videos. Additionally, many more students contributed their ideas as well as the class supporting the effort through agreeing with the video plan and as Mrs. B and I leveraged more of their ideas. This shows how the enactment of one practice can be the impetus for another practice.

When the students came back to the room during recess, the students flexibly chose how they wanted to support the STEM night planning. Cristina and Eric chose to work together on one video and Abby chose to work on her own to make a different video. Chad helped Steph, and Deedee worked with another research assistant to make their own electric art to display at the STEM night. While it may seem like Chad, Steph and Deedee may have not followed through with what they volunteered to do, they were still contributing to their class's planning efforts to support community-oriented outcomes that make a difference by creating working examples of electric art to display with the other sixth graders' electric art. Both Steph and Deedee had not finished their electric art at the same time because Steph was out of class due to disciplinary policies that were enacted by the school administration, and Deedee was visiting family. The flexibility in the participatory planning allowed them to reach their learning goals and plan in ways that might not have happened given their absences.

As Cristina and Eric worked on creating their electric art video, they leveraged expertise from each other multiple times, were flexible in their approach and worked to reach their class' goal of supporting others in learning how to make electric art. Additionally, they supported more equity-oriented participation by designing more ways to make learning more engaging and accessible to adults and youth visitors. They did so by highlighting the step-by-step process of making electric art and making sure it could be made more GIF-like. Additionally, they worked to support equity-oriented participation in the planning itself as they both made sure each partner had access to the resources (the template, scissors, copper tape, the LED light bulb, the camera, and space) and had chances to use the resources to collaboratively complete the video by making the electric art template. Multiple resources supported them in enacting these practices. Below is the timeline of their process (see Table 12). I highlight their interactions with each other and others in their classroom during recess and school library at the beginning of their next class period. Green highlights indicate the speaker. Yellow highlights indicate the space of activity. Fuchsia highlights indicate verbal exchanges around specific challenges. Blue highlights indicate troubleshooting strategies.

Table 12. Cristina and Eric making electric art video timeline

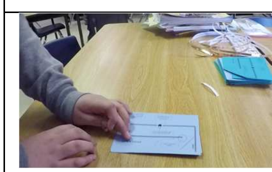
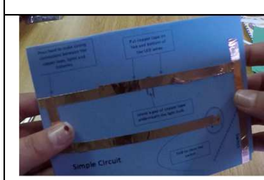
Selected Frames	Chronological description highlight various actors, resources leveraged and interactions.
 #1	0:27 As Cristina and Eric began making their video in the classroom during recess, I said, "One thing you can do, I might be directing this too much, is put it like this (moves the template so it faces the camera.) and stand like this. But you can do it that way too (moves the template back to face Cristina and Eric). You can do whatever you want. It's your project." I walk away. Cristina and Eric move to be next to the camera and have the template face the camera. They keep systematically measuring, cutting and applying the copper tape to make a circuit.
 #2	2:08 Eric went to get a light bulb and Cristina showed the card with a completed copper tape loop directly to the camera. Eric came back and said, "You forgot to leave a gap." Cristina replied, "No she[Katie] said make a copper tape sandwich." Cristina and Eric work together to secure the LED light to the template.

Table 12 (Cont'd)

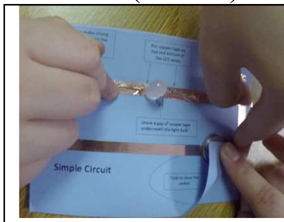
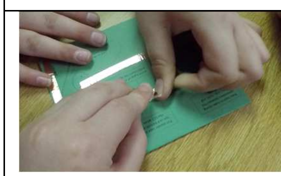
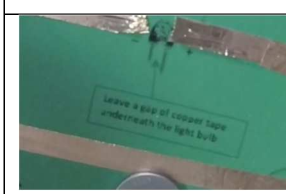
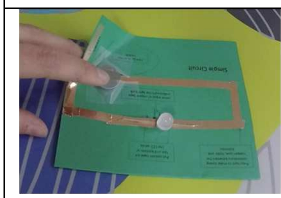
 #3	5:12 Cristina and Eric pressed down tightly on all of the copper tape. They added a battery and folded the switch. The card did not light up. They tried 4 trouble shooting strategies that they discussed and/or tried on their own. 8 minutes into the effort Eric said, "There is supposed to be a gap there. (pointing to the copper tape that goes under the LED light bulb.) Cristina replied, "She [Katie] said a sandwich." They tried 2 more strategies to troubleshoot the circuit.
 #4	10:46 Eric asks me for help. I tried flipping the battery over, a strategy they already did. I then suggested that they test the battery. Eric went to get a new battery. I walked away. Eric and Cristina replaced the battery. It doesn't light up. They then test both batteries and their light by connecting them directly. When the lights lit this way, Eric exclaimed, "Then we might have done something wrong." Cristina replied, "Want to try another one[different circuit template]? During this time period, they tried six trouble shooting strategies.
 #5	15:20 Cristina and Eric found a new electric art template and began building the circuit again. I asked if they got it to work, Cristina explained how they tested the battery and light bulbs and discovered that they worked so something must have been wrong with the circuit. I walked away. Cristina and Eric worked on adding the copper tape to the circuit. Eric says, "Remember leave a gap." Cristina replied, "No, we have to do a sandwich. Read this, 'the top and bottom'". Eric says, "I don't get it." They added a battery and light bulb, and fold the switch. The card does not light up. Steph comes and joins their efforts. They try make stronger connections by pressingon the copper tape, but the light did not turn on. During this time period, they tried two trouble shooting strategies.
 #6	20:34 Cristina exclaimed, "Okay. I got to read this. (looks at the template). It does say it! [Leave a gap of copper tape underneath the light bulb] I am sorry, Eric!" Cristina attaches the LED light by putting its lead wires over copper tape and putting copper tape on top of it. She left a gap in the copper tape underneath the copper tape.

Table 12 (Cont'd)

 #7	21:51: Steph moves the camera from the circuit to Cristina and back and says, "This is Cristina." Eric puts two batteries onto the template and folds the switch to complete the circuit. The light bulb illuminates. Steph yells: "OOOOOOOO GREAT JOB, Cristina!" Cristina, celebrated by saying, "I got it! I got it!" Douglas, a classmate that just came over because recess was over, said, "Good job! She just did it!" Cristina exclaims, "It's because I left a gap, Eric!". He responded by saying, "I told you, Cristina!". Douglas, Steph, Eric and Cristina continue to share their happiness about successfully completing the circuit. Christina and Eric go back and forth teasing each other happily about who did what.
 #8	25:00 Eric and Cristina pack up the card materials and video camera. They go to the school library because recess was over and they wanted to finish their card. I helped them tape their battery down to the template. We then organized some more supplies for STEM night and talked about participatory planning.
Highlighted text legend: Troubleshooting strategies enacted Class community members supporting efforts Discussion of need for copper tape gap to avoid short circuiting Spaces utilized	

This timeline shows how Cristina and Eric overcame their struggle to create a working electric art template for the video. Across 25 minutes, they tried 15 different troubleshooting strategies (highlighted in blue in the transcript), to get their card to light up. They did not give up, get angry with each other or stop working with each other as they leveraged multiple resources as they enacted participatory planning and teaching practice to reach their planning goals of creating a video to help others make electric art. In doing so they disrupted and amplified norms within their classroom space which expanded the authority that they and others had.

Disrupting and Amplifying Class Norms supporting Authority Expansion

The amplification and disruption of classroom norms were examined by comparing the recording of the students making the video (25 minutes) to the broader class context, culture and norms. Participatory planning and teaching practices amplified some norms and disrupted others. This was evident in the video-making process. For example, both Cristina and Eric had active roles in producing the video during and after their recess time. This collaborative effort resisted the ways that, in the broader classroom context, Cristina was often not positioned as a class helper and Eric was. It also resisted the classification of students as "high-achieving" and "low-achieving"[3] as well as the idea that students labeled as self managers do not work in egalitarian ways with students labeled as non-self managers. Additionally, Cristina and Eric's example resisted the way that adults often direct large portions of learning processes. Their participatory planning practices amplified the class norms, which supported students use of the classroom and its resources in and out of class time as needed. Both amplification and disruption of classroom norms supported an expansion of positional and epistemic authority.

Importantly, this case highlights a disruption of class norms that positioned some students as more capable of contributing to class than others. In particular, Cristina and Eric resisted the ways that Cristina was positioned in her classroom community. Within the school, her peers and teachers often did not position Cristina with much epistemic authority within dominant school science. Cristina was rarely positioned by her teachers and peers as someone capable and able to contribute technical expertise. This was evidenced by how infrequently her teacher asked her to help others or to complete volunteering tasks for the whole class, though she did spend much of her time helping with classroom tasks like watering plants and organizing materials during recess time. Mrs. B expressed concerns for Cristina by sharing with me that she was a student with, "low academic confidence," who was "socially isolated, and doesn't have a friend group." Similarly, Cristina reflected on her social isolation during an interview where she told me that

[3] I use "high-achieving" and "low-achieving" to represent the ways that, through dominant schooling practices, students have been clumped into broad categories based on how others perceive their meeting of narrowly defined criteria of success, which often ignore the multiple ways students achieve and are successful in and out of school.

she had one or two friends, but they changed often. In response to the question, “If we are in different groups, with whom would you like to work?” on a reflection form shared only with Mrs. B and myself, only three classroom peers listed Cristina. The mean number was 5.78 nominations. This highlights how her peers rarely chose to interact with her in social and academic tasks.

Peers positioned Cristina as a “low-achieving” student through their discourse as well. For example, Cristina described to me a verbal fight with a “high-achieving” student, who told her, “I'm not as stupid as you because you had to go into special classes for math and reading.” Cristina responded to her peer by saying, “Well at least I'm trying to get smart with life.” Cristina highlighted how she saw herself as taking advantage of those “special classes” to improve for life. However, what Cristina shared also shows how her peers used school-wide practices (pulling students out of class for reading and math interventions) as proxies for smartness. Students’ interpretations of those proxies impacted what they thought of each other, as well as if and how they wanted to work together.

Cristina’s social positioning by her peers and teachers as socially and academically isolated was a consequence of the forms of oppression that reflect broader school, district and sociohistorical norms. This enactment of oppression could have been connected to others’ reactions to her socially constructed identities of not being a self manager, being Latinx, being a girl, being placed in special education pull-out classes, and having Spanish-speaking parents who were immigrants. While I do not have specific data that point to what forms of intersectional oppression were operating most saliently in conjunction to Cristina’s various identities, it was clear that in the past, teachers and peers limited her opportunities to interact and contribute to academic efforts.

Eric, unlike Cristina, was positioned by his peers and teachers as academically high-achieving and socially connected. While he was closest to two friends, Mara and Megan, I often saw him interacting with others. Eric was always picked quickly to work in groups. In the same group work nomination reflection form, Eric was nominated by seven of his peers as someone they would want to work with, which was higher than the mean number of 5.78 nominations. Mrs. B often positioned Eric as a classroom helper during class time, frequently asking him to take care of school subject tasks like helping others with assignments, calming down upset classmates, or organizing the class's iPad set. This included coming back to help during recess. Eric did not experience many barriers to full academic and social participation within the classroom. However, he did not interact or work voluntarily with Cristina, which highlights how students also miss out from being able to learn with their peers who are socially or academically isolated.

Eric's social and academic status may reflect the many ways power and oppression operate within his classroom. Eric's interactions with his peers and teachers in the classroom could have been based on his socially constructed identities of being a self manager, being Asian, being a boy, not being pulled out of classes for interventions and having monolingual, English-speaking parents at home. While I do not have specific data that can pinpoint the exact rationale for how peers and adults treated him based on his various identities, it was clear that in the past, Eric was often positioned with more opportunities to interact and contribute to academic efforts than Cristina. Both of their experiences are situated within broader sociohistorical contexts, such as the effects of the racialization of ability in education (Artiles, Dorn & Bal, 2016), the gendering of STEM success (Archer et al., 2012), and the role oppression operates in intersectional ways to disadvantage students with multiple minoritized identities (Brah & Phoenix, 2016).

Cristina and Eric enacted participatory planning and teaching practices, which disrupted classroom norms that positioned Cristina as not having much to contribute to academic projects as well as disrupting the notion that “high-achieving”/self managers and “low achieving”/non-self managers rarely work together collaboratively. In the analysis of the video of Cristina and Eric making the electric art circuit, it was evident that they were both being flexible in how they participatory planned and leveraged their expertise. In doing so, they positioned each other with more positional and epistemic authority.

For example, both Cristina and Eric actively accessed needed resources (copper tape, light bulbs, batteries, the template, scissors) as well as positioned each other and themselves to contribute to their planning goals. By looking at the timeline frames and chronological narrative (Table 12), it becomes evident that each student often had their hands on the template, worked on the project, and rotated turn-taking. For example, picture #3 shows both students pressing on the circuit when they tried to light their electric art circuit for the first time. Frame #5 shows both students adding copper tape to their new electric art template. Frame #4 shows Cristina testing a battery and light bulb by connecting them, but immediately after that frame, Eric did the same. Frame #7 shows Eric folding the switch closed to light up the card, which happened immediately after Cristina made a gap in the copper and re-attached the light to avoid a short-circuit. When she exclaimed, “I got it! I got it!” it was clear that she felt like she made the electric art card work, which mattered for her because “to be a successful student means like to be a student that accomplish stuff". At this moment, she was able to collaboratively accomplish making an electric art card template for the video with Eric.

Through leveraging each other's expertise, Cristina and Eric were disrupting class norms which typically do not lead to collaboration between students with different academic status. This supported not only Cristina, but also Eric, in having more epistemic authority. Consider how in Video Frames #3 and #5, the students were working to test ideas at the same exact time. By working together, Eric and Cristina were able to test more ideas than if Cristina was not a part of the collaboration. Additionally, Eric's troubleshooting practices were expanded when working with Cristina. For example, when he saw Cristina test the light and battery in frame #4, he then tested the new battery using the same technique. By engaging in participatory planning and teaching practices, students with varying academic statuses are able to enact more epistemic and positional authority as norms are disrupted than are promoted in segregated or one-sided group/partner work.

Just as Cristina and Eric cooperatively used the physical resources together, the dialogue of their participatory planning practices highlights how they disrupted their positioning by peers and adults as having different ability levels for developing and contributing expertise. Through their words, Cristina and Eric both shared multiple ideas for fixing their circuits. Table 13. shows the tips, directions and ideas the students and I verbally shared throughout the twenty-five minutes they worked on their electric art template video. I included everything I said to highlight how the students directed most of their choices as they participated in this video-making session. Over the twenty-five minutes, Cristina and Eric both contributed a lot of directions and ideas for how to make the electric art. They had to go through multiple iterations of troubleshooting to find a solution. Both students gave each other directions and took directions as well (e.g. put it right here, let's add copper tape). While Eric did repeatedly suggest that there might need to be a gap of copper tape underneath the LED light (e.g. you forgot to leave a gap, remember to leave a gap), he and Cristina were both able to develop and utilize their troubleshooting skills before coming to that solution.

While some may argue that Cristina should have immediately tried out Eric's suggestion, she was working to use my suggestion of making copper tape sandwiches with the copper tape and light as well as ruling out other possible failure modes like dead batteries, burnt out light bulbs and too much resistance across the copper tape loop. She and Eric were able to explore together multiple solutions before ultimately getting their circuit to work. He took up some of her ideas and she took up some of his ideas. They, their peers, and I all celebrated when they found success in the lighting the light bulb.

Table 13. The tips, directions and ideas the students and I verbally shared throughout the electric art video-making process

Cristina	Eric	Katie
• Put it right here. • It has to be really tight. • So we got everything on right and there are no breaks. • No because this is the bigger one and this is the smaller one. (showing what side of the light was positive and negative) • Look this is the positive and negative. • She told to put a sandwich of copper tape. • Let's look and see if this light works. • Want to try another one? • We tried that. We put the battery right here and then like this (shows Katie how she tested the light bulb with a battery) • No we have to do a sandwich. Read this, "the top and bottom" • Okay. I got to read this. (looks at the template). It does say it! I am sorry Eric. • It's because I left a gap, Eric!	• Remember we can't have any breaks. • You forgot to leave a gap. • We need to make this tight before we are done. • I see why. This one (points out little copper tape overlap) • Let's add newer copper tape. Take that thing off. • Then we might have done something wrong. • Remember leave a gap. • This is why we need to flatten the stuff. • I told you, Cristina!	• Remember the copper tape sandwich? • Should we try a new battery?

In addition to disrupting norms to support expanding epistemic and positional authority, participatory planning and teaching also supported the amplification of some class norms to the same end. The video-making process amplified the ways that students used the classroom and its resources to reach their learning goals inside and outside of class time. Mrs. B's class culture supported students in coming into the class during recess time, often to meet their own or their class community's needs. Students came and did work, watered plants, played games, rested during their Ramadan fasts, organized class materials and so forth. The only time I ever saw Mrs.

B tell students that they could not come back into the classroom was when she had to have a confidential meeting. When Cristina and Eric made their how-to, GIF-style electric art video, multiple students came back to the classroom at recess. They spread across the room and got the electric art supplies that they needed. The students chose who they wanted to work with and shifted between groups as needed. Eric repeatedly went to find resources for the electric art templates that they needed. When recess ended, Mrs. B encouraged Eric and Cristina to go to the library to finish their how-to, GIF-style electric art video project. Through working in the different spaces as needed and getting the social and physical resources that they needed, Cristina and Eric were able to enact their positional authority, which supported them in enacting their epistemic authority as they took action towards their class community's goal of supporting visitors in enjoying making electric art.

Mrs. B's classroom culture of care was amplified as the students struggled together to get their electric art to work. Mrs. Eric and Cristina were willing to work together and be patient with each other as they required multiple iterations of troubleshooting. This occurred even when they had differing ideas about how to make the circuitry work. Consider how Eric brought up three times the need for a copper tape gap underneath the light bulb. (That gap was necessary because if there was a path of copper tape that went around the light bulb, the electricity would take that path instead of going through the light bulb.) Cristina did not agree with him, and they did not try that troubleshooting strategy until over 20 minutes into their work together when Cristina became exasperated and read the template directions that shared the same information. She apologized when she realized that Eric was right. Additionally, Eric and Cristina's relationships with Mrs. B and I supported them because we trusted that they could do the work and intervened very little in their process even though they had to go through multiple iterations in making the electric art template. This supported the practice of allowing flexibility and in participatory planning and teaching of the curriculum. Cristina and Eric also drew on their relationships with Steph, Douglas and me as they persisted in making their electric art template work and leveraged each other's expertise.

Cristina and Eric's experience highlights how across the processes of enacting participatory planning and teaching practices, norms were disrupted and amplified and students had expanded authority as they worked towards co-defining and addressing learning goals. Through Cristina and Eric's vignette, I highlighted how participatory planning and teaching practices supported them both in having expanded authority by disrupting the self manager and high academic achieving students' norms that would have positioned Eric with more authority to resources and decision-making opportunities. They also disrupted their class community norms in which teachers were most often the ones who made pedagogical decisions as they enacted the participatory planning and teaching practices. Through making their video, they amplified the class norm that supported students in having access to school spaces as needed and built on the classroom culture of care by treating each other kindly through frustrating times as well as creating supports for families to learn more easily how to make electric art. Tables 14 and 15 highlight examples of key norms that were disrupted and amplified throughout the enactment of participatory planning and teaching practices.

Table 14. Selected norms disrupted through participatory planning and teaching practices

Norms Disrupted	Positional and epistemic authority was expanded by:	Selected Examples:	Particular Practices supporting this.
Self manager system	Expanding what students were privileged to fully share their expertise and access all school resources from self managers to all classroom students.	Cristina and Eric each participated fully and accessed resources as needed to make the how-to, GIF-style electric art video All students were invited to participatory, plan and teach	Valuing and leveraging students' different expertise and interests Planning for more equity-oriented participation (e.g. providing multiple ways to participate and learn) as well as science learning.
High achieving students had more opportunities to be recognized and contribute their expertise in group work and whole class activities:	Expanding what students had chances to leverage and have their expertise taken up from high academic status to all students	Cristina and Eric both contributed ideas, made and troubleshot the electric art template together even though Eric was positioned with a high academic status and Cristina was not Conversation group participants represented students positioned across the academic status	Valuing and leveraging students' different expertise and interests Planning for more equity-oriented participation (e.g. providing multiple ways to participate and learn) as well as science learning.
Teachers and other school officials dictated what and how students learn	Expanded pedagogical decision making from adults to students	Cristina chose to use her educative video to teach her family how to create electric art. One-on-one, conversation groups, whole class planning conversation used to co-define meaningful outcomes	All practices
Across the disruption of these norms, both epistemic and positional authority was expanded. Students' expanded epistemic authority supported them in having more access and rights to share and have their ideas taken up. Students' expanded positional authority supported them in leveraging resources to take action with their expertise.			

Table 15. Selected norms amplified through participatory planning and teaching practices

Norms Amplified	Positional and epistemic authority was expanded by:	Selected Examples:	Particular Practices supporting this.
Students had access to the classroom and its resources during and outside of class time as they chose	Maintained and built on how students and Mrs. B had the right to choose how and when to leverage resources within the classroom space	Cristina and Eric made their electric art in the classroom during recess. Conversations took place in the classroom during lunch.	Valuing and leveraging students' different expertise and interests Allowing flexibility in participatory planning and teaching of the curriculum
Mrs. B's classroom culture of care fostering relationships between students, teachers and researchers that allowed for trusting and valuing each person and their expertise.	Maintained and built on the ways that Mrs. B, students and I recognized each others' worth as integral members of the classroom community, potential to positively develop, enact and contribute to the STEM night planning and enactment. Maintained and built on how Mrs. B used knowledge of her students and their family to support their learning in responsive ways.	Cristina apologizing to Eric for ignoring his suggestion. Cristina, Eric, Douglas and Steph cheering after the light worked. Students asked other teachers for multiple language expertise as they made the Welcome sign. Mrs. B helping students figure out logistics for getting to the STEM night. Katie advocated for all students to be able to participate in planning Students were able to introduce ideas and discuss them with each other	Valuing and leveraging students' different expertise and interests Allowing flexibility in participatory planning and teaching of the curriculum Consensus building between all classroom community members Planning for more equity-oriented participation (e.g. providing multiple ways to participate and learn) as well as science learning. Planning for community-oriented outcomes that matter.
Across the amplification of these norms, both epistemic and positional authority was expanded. Students' expanded epistemic authority supported them in having more access and rights to share and have their ideas taken up. Students' expanded positional authority supported them in leveraging resources to take action with their expertise.			

Extending Beyond the GIF: Returning to how Co-produced Practices for Planning for STEM Night Disrupted Norms and Shared Authority Broadly

To further highlight how Mrs. B's class community disrupted and amplified class norms towards more just ends and expanded authority through the enactment of participatory planning and teaching practices, I delve more deeply into the ways some class norms were at least temporarily restructured. I highlight the ways disrupting two norms (the self manager program and teachers dictating pedagogy) and amplifying one norm (Mrs. B's classroom culture of care). While I discussed the ways all of the norms in Tables 14 and 15 were restructured, I delve into these three norms in particular because 1) they impacted students' learning opportunities, 2) they highlight how class norms are situated within broader sociohistorical contexts and 3) amplifying/disrupting them seemed to have powerful effects on expanding students authority.

Norms Disrupted or Amplified Expanding Authority

Planning and teaching practices disrupting the self manager program and expanding students authority. Mrs. B's class community enacting the practices of valuing and leveraging students' different expertise and interests and planning for more equity-oriented participation (e.g. providing multiple ways to participate and learn) as well as science learning supported a disruption of the classroom norms connected to the self manager program. Recall, in the pre-STEM night logistics planning meeting with the all of the sixth-grade teachers, the idea of having students in the self manager program participatory plan and teach was shared. However, quickly the teachers decided that all of the students should be able to plan. This shift in which students were involved expanded whose expertise was leveraged to support the class reaching its goal. The shift in who was involved also challenged the schoolwide norm that only certain students – those deemed self managers - were capable and trustworthy to contribute to the school community through their expertise.

11 of the 23 students in Mrs. B's class were self managers. If they were the only ones invited to participatory plan, over half of the students would not have had a chance to share their expertise or leverage resources to what would have not been a collectively co-defined STEM night goals. I delve into how and why it was important for students who were not self managers to be involved in the process. At Wilkerson Road School, the self manager program was designed to reward students for good behavior (e.g., complying with school expectations such as being quiet in the hallways, following directions and being kind), completing homework in a timely fashion, and achieving good grades. These students were given extra privileges, such as working in the hallways without supervision, having self managers-only parties and a special table at lunch. In Mrs. B's classroom, self managers also helped to run errands or complete tasks for the whole class like put the IPads away or tutor peers.

Students became self managers by applying first to their teacher and then getting the principal's approval. While the district-wide self manager program was designed to recognize students positively, it created a hierarchy within the classroom space that positioned a select group of students as most likely to be asked to contribute their expertise and talents to the broader school community. Students who were not self managers recognized this hierarchy and how it impacted them. Consider why Cristina wanted to someday become a self manager:

Cristina: It's kind of cool, I think, I want to be one because it's cool because like then there's a separate table for them.

Katie: Oh.

Cristina: Then like they get so annoyed from the other kids they can just move from that to that table.

Cristina noticed that when something annoyed self managers, they had an actual physical space that they could move to in the lunchroom. She was motivated to become a self manager to get access to different spaces within the school. Wan pointed out in an informal conversation that sometimes self managers and students who were not self managers would do the same thing, but teachers would only notice the students who were not self managers. All students would see when Mrs. B would ask for a "self manager volunteer" to run an errand or complete a task.

School-wide norms, enacted in Mrs. B's classroom of having students designated as self managers be the main contributors to broader classroom activities, limited who was able to contribute expertise to class and schoolwide events. Such a system also implied the forms of expertise that mattered most in these settings (e.g., getting good grades, specific behaviors).

A demographic breakdown of the self managers in Mrs. B's classroom (see Table 16) suggests a form of racial discrimination well documented in the literature on race and school discipline (e.g., Morris, 2005). As Table 16 below shows, nearly half the class were designated as self managers (47.8%). However, when this statistic is disaggregated, the racial bias becomes evident, with less than half (37.5%) of students of color, and more than half (71.4%) of white students designated as self managers. While the self manager system aimed to students, teachers and administrators to celebrate students' success as students, its enactment disproportionately positioned white students as able and disproportionately positioned students of color as less able to contribute their expertise to their class and school communities.

Table 16. The racial distribution of self managers in Mrs. B's classroom

	Self Managers	Total Students	Percentage of Self Managers
Students of Color	6	16	37.5%
White Students	5	7	71.4%
Total Students	11	23	47.8%

As self managers were more likely to be white students, and self managers were more likely to have full access to participate in the dominant academic and social structures of the school, an expansion of authority from self managers to all students may have supported more racial equity-oriented opportunities to leverage and value students expertise. The valuing and leveraging students' different expertise and interests practice may have supported disrupting the norm that positioned self managers who were predominantly white from being the students mostly chosen to contribute their expertise and join in more fully in class and school events.

Consider how the practice of valuing and leveraging students' different expertise and interests supported many students who were not self managers, who were predominantly students of color, in having new roles within the classroom community. Steph, a black boy, was the student most often suspended from Mrs. B's classroom. The music and gym teacher often did not allow him to come to their class even before it started. Teachers and administrators actively excluded him from being in spaces, let alone asking him to share his expertise to support his school community. However, as a class community worked to value all students' expertise, Steph was able to choose to take on more roles within his class. For example, he finished his electric art during recess time so others could see it at STEM night. Steph joined four of the five conversation groups and the one he missed was because he was suspended. Additionally, instead of just asking a self manager for ideas and special help, the whole class' expertise was leveraged through the whole class discussion and multiple opportunities for students to participate in the prepping in and out of class.

Additionally, consider how the practice of planning for more equity-oriented participation (e.g. providing multiple ways to participate and learn) as well as science learning disrupted the self manager program norms. Cristina, a student who did not have the self manager designation, and Eric, a student who did, in both having access to all the materials, spaces and people necessary to leverage their expertise to make their how-to, GIF-style electric art video.

Planning and teaching practices disrupting teachers dictating pedagogy and expanding students' authority. Each participatory planning and teaching practice disrupted the norm that teachers and other school officials dictated what and how students learned. This led to the expanding of the pedagogical decision making from adults to students. Remember how the GIF-style electric art video-making process was supported by every participatory planning and teaching practice from Rachel's idea to Cristina using the finished video to teach her family. Throughout this whole process, there was an expansion of pedagogical decision making from teachers to students. Students had expanded epistemic authority in deciding what types of knowledge and practices to use to support STEM night visitors in learning how to make electric art. There was expanded positional authority as so many students had opportunities to leverage resources to support making the video.

Delving into how the norm of teachers and other school official dictated what and how students learn is important for understanding why disrupting it expanded students' authority. Due to district policies, students' expertise was rarely leveraged to determine what and how Mrs. B's class would learn. While Mrs. B connected curriculum to her students' lives as best as she could, her choices were constrained by district standards and she experienced more official pressure to meet those standards rather than design a curriculum to students' holistic lives. For example, the school administration evaluated Mrs. B's performance in a major way by assessing how she adjusted her instruction based on students' results on practice standardized tests. Curriculum changes based on standardized test scores were valued by official professional evaluation rubrics more than if Mrs. B was connecting the curriculum to her or her students' lives. Due to these high-stakes testing pressures, students' input on the curriculum was not always welcomed nor was planning for community-oriented outcomes that matter prioritized.

However, as the participatory planning and teaching practices were enacted pedagogical decision making expanded from adults to students. Consider how the practice of valuing and leveraging students' different expertise and interests supported the classroom community in co-defining a STEM learning night goal that highlighted students' expertise about both how and what they wanted their community members to learn. Similarly, consider how the students leveraged their expertise about their community, circuitry and their experiences of making electric art to plan scaffolding tools to support learning as the class planned for more equity-oriented participation.

Planning and teaching amplifying Mrs. B's class culture of care. The participatory planning and teaching practices amplified Mrs. B's class culture of care to support expanded student authority. Consider how even though Cristina fixed the electric art template using a tip that Eric shared around 15 minutes prior, they both celebrated. Enacting the participatory planning and teaching practices supported maintained and built on the ways that Mrs. B, students and I recognized each others' worth as integral members of the classroom community, potential to positively develop, enact and contribute to the STEM night planning and enactment. For example, as the class enacted the practice of flexible planning, they were being conscious that students were whole people with different commitments in the school so when Deedee came back to recess and made her electric art card instead of working on a video, she was supported by her peers and myself too. The practices of consensus building and valuing and leveraging students' expertise further supported students by recognizing and valuing their roles of contributing members of Mrs. B's classroom. Additionally, the class community needed to know each other well to best leverage each other's expertise. Enacting the participatory planning practices of planning for equity-oriented participation and community-oriented outcomes maintained and built on how Mrs. B used knowledge of her students and their families to support their learning in responsive ways.

There was much evidence of a culture of care in Mrs. B's classroom. For example, Mrs. B showed care and built relationships with her students in multiple ways that showed that she valued her students. What follows are just glimpses into the ways that she expressed cared for her students that I observed over the year spent with this class. Mrs. B would deliver food and her own children's clothes to students' homes when she learned that their families were food insecure. She would have her parents, husband and friends come and interact with the students so that they could be encouraged by even more positive adults in their lives. She would work to support classroom morale by bringing in treats for both special and regular occasions. Mrs. B would reach out to parents to share positive news about her students. Mrs. B pushed for interventions for her students when she saw that they were struggling with the dominant structures of the school. She showed up for her students' sporting events and cheered enthusiastically. Through these and so many more interactions, Mrs. B showed that she valued and cared for the students. Enacting the participatory planning and teaching practices further showed that care.

The students also expressed strong care for Mrs. B. While Mrs. B's interactions with students do not highlight how students felt valued by her or not, their expression of how they appreciated Mrs. B did. During a conversation group, I asked students what one thing they would like to change about their class community and no one said Mrs. B. Across the study, I asked students to share what they liked about their class and what would they want to change in interviews and no one shared Mrs. B. While this could be because they knew Mrs. B and I consider each other friends, but the students also expressed their care for their teacher through interactions in multiple ways. This was seen in the year after how students come back to see her at the end of the school days. Students often wrote cards to her. Their trust in her was evident in how they shared both exciting and sad news with her during class time, recess and at the end of the day; all different spaces where Mrs. B also invited participatory planning to take place. These relationships of trust were further supported as the participatory planning and teaching practices were enacted to leverage more students' expertise and plan for more equity-oriented outcomes.

The students in Mrs. B’s class expressed for each other and built relationships in many positive ways. For example, one group was concerned that students were being bullied so they designed an engineering design to encourage students not to bully. Another group knew that some students were not comfortable raising their hands in class so they created a light-up system for students to be able to be called on without having to raise their hands. In their regular interactions, students could be seen comforting students who were having a hard time. Often, you would see the boys and girls sitting quietly next to their classmates who were visibly upset, whispering to them to figure out what was going on, and patting them on the back. If they could solve the problem on their own, they would. If not, they would include Mrs. B or other peers to help their classmate. This approach crossed friendship clique lines and occurred often. As students enacted the participatory planning and teaching practices, they further were open to sharing ideas with each other as they consensus built and worked together to plan community outcomes that mattered.

The students and Mrs. B expressed a lot of care for me throughout our time together. Repeatedly, I noticed their thoughtfulness for me in many ways. This ranged from encouraging phone calls, cards and multiple meals shared by Mrs. B and invitations from students to take part in other areas of their lives in school provide some insight into how they cared for me in their classroom. Another example was when there was a miscommunication between Mrs. B and me when I was coming during the day for science class, the whole class called me and left me a voicemail to make sure I was okay. Then the students encouraged Mrs. B to switch their class subject schedule around so I would not miss participating in any of the science class. The whole class cheered when I came into class that afternoon. Multiple students asked me to chaperone their groups on field trips. When students saw me in the community (soccer fields, at Wilkerson school, at a local university) after they graduated, they often stopped to talk with me as we updated each other about our lives. While there are many ways to describe how care was expressed throughout a classroom community, this is just some evidence of how care was expressed between people in the class.

Enacting the participatory planning practices further amplified the ways that Mrs. B's class community trusted and cared for each other and their families as students had expanded authority. For example, as the students planned for community-outcomes that mattered, students learned more about each other's family. Consider how Abby and Cristina learned new ways to say welcome to members of their community when they enacted the practice of planning for more equity-oriented participation at STEM night. Consider how when Mrs. B repeatedly invited students to engage in teaching at STEM night, she was expressing that she recognized their potential and value in the class and reaching the class goal.

Expanded Authority

Across all of the norms highlighted above, when they were amplified or disrupted, students had more expanded authority. This was evident in how students' ideas about content, community and learning experiences were shared and taken up by others in the class community. Additionally, the authority expansion was evident in the ways that students leveraged resources and took action leveraging their expertise.

Students' expanded authority supported the class community in leveraging multiple forms of expertise as they addressed co-defined learning goals. Looking across Mrs. B's classroom community's participatory planning and teaching STEM events, there was, as indicated earlier, an expansion of both positional and epistemic authority. This is important because by expanding epistemic authority, the class community challenged and increased whose ways of knowing (knowledge), talking (discourse), and doing (practices) mattered in their science classroom, how and why, while still supporting more students in having access to the dominant forms of expertise being used within the space. Such sharing of epistemic authority in the STEM night activities addressed *both* the nature of knowledge itself, as well as the social processes for achieving possible epistemic aims (Elby, Macrander, Hammer, 2016; Tan, Calabrese Barton & Benavides, 2019). Expanding positional authority was also important because this refers to the ways more actors within the classroom community were able to make decisions about how spaces and resources were used to support learning goals. As noted across this chapter, authority expanded from teachers, parents and high academic status students to all students, disrupting dominant patterns of participation in science classrooms – patterns which reproduce inequalities along race, class and gender lines (Philip & Azevedo, 2017). Additionally, authority expanded from school officials to families and from English dominant speakers to the multilingual speakers within the school community.

Table 17 summarizes the multiple examples shared throughout this dissertation showing each type of authority expansion that was evident across the STEM night planning, prepping and teaching. With the expanded authority, the classroom community was supported in using distributed and diverse forms of expertise in the forms of knowledge and practice. The expanded authority examples are shared in chronological order to highlight the positive feedback loop that occurred when participatory planning and teaching practices led to students' expanded authority, which led to the further enactment of the practices and expansion of authority.

Table 17. Examples of expanded across the planning, preparing and teaching of STEM night

Event	Examples of expanded positional authority	Examples of expanded epistemic authority	Authority was expanded from:
Planning Stem Night	• Teachers agreed to support Mrs. B's class community to have access to and leverage the material and space resources needed to support them in deciding their plan • Students were welcomed to talk about the STEM night plan in and out of science class time	• Teachers agreed to have Mrs. B's class community decide on what and how they wanted STEM night visitors to learn. • Students shared expertise about what and how they wanted STEM night visitors to learn	• Teachers to students

Table 17 (Cont'd)

Preparing for STEM night	• Students decided if they would work on the projects during recess, science class or before STEM night • Students leveraged multiple spaces (classroom, STEM lab, library, gym) as they completed their selected prepping projects • Students leveraged materials (batteries, copper tape, extra templates) as needed. • Students used multiple spaces (classroom, library) to complete the video project • Cristina and Abby leveraged multiple resources (multilingual speakers, different school spaces, poster making materials) to making a welcoming sign.	• Students with varying academic statuses had equal chances to contribute to the partner work of making the video • Students used their knowledge about building circuits and what made it challenging, their video-making experience and community expertise about what is enjoyable and appealing. • Cristina and Abby used their knowledge of the importance of welcoming multilingual families into their English dominant school.	• Teacher to students • High academic status students to all students • Monolingual English speakers to multilingual speakers
Enacting STEM night	• Students rearrange the tables in the gymnasium to make the STEM night run smoothly. • Students made sure resources would be readily available to visitors. • Cristina attended the STEM night with her family.	• Students chose how they wanted families to access and use each station and resources. • Students leveraged their circuitry expertise developed during the electric art unit and the process of preparing for STEM night • STEM night visitors used what they learned to help newcomers make working electric art. • Students and families used multiple resources (how-to, GIF-style electric art videos, educative posters, others' completed circuits) to support their learning.	• Teachers to students • High academic status to all students • Parents/elders to students • School officials to family members

Participatory Planning and Teaching Supporting Critical Science Agency

The enactment of participatory planning and teaching practices supported collective critical science agency by: disrupting and amplifying class norms towards more just ends, expanded authority and allowing for addressing and co-defining outcomes of learning. Critical science agency was enacted as Mrs. B's class community participatory planned and taught STEM night. Students and then the visitors at STEM night leveraged multiple forms of expertise towards reaching co-defined learning goals. Participatory planning and teaching practices supported collectively disrupting and/or amplifying classroom norms and expanding students' authority. Through doing so, the class community was better able to generatively develop and apply their knowledge to support meaningful STEM learning opportunities while reshaping norms and interactions. Below I first share and explain a model that shows the relationship between the participatory planning and teaching practices and then between the practices, impacting class norms and expanded authority. Then I look further into the relationship between participatory planning and teaching, authority, class norms and the collective enactment of critical science agency.

Dynamic Process of Expanding Authority through Participatory Planning and Teaching

Cristina, Eric and their class community's experiences planning and teaching STEM night highlight the dynamic nature of expanding authority through participatory planning. The model (Figure 10.) highlighting Mrs. B's class community's experience shows:

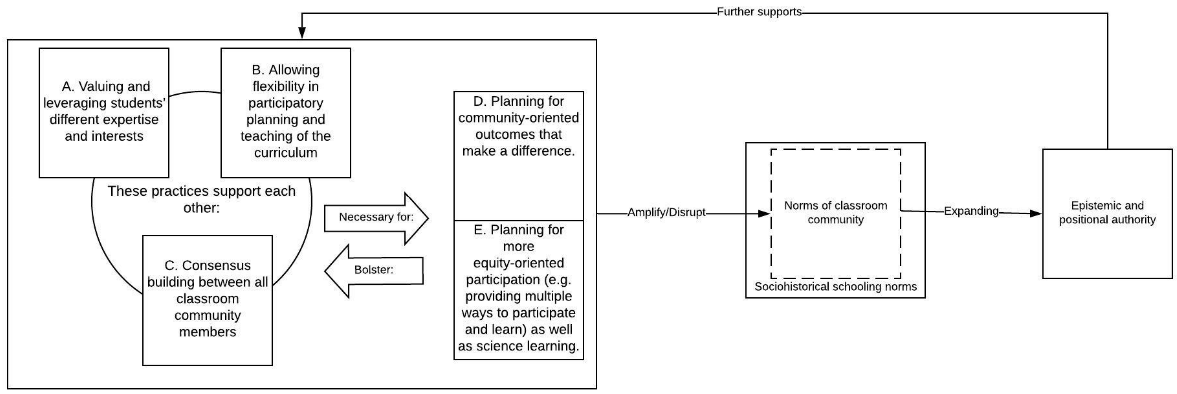
1) Participatory planning and teaching practices always interacting

2) Participatory planning and teaching practices may support disrupting/amplifying class norms to expand authority.

3) Expanded authority supports the further enactment of participatory planning and teaching practices.

Below I highlight each aspect of this model in more depth.

Figure 10. Participatory planning and teaching practices supporting expanded authority mechanism



Interacting participatory planning and teaching practices. The participatory planning and teaching practices interacted as they were enacted by Mrs. B, the students and me. These interactions are represented in Figure 10. Enacting one of these practices of A. leveraging students' different expertise and interests, B. allowing flexibility in participatory planning and teaching of the curriculum and C. enacting consensus building often led to the enactment of the other two practices. For example, enacting A. often led to B. and C. The enactment of these three practices collectively supported the practices of D. planning for community-oriented outcomes that made a difference and E. more equity-oriented participation. Without the planning practices D. and E., the class community would not have planned for justice-oriented learning outcomes to address. As the planning practices (D. and E.) further bolstered the classroom community's efforts to A. value leverage students' different expertise and interests, B. allow flexibility in participatory planning and teaching of the curriculum and C. enact consensus building between all the community members. The practices required, supported and were catalysts for each other.

Disrupting/amplifying class norms to expand authority. All of the participatory planning and teaching practices in combination and on their own amplified class norms that supported more expansive authority sharing within the classroom community. These practices also disrupted some norms that limited authority within the classroom. This amplification and disruption of class norms supported students' expanded epistemic and positional authority expansion.

Authority expansion through the enactment of participatory planning and teaching practices enactment did not happen in isolation. For example, the authority expansion that occurred Cristina and Eric's experiences making the video was situated within a wider system where participatory planning and teaching practices were already happening. Rachel generated the idea, the whole class discussed it, and for this video Eric, Cristina, Steph, Douglas and I all supported the process of making it. While Cristina and Eric were enacting new practices of leveraging each other's expertise and being flexible in their preparation, they were maintaining the consensus-built goal of making a video to support circuitry newcomers in making electric art. While they were planning for equity-oriented participation as well as science learning by providing scaffolding through a Gif-style video for visitors to watch, they also through their interactions were ensuring that each other had access to the materials needed and opportunities to enact their ideas.

Disrupting authority leading to more participatory planning and teaching. Further expansions of epistemic and positional authority positioned Mrs. B's class community to enact more participatory planning and teaching practices. For example, when I asked, "Do you think you can help people do these [electric art templates]" after she made the how-to, GIF-style electric art video, Cristina replied, "Yeah! And I can help my sisters." Cristina, a student who often was not positioned with epistemic and positional authority within her class community, was now excited to teach her family when they were visitors to STEM night.

Additionally, when Mrs. B's class community enacted the participatory planning and teaching practices, they amplified and disrupted norms in ways that expanded students' authority to make pedagogical decisions. As more ideas and actions were elicited from more students in the class, students were supported in participatory planning and teaching. When asked if they would like students to continue to help plan, Cristina and Eric both said, "yes." Cristina explained, "I think it is good because we can get all the plans they are thinking of, all the good things." Mrs. B similarly shared her answer to the same question:

> It is a good idea because they do come up with really good ideas, and then that makes it seem more—I look at my classroom as a community, but now, it's more so the community because now they have an input.

Both the students and their teachers highlighted how participatory planning and teaching practices provided opportunities to bring "more" of students' "good" ideas and motivated them to continue to enact participatory planning and teaching practices, which would further support the expansion of students' authority within the space. Looking across Mrs. B's class community experiences enacting participatory planning and teaching practices are one way to support collective enactments of critical science agency because they: disrupt and amplify classroom norm towards more just ends, supports expanding authority and allows for co-defining outcomes of learning.

Participatory planning and Teaching, Authority, Norms and Critical Science Agency

Participatory planning and teaching practices expanding authority and norms supported Mrs. B's class in enacting critical science agency. The model (Figure 11.) highlighting this process shows:

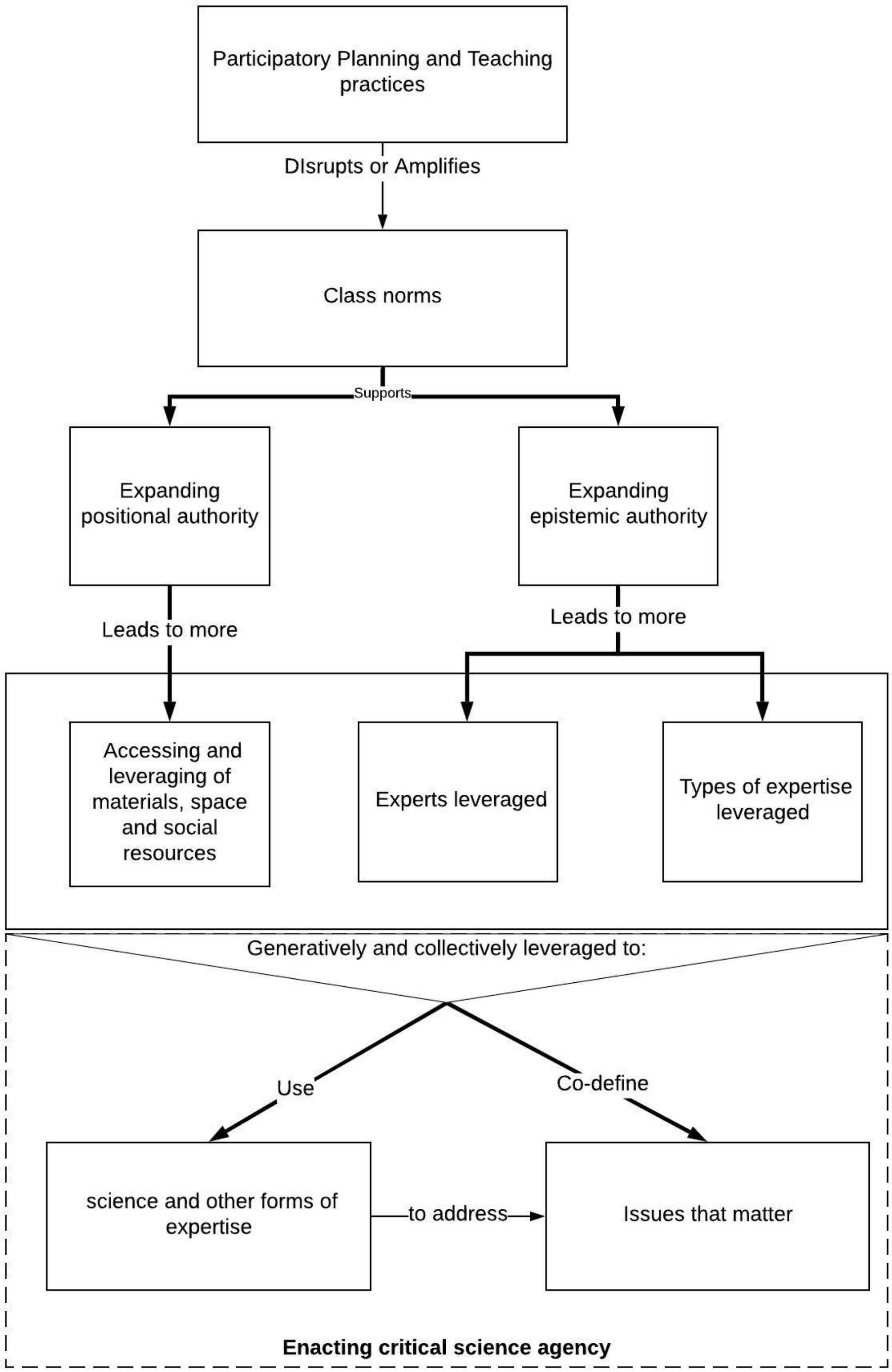
1) Participatory planning and teaching practices supporting disrupting class norms and expanding authority.

2) Expanded authority and restructured class norms leads to more opportunities to access resources to develop and put into action multiple experts' expertise and multiple types of expertise.

3) Through collectively leveraging the resources and collective knowledge the class enacted critical science agency as they used that expertise to collectively define and take action to address issues that mattered.

I highlighted the process of disrupting class norms and expanding authority. Now I highlight how expanded authority and restructured class norms led to more opportunities to access resources and leverage expertise and how that led to the class enacting critical science agency.

Figure 11. The relationship between participatory planning and teaching, authority, norms and critical science agency



Through restructuring class norms and students having more authority, Mrs. B's class community was better able to access to the necessary resources, and rights to share and enact expertise. Expanded authority supported students to share their expertise in what and how they wanted learning to happen. Positional authority supports students in having the resources necessary to leverage that knowledge and enact practices.

Students' expanded authority supported the generative leveraging and building on multiple forms of expertise that was central to the collective enactment of critical science agency. First, students were able to co-define what issues mattered using multiple students' expertise. The class community-supported new understandings of what and how their families should learn and in how they shared. This shaped both the purpose and experience of STEM night as they challenged together why the electric art should be interactive, who matters in school settings, why and how to make the STEM night fun. Then, they were able to leverage their expertise to reach and also refine the goal. As the class community leveraged multiple sources of expertise, they generated new tools (e.g., posters, movies, activities) to support families in learning as they worked to make STEM night an enjoyable, supportive and meaningful learning experience. The examples shared in this dissertation show how expanded authority supported new collaborative actions (planning, setting up, teaching) from all students and their families. The new tools, knowledge and actions all reflect how the class enacted critical science agency because they supported providing access and opportunity in culturally relevant and humanizing ways.

Chapter Five: Discussion

Across this dissertation, I shared two main findings. First, critical science agency is a collective act, involving:

a. using distributed and diverse forms of expertise,
b. generatively building on and welcoming shared expertise over time through actions and discourse taken up by multiple community members
c. using that hybrid expertise towards co-defined meaningful ends.

Second, the enactment of participatory planning and teaching practices supported collective critical science agency by: disrupting and amplifying class norms towards more just ends, supporting expanded authority and allowing for addressing and co-defining outcomes of learning. These findings and the process of enacting this study highlight important implications for educational researchers, teachers and students and teacher educators.

Advancing the Field of Science Educational Research

The experiences of Mrs. B's class community participatory planning and teaching STEM night and the analysis of their process provide implications for the field of educational research in three areas: critical science agency, analyzing power within classroom interactions using sociocultural theories of learning, and youth participatory research methodologies. Below, I highlight the ways that this study pushes on the field's understanding of each of these topics. Then, I highlight the relationship between making space for the class community to leverage their community cultural wealth and the enactment of critical science agency, disrupting power and engaging in participatory planning. Yosso (2005) defines community cultural wealth as, "an array of knowledge, skills, abilities and contacts possessed and utilized by Communities of Color to survive and resist macro and micro-forms of oppression" (pg. 77). Teacher, students, their families and researchers collectively leveraging community cultural wealth can recognize the assets of students' communities and support more justice-oriented learning.

Critical Science Agency

This dissertation shows how enacting critical science agency is a collective, generative, relational and political process. This study supports the field of science education better understanding of what critical science agency looks like. Previous studies have shown that critical science agency requires the leveraging of science and community expertise to address injustice. This definition of critical science agency has been developed and highlighted through studies showing youth leveraging science and community expertise to address injustice in multiple ways. Some examples include students teaching physics in meaningful ways to their classmates (Basu & Calabrese Barton, 2010; Basu, Calabrese Barton, Clairmont, & Locke, 2009), youth educating their community about urban heat islands (Calabrese Barton & Tan, 2010) and effectively advocating for a new environmentally-friendly roof for their after-school club (Calabrese Barton & Tan, 2010). This built on Turner's (2012) work that highlighted how students used math and community expertise to fight their school board about overcrowding in their school as a form of critical disciplinary agency. Further work has shown how youth enacting critical science agency connect their efforts to addressing injustice on multiple scales. For example, youth at a summer camp demonstrated how enacting critical science agency involved youth working to understand injustice at multiple scales and then addressing it through local action. Four girls first used community ethnography to understand the impacts of landfill waste on multiple scales (local, regional and global) of injustice by using community ethnography, drawing on their own lived experiences and developing their understanding of global climate change. Then they addressed this issue by creating engineering designs to encourage recycling and waste reduction (Schenkel, Calabrese Barton, Tan, Nazar, & González Flores, 2019).

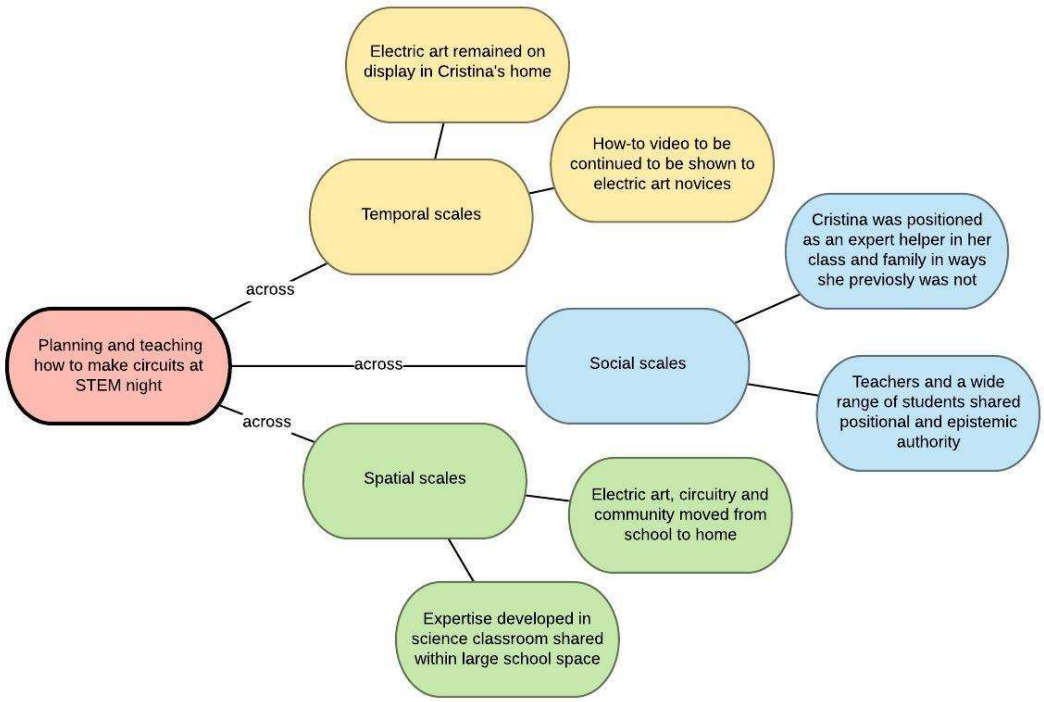
This study furthers aligns with the field's definition of critical science agency as using science and other expertise to address injustice, but builds on it by highlighting how enacting critical science agency can be a collective and generative process. The process was collective in both how teachers and students jointly co-defined their hopes for outcomes and the process they developed for reaching those goals. As Mrs. B's class community planned STEM night, they had to first define a learning goal that mattered. To do so, they drew upon each other's expertise about engineering and circuitry, the processes of learning, and what members of their community may care about to co-define and refine the learning process and outcomes that mattered. Once the members of the class community defined their goal, they continued to generatively leverage and build on each other's expertise. In doing so they were better able to understand and reach their goal of STEM night visitors in being able to enjoy learning about engineering, electricity and energy in meaningful ways.

Understanding the generative and collective process of enacting critical science agency because it challenges the field to explore the relational dimension of students, teachers and their expertise. There is little empirical research about what supports the social dynamics of enacting critical science agency. A previous study at Wilkerson School showed how role distribution and recognition practices within small engineering design groups supported those groups in enacting critical science agency. By distributing roles and recognizing each other for multiple forms of expertise, students were better able to work together to understand and address issues of injustice within their classroom (Schenkel & Calabrese Barton, under review).

The experiences of Mrs. B's class community further provides insight into the social dynamics of enacting critical science agency operating at the classroom level. By expanding authority within the classroom and restructuring class norms, the class community was better able to elicit and use distributed and diverse forms of expertise, generatively building on and welcoming more expertise over time and use that hybrid expertise towards co-defined meaningful ends. Seeing the collective process of enacting critical science agency provides insight into how to better support through participatory planning and teaching practices.

This study further highlights how critical science agency can be considered as a type of consequential learning, as it is a political process. In chapter 2, I used Jurow et al.'s (2016) definition of consequential learning as being "meaningful actions that extend across temporal, social and spatial scales of practice" (p. 210). This study highlighted how the class community took meaningful action across spaces (class, library, STEM lab, gymnasium, students' homes), across relationships (learning, challenging multiple hierarchies, restructuring of interactions) and across time (the planning, prepping, teaching, and afterlife of the electric art at home). Across of each of those scales, students, teachers and families restructured norms and supported students' authority. In doing so they challenged the political space within which all learning takes place (Jurrow & Shea, 2015). Figure 12 highlights just some ways Mrs. B's class enacted critical science agency/consequential across these three scales as they used expertise to take meaningful action. Understanding critical science as consequential learning is useful for the field of science education because it supports the field in better analyzing how critical science agency enactment leads to meaningful change and power restructuring across time, relationships and space.

Figure 12. Mrs. B's class community's critical science agency enactment and outcomes across time, space and relationships.



Expanding Authority and Restructuring Norms as a way to Analyze Power

My motivation for this study and its conceptual framework focused significantly on analyzing how power operates and is disrupted within classrooms to support learning. Therefore, this study built on multiple other sociocultural theorists' work who have worked to analyze how power impacts students' opportunities to learn within classrooms (Esmonde, 2009; Esmonde & Booker, 2017; Langer-Osuna, 2013; Lewis, Enciso & Moje, 2007). This work provides insight into how analyzing students' expanding authority seemed to be a powerful proxy for power in this classroom.

Analyzing students' authority, both epistemic and positional, was a useful analytic lens because there were multiple ways that it was made visible in classroom interactions. This is useful as power and oppression is endemic and always impacting societal structures likes schools, but not always in explicitly visible ways in local classroom practice (Bell, 1992; Gillborn, 2016; Leonardo, 2013). Students' authority could be seen in multiple ways. Students' expanded positional authority was seen in their leveraging of resources to take action. Students' expanded epistemic authority was seen in if and how their ideas were shared, and how those ideas were taken up by others. How it was expanded was made visible when comparing their actions and knowledge sharing to broader class norms.

Comparing students' enactments of positional and epistemic authority to class norms provided a useful tool to analyze students' interactions and practices within the broader sociohistorical system within which Mrs. B's class was operating. Through my long-term ethnographic engagement within the school community and the work of critical educational scholars, I was able to parse out some ways norms of interacting and being mirrored broader systems of oppression. When students had expanded authority, it was visible in how their ideas were shared and taken up through action in new ways. I could identify ways that class norms shifted to support students' fuller participation within the class community. Disrupting norms within the classroom community supported the expansion of both positional and epistemic authority. Students were able to access resources needed with their positional authority to take action with their ideas leveraged with their epistemic authority. This approach provides insight into how comparing students' actions to class norms situated within broader sociohistorical systems can support a more critical leveraging of social practice theory.

This study provides insight to the field about the ways authority, disrupting/amplifying class norms and critical science agency and participatory planning and teaching interact. This matters because it supports the field in better understanding a mechanism to support students' in having more positional and epistemic authority to collectively and generatively use their expertise in meaningful ways. In doing so, power is disrupted at local interactional levels, the class norm level and broader community level.

Participatory Planning Contributions

Participatory planning and teaching as a methodological approach. This study shares a unique participatory methodological approach with the field of education research. Limited work has been done to conceptualize the possibilities and impacts of positioning youth as teachers within their classroom. By providing insight into the multiple ways students in Mrs. B's class participatory plan and taught pushes educational researchers to expand the roles students can have as teachers in their own classroom spaces.

Research in the past has focused predominantly on a range of near-peer and peer teaching (also described as "learning assistants") experiences, most of which focus on involving students as near-peer teachers – or, students in generally one to a few years ahead in their learning (e.g., Evans & Cuffe, 2009). While most of these studies take place at the university level, and primarily in medical education and STEM (e.g., (Gottlieb, Epstein & Richards, 2017; Otero et al, 2010), there are some studies which take place in teacher education and K-12 education (Gray, Webb & Otero, 2016). In addition, contexts for near-peer and peer teaching have varied greatly, with studies ranging from one-on-one mentoring or tutoring interactions (Stigmar, 2016) to small group peer teaching (Otero, Pollock & Finkelstein, 2010). Across these approaches, the value of leveraging near-peer teaching opportunities has been promoted as a way to support deepening content learning among the near-peer teachers and their students (Evans & Cuffe, 2009; Otero et al, 2010); supporting skills in learning to teach (Otero, Pollock & Finkelstein, 2010) increasing participation in learning (Lockspeiser et al, 2008), and in support of recruitment and retention of students from under-represented groups. This study pushes on the research methodologies that position youth as teachers because they are not just experts on what the teacher wants them to teach, but they have authority to co-determine what should be taught and how it should be taught. They are not just "mini" teachers reproducing the norm. Rather, they determine the roles they will take on and the expertise that they will leverage to support meaningful learning outcomes.

This study also highlights how participatory planning and teaching as a research methodology can support more justice-oriented learning processes and outcomes. Additionally, this study highlights the way that participatory planning and teaching can be used in conjunction with other critical methodologies to analyze and disrupt power operating within a space. the multiple ways class communities can disrupt/amplify class norms and expand their authority as they participatory plan and teach. The co-developed participatory planning and teaching approach shared in this study can be taken up and adapted by other research practice partners.

Participatory planning and teaching as a pedagogical approach. Within the field of science education, there are many valuable design-based research initiatives that position teachers and researchers as research practice partners as they work together to implement new strategies and/or curriculum to support students' learning. This study helps push the field to consider what it means for students to be positioned as experts also in the designing of their learning experiences. This participatory planning and teaching approach supported the class community in designing powerful learning environments where power hierarchies were restructured and more community-connected learning was supported.

First, the participatory planning and teaching approach disrupted immediately, though partially, norms that positioned researchers and teachers as the experts of students' learning experiences (Kinloch & San Pedro, 2014). Through disrupting the power hierarchies and having students being positioned with expanded authority, Mrs. B, students and my learning occurred as we took up new practices and engaged in the process of becoming (Nasir & Cooks, 2009). Through expanding who and how students could contribute their expertise, more learning was being supported. The participatory planning and teaching practices helped the class community to collectively enact hybrid expertise through action.

Second, the participatory planning and teaching approach in this study supported more justice-oriented learning than if Mrs. B and I enacted the STEM night planning and teaching practice on our own. As students used their positional authority to leverage their expanded epistemic authority, they challenged learning for who and what purposes. This resists how dominant science education has positioned certain ways of knowing over others, making science learning both oppressive and disconnected from who students and their families are (Bang & Medin, 2010; Bang, Warren, Rosebery, & Medin, 2012). While the analytical focus of this study was on expertise (mostly knowledge and action), a different analysis lens would most likely highlight how multiple epistemologies were welcomed into the Wilkerson School space. Disrupting and expanding the types of epistemologies valued and leveraged within a learning space supports more equity-oriented learning (Tan, Calabrese Barton & Benavides, 2019). The participatory planning and teaching developed by Mrs. B's class community could be adapted to support both more community-connected pedagogy and justice-oriented research-practice partnerships.

Community Cultural Wealth, Critical Science Agency, Power and Participatory Planning

The experiences of Mrs. B and her students highlight ways teachers, students and researchers can work together to make space in school settings to leverage community cultural wealth. I will now expand on what community cultural wealth is, its importance and its relationship with critical science agency, power, and participatory planning and teaching.

Community cultural wealth, which is grounded in critical race theory, focuses on the assets that communities of color leverage as they navigate structures and institutions. Acknowledging community cultural wealth is an approach to focus on communities' assets rather than the deficits perceived by those in dominant positions within society. Community cultural wealth pushes on Bourdieu's concept of cultural capital. While Bourdieu (1973) used the idea of cultural capital (eg. access to social resources) as a way to explain social reproduction, the construct has been used to describe the deficits of students and their communities in education (Yosso, 2005). Rather than comparing what students do or do not possess in connection to the dominant "norm" as defined by white supremacy, community cultural wealth challenges the white gaze by highlighting the assets that students of color and their families develop and regularly leverage.

Individuals' actions and systematic schooling policies often ignore and/or limit the multiple types of community cultural wealth in a space (Delgado Bernal, 1998). However, students embody a wide array of community cultural wealth, including aspirational, navigational, social and linguistic capital (Solórzano & Delgado Bernal, 2001). Students, Mrs. B and their families develop, share and use their community cultural wealth in many ways inside and outside of school settings. However, science classrooms often are spaces that precludes multiple ways of knowing and being. Additionally, through presenting a narrow idea of what counts as science, students and their families are often positioned as lacking. Throughout our work together, the students, Mrs. B and their families leverage their community cultural wealth in many ways. In doing so, students and Mrs. B were able to draw on the rich assets of their communities while enacting critical science agency.

Community cultural wealth and critical science agency. This dissertation shows how enacting critical science agency required and made space for community cultural wealth. Consider how students enacted critical science agency through both the process of planning and enacting STEM night, in doing so they challenged both what and how their families learned about circuits. As they made those decisions they expanded what community assets were leveraged. For example, as Cristina and Abby made the multilingual welcome sign, they drew on the diverse linguistic capital of their teachers, peers and families. When the students planned and created their GIF-style, electric art how-to videos, they were leveraging their community cultural wealth as they created a technological tool based on how they have used resources at home in ways to be both be entertained and learn new DIY-skills. As students addressed issues that mattered as they enacted critical science agency, they were drawing upon multiple forms of community cultural wealth. Additionally, in this case, they were supporting families at STEM night to do so as well.

Expanded epistemic authority welcoming community cultural wealth. As students had more expanded authority through participatory planning and teaching, they were able to leverage more of their community cultural wealth. For example, as the students made decisions about how the gym should be set up for STEM night, they used their positional and epistemic authority to make ways to better support families in leveraging their community cultural wealth. Remember in my field notes, I described families working together and across families to learn how to make electric art. The students supported that by spreading materials (the batteries, light bulbs, copper tape, templates, IPads loaded with how-to videos) across the long cafeteria table.

In doing so, the families were supported in automatically working together as they passed materials. However, the families supported each other in making electric art by showing their working electric art to others and asking each other questions. The students using their epistemic and positional authority made ways for families to interact and learn in collective ways rather than the individualistic ways often pushed in school settings (Baquedano-López, Alexander, & Hernandez, 2013).This supported families in leveraging their social capital as they learned together. Students having expanded authority is a key way to support community cultural wealth to be recognized and leveraged within science learning spaces.

Community cultural wealth and participatory planning and teaching. Participatory planning and teaching both required and made space for students and their families to leverage their community cultural wealth. As students decided what and how they wanted their families to learn at STEM night, they had opportunities to draw upon their rich community cultural wealth. As students expressed that they wanted their family members to "interact", "have fun" and "do something, they were planning for families to have access to develop and use new knowledge with their assets. Students resisted ways that school policies often position families of Students of Color as deficit instead of supporting them in leveraging their expertise within school spaces (Allen & White-Smith, 2018). Mrs. B's class experience provides insight into ways that participatory planning and teaching can support school spaces to recognize and welcome students' community cultural wealth.

Implications for Teaching and Learning

I see two main implications from this study for teaching and learning: 1) Classroom communities can benefit in multiple ways from co-developing and enacting participatory planning and teaching practices, and 2) Classroom communities can benefit from enacting critical science agency. Below I expand on the benefits of enacting both participatory planning and teaching practices with students and students. Then I highlight the role teacher educators could have in supporting teachers in taking up these practices.

The results of this study highlight ways students can benefit from class communities adapting and enacting participatory planning and teaching practices. Students and teachers can use the participatory practices to expand the types of expertise developed and leveraged within the classroom. Additionally, they can enact the practices to expand the sources of expertise welcomed within their classroom. Finally, through the enactment of participatory planning and teaching practices, students and teachers can collaboratively work to understand issues together and address them together through leveraging their collective expertise.

Teacher educators need to support in-service and pre-service teachers in understanding how to co-develop participatory planning and teaching practices with students. First, teachers must be supported in developing/maintaining asset-oriented views of students and their community while shifting how they see their role from planner to co-learning. Teachers may see three main challenges to taking up participatory planning and teaching practices: 1) meeting curriculum standards, 2) time and 3) resisting traditional planning methods. Teacher educators can support teachers in addressing their concerns about meeting curriculum standards by helping them constrain the participatory planning and goals with the students. For example, if the standards require that students analyze the environmental impacts of invasive plants, a teacher could ask students to participatory plan and teach in response to this question, "What should we do to support our community stop the spread of invasive plants and why?". To support teachers as they mitigate concerns about the time it may take to participatory plan and teach, teacher educators can help future teachers consider what participatory planning tasks, which are also learning tasks, could happen within the class time. Finally, as a field, there has been a push to support teachers in being responsive to students' thinking rather than a set curriculum (Windschitl, Thompson & Braaten, 2018). Teacher educators can support teachers in being responsive to students' expressed content knowledge, but also in all their other forms of expertise as well.

This study highlights ways teachers and students can plan for critical science agency as a way to promote more equity-oriented science teaching and learning. Both the process and planned outcome of enacting critical science agency can reshape relationalities within and beyond classroom spaces. This study shows how the relationships, norms and interactions were reshaped within Mrs. B's class as they worked together to reach their class's STEM night goals. Not only was the outcome supportive of expanded learning opportunities for students and their families, but so was the process of planning, preparing and teaching it for students within Mrs. B's class.

Teacher educators need to support teachers in planning opportunities to enact critical science agency. Designing for critical science agency requires teachers to take up stances within their class community that is open to sharing authority and disrupting participation norms with students. Teacher educators can support teachers in understanding the critical science agency and the powerful ways it can support more-justice oriented learning and relations within classroom spaces. Sharing examples of youths' experiences may support them in seeing the purpose and possibility of supporting critical science agency within their classroom.

When teachers embrace a disposition that is open to sharing authority with students, then teacher educators can support them in understanding how to plan for the different components necessary for critical science agency to be enacted. Teachers need to be supported in both the planning of and the smaller grain teacher moves that would answer these three questions: 1) How will I elicit distributed and multiple types of expertise from students? 2) How will I create opportunities for students to generatively build on each others' expertise? 3) How will I support the class in collectively evaluating and leveraging expertise to take action towards their meaningful co-defined goals? Working through these three questions at a planning and in-the-moment scale could support teachers to design for critical science agency enactment within their current or future classrooms.

Limitations

While this study supported powerful learning opportunities for Mrs. B's class community, there are limitations. First, while I sought to disrupt power hierarchies through this work, I still maintained them in some ways. Second, this study is limited in its size and scope. I will now delve more deeply into these limitations.

In this study, I can see three major ways that power was not distributed evenly. First, the adults in the study chose the learning event that the class was going to participatory plan and teach. While students had active roles in deciding what and how they wanted their families to learn, this still perpetuated the ways that teachers and adults often shaped the learning goals within school spaces. Second, while all sixth-grade students' electric art was on display, Mrs. B's class community had a much larger role in the planning, enacting and teaching of STEM night. While I highlighted the valuable outcomes of participatory planning and teaching had in Mrs. B's classroom, I do not know how and if the other sixth grade classes were affected by their limited opportunity to participate in the planning and enacting of the event. Finally, while the class community leveraged a participatory methodology, I did the bulk of the analysis that occurred within this study. While I member checked with Mrs. B throughout the process and with students when I saw them in the community, the limit of their time to collaborate and my imagination to find new collaborative ways to analyze data did not support a significant amount of participatory analysis.

Second, in this study, I chose to examine in depth a class community's experiences enacting critical science agency as they participatory planned, prepared and taught one major event. The learning that came from this analysis has valuable implications for researchers, teachers, students and teacher educators as I was able to analyze deeply individual students and the broader class community's experiences. However, the scope of the study was limited. Understanding students and teachers enacted critical science agency and participatory planned and taught across multiple units could provide further insight into these findings.

Future Research Directions

Throughout this study, as I sought to investigate how to support more equity-oriented science teaching and learning, I learned many powerful things about critical science agency and participatory planning and teaching with Mrs. B's classroom community. For example, through the participatory planning and teaching process, my learning was pushed by the students to think much more deeply about not just designing for meaningful learning outcomes, but also how the feelings and experiences one has in engaging with that learning outcome. Consider how the students' thoughtfully considered their own experiences making electric art. They remembered their frustration, and planned ways to make sure their STEM night visitors did not feel the same way. This pushed me to further consider how can learning environments be designed to support community-oriented outcomes, while still being attentive to the experiences of everyone interacting and learning together. Students reminded me that collectively and generatively taking up new practices can and should be fun.

Through the participatory methodological approach used in this study and exploring critical science agency, I saw ways that power still operates between students, teachers and researchers. This has led me to consider, *How can students have more authority to shape and enact the participatory planning and teaching?,* and *How can teachers and students be better supported to engage in analysis of the participatory planning and teaching and their critical science enactment process?*. In the future, I would like to support students and teachers in not just having participatory roles within the curriculum design, but also more roles within the research design. This is particularly important as I continue to share students and teachers' stories. Another issue of power that I would like to wrestle with is how can students be involved earlier in the process of participatory planning and teaching. Consider how Mrs. B and I told the students that they could help plan STEM night. What does it look like for class communities to enact norms that support students initiating participatory planning and teaching projects?

Finally, this work has left me wondering, *In what ways can research practice partnerships support students and teachers enacting critical science agency and participatory planning and teaching practices across units and classrooms?* For Mrs. B, the students and I, we had powerful experiences participatory planning and teaching as we enacted STEM night. But how in the future, can I support teachers and students enacting co-produced participatory planning and teaching practices throughout all science curricula across the whole academic year?

These three questions are important for me to explore as I consider how I will continue to work with current and new school partners. As I seek to answer these questions, I will be working to further distribute power amongst teachers, students, researchers. These questions also support me in investigating the impact of critical science agency and participatory planning and teaching across multiple class communities and space. Finally, pursuing these questions should further support meaningful learning outcomes for students, teachers, researchers and me.

APPENDICES

Appendix A. Mid-Unit (Electric Art) Interview Protocol

1) How would you like me to describe you to others if I write about what we learned together?
2) Who are your friends in the class? Useful for mapping out class sociograms.
3) What does it mean to be a successful student in your class? What about a successful science student?
4) How do you think others would describe you in your class? Students? Mrs. B?
5) Who did you make your electric art card for and why?
6) Did you give the card to them? How did they react? Where did they put it?
7) How does it work?
   a) What kind of circuit did you use?
   b) Why did you pick that kind of circuit?
   c) Can you show me how electricity moves through the circuit?
   d) Can you tell me about the different parts to your circuit?
8) Tell me about what it was like to make this card
   a) What inspired you?
   b) What ideas did you bring in from other places (like home, your friends, social media) that helped you make your card?
   c) How did you figure out how to make it? Did any people help you?
   d) Were there any challenges in making it? How did you overcome those challenges?
   e) What are you most proud of about your card?
   f) What tips do you have for other kids who will make these cards in other classrooms?
9) When other people see the card, what do you think they will say about the card? About you?
10) Have you told anyone about this card? What did they say?
11) Who in your class was really good at making electric art? Why? Did that surprise you?
12) Did you help anyone make their electric art? Improve it?
13) What do you like about school/class? What do you think would make this school/class better? Why?

Appendix B. Post- I-Engineering Unit Student Interviews

Problem Space and Solution

1. What problem did your group choose to address?
2. Why did you decide to solve that problem? Why?
3. How have you seen others affected by this problem? How have you been affected by this problem? (probe for some details so that you get a story out of this. Can you tell me about a time when you had this problem? What happened? How did this impact you? Your peers?)
4. How does your design address the problem you identified? Does it address any other problems?
    a. Can you share some examples of when its invention was used?
    b. Did your design meet its goal?
5. What are you most proud with respect to this artifact? Why?
6. How does your project help with sustainable communities? How are you thinking about sustainability now that you have made your project?

Learning:

7. What did you learn about … to make your design?
    a. Energy and electricity
    b. The engineering process (probe into defining problems* & designing solutions**)

    *We are interested in supporting students in more precisely understanding a design task's boundaries, including its criteria and constraints from this integrated vantage point. We are concerned with how to support students in seeking out, analyzing and integrating both scientific and community knowledge to specify, expand or limit movement towards possible solutions.

    **This practice includes multiple cycles of prototyping solutions, designing/conducting tests towards optimizing solutions, gathering/ analyzing data from multiple perspectives, and engaging in dialog on complicated conflicts in perspective and design trade-offs. We view ongoing communication among design partners and with stakeholders as elemental to this practice.

    c. Your community
    d. Other (have kids name)
8. How and who supported you in learning these things?

Group Dynamics:

9. What are the different roles that group members played? (Walk me through the different contributions of each member)
10. Where there any surprising moments? What or who surprised you? Why?
11. What was really helpful about your group? Why?
12. What was challenging? Why?
13. I noticed you said …. about x. Can you tell me a little bit more about that?

14. Let's look at this little timeline from the second part of the unit. Will you put stars where you thought your group was working in a really fair way? Will you put X's where you thought your group was not working together in a fair way? Then walk through each part and have the student explain each event.

Defining a Problem w/ surveys	Sketching a solution	Community Feedback Day	Building your Design	Showcase

15. Do you notice any patterns in how your group worked together and what happens in your classroom normally? Did you notice any similarities or differences in how your group interacted and things you see or hear outside of school like at home, on TV or in the news?
16. What helped your group work better together? What made it harder to work together? Were there moments when you thought you were working well together? What happened in those moments?
17. How can Mrs. B and I support groups working well together in the next unit?
18. What would your ideal group look like, sounds like, do?

Individual

19. What did you teach others with your design? Peers, 4th graders, adults?
20. Did you teach people in other ways during this unit? What impact did that have on them? on you?
21. What do you think your design says about you?
    a. As a learner?
    b. As a member of Mrs. B's class
    c. A scientist/engineer?
22. What does it mean to be a successful I-Engineering student? Where you a successful I-Engineering student?
23. You said xxx about being involved in the ecology unit on the survey, let's talk about how you and I think that could work.

Appendix F. Post-Ecology Unit Interviews

1. Will you tell me about the project you worked on and what you shared at the exhibit?
2. How did you decide to make it?
3. Why is this project important to you and your group?
4. What impact did you hope it will have? (who do you hope your project will impact? in what ways?
5. Has it had that impact? how do you know?
6. What was your experience at the exhibit yesterday? Who did you show your work to? What did you tell them? What did they say? What did you teach them?

Learning:

7. What did you learn in this unit?
    a. Invasive plant species
    b. Ecosystems
    c. Group members (have kids name)
8. Think back to I-Engineering, how is your thinking about community similar or different? Did either of the units help you think more about the purpose of learning and the community?
9. How do you think garlic mustard and invasive plants impact the biodiversity of an ecosystem? Should we care about that or not?

10. Have you done anything at home or in your neighborhood to help with protecting biodiversity? Since working on this unit? Do you plan on doing anything or plan on doing anything?

(Throughout this section→ ask How and who supported you in learning these things?)

Group Dynamics:

11. Can you tell me about the process of creating your exhibit contribution? What roles/who did what? How did you all decide that? (name each group member)
12. Let's look at this little timeline from the second part of the unit. Will you put smiley faces where you thought your group was working really well together? Will you put frowny faces for the time that you felt like your group was not working well together? (Then walk through each part and have the student explain each event.)

Learning how to identify and label garlic mustard	Designing how to harvest garlic mustard (dandelion pull) and practicing with biocubes	Field trip to the park	Paper Making	Artist Visit	Planning your exhibit contribution	Making your exhibit contribution	The exhibit

13. What helped your group work better together or not together? (probe about the moments they highlighted, roles they, their peers and adults played?)
14. Did any group member surprise you? Why?
15. How do you think ____ impacted how your group's experience working together and within your class community?
    a. Race
    b. Language
    c. Gender
16. Now let's look back at the unit timeline. Can you put a check mark where your contributed to the unit plan, lesson or event for the class?
    a. Tell me what you did for each check mark. Did you help plan something, be an expert teacher, contributed ideas?
    b. How did you feel contributing in these ways xxxx?
    c. How do you think contributing in xxx ways impacted your learning? Others learning? Why?
    d. How do you think kids contributing to the planning impacted the power dynamics of the classroom?
17. Think back to your work on the I-Engineering project. Did I-Eng help you with this project, if at all? If yes, in what ways? Do you see the ecology unit helping you in the future?
18. What do you think your exhibit contribution (use the name of it) says about you?
    a. As a learner?
    b. As a member of Mrs. B's class

    c. A scientist/engineer?
    d. As a member of your community
19. What would you want others to know about this unit?
20. What changes would you like to make to it for the future? What things would you want to keep? Why?

Appendix C. IRB Approval

MICHIGAN STATE
UNIVERSITY

Initial IRB Application Determination *Exempt*

February 23, 2015

To: Angela Calabrese Barton
329 Erickson Hall

Re: **IRB# x15-215e Category: Exempt 1**
Approval Date: February 23, 2015

Title: Tools for Teaching and Learning Engineering Practices: Pathways Towards Productive Identity Development in Engineering [I-Engineering]

The Institutional Review Board has completed their review of your project. I am pleased to advise you that **your project has been deemed as exempt** in accordance with federal regulations.

The IRB has found that your research project meets the criteria for exempt status and the criteria for the protection of human subjects in exempt research. **Under our exempt policy the Principal Investigator assumes the responsibilities for the protection of human subjects** in this project as outlined in the assurance letter and exempt educational material. The IRB office has received your signed assurance for exempt research. A copy of this signed agreement is appended for your information and records.

Renewals: Exempt protocols do not need to be renewed. If the project is completed, please submit an *Application for Permanent Closure*.

Revisions: Exempt protocols do not require revisions. However, if changes are made to a protocol that may no longer meet the exempt criteria, a new initial application will be required.

Problems: If issues should arise during the conduct of the research, such as unanticipated problems, adverse events, or any problem that may increase the risk to the human subjects and change the category of review, notify the IRB office promptly. Any complaints from participants regarding the risk and benefits of the project must be reported to the IRB.

Follow-up: If your exempt project is not completed and closed after three years, the IRB office will contact you regarding the status of the project and to verify that no changes have occurred that may affect exempt status.

Please use the IRB number listed above on any forms submitted which relate to this project, or on any correspondence with the IRB office.

Good luck in your research. If we can be of further assistance, please contact us at 517-355-2180 or via email at IRB@msu.edu. Thank you for your cooperation.

Sincerely,

H. McGee

Harry McGee, MPH
SIRB Chair

Office of Regulatory Affairs
Human Research Protection Programs

Biomedical & Health Institutional Review Board (BIRB)

Community Research Institutional Review Board (CRIRB)

Social Science Behavioral/Education Institutional Review Board (SIRB)

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