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**How Students Engage in Environmental Science Learning
and Engineering Design across Settings**

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Abstract

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This dissertation uses ethnographic and design-based research approaches to focus on spaces of environmental science and engineering education as potential sites of intentionally designed hybridity and coordination along a cultural learning. By examining how these spaces afford and constrain learning for culturally and linguistically diverse fifth-grade students as they take part in a coordinated set of learning experiences across multiple settings over a school year, this study addresses the kinds of learning and identification processes that occur as youth engage in science and engineering practices. This set of studies focuses on the social and material features of places, the available social positions, and the actions that are related to learning and identification in order to provide empirical evidence of the key features that facilitate access to new forms of participation and identification in relation to science in young peoples’

communities. Chapter 2 focuses on the development and implementation of an ecologically-grounded survey and interview protocol used to examine the different meanings that young people have for science in relation to the social practices in which they engage. This analysis shows that while young people understand science as being primarily associated with school, they also recognize the ways in which a variety of activities across their lives have the potential to be science-related. The findings in this study are important for the design of equitable formal and informal STEM learning environments that draw on young people's everyday experiences and understandings of science. Chapter 3 describes a cross-setting approach for supporting and investigating student learning of environmental science in a fifth-grade classroom by focusing on the development of hybrid learning spaces in which youth gain access to new forms of participation and identification in relation to science in their community. Key design features of these environments—narratives of science as multi-voiced and an important tool for communities, youth-authored boundary objects that serve community interests, and access to authentic resources—supported new positionings and identities for youth in relation to science and engineering. In Chapter 4, I examined the implementation of a fifth-grade engineering design curriculum unit to understand how engineering design work has the potential to be an agentic context for engaging youth in scientific and engineering practices that position them as producers of knowledge and useful designs. This study shows that equitable engagement in engineering practices requires specific criteria for design proposals and scaffolded social norms that help students negotiate the relational space of small group work for their own goals. As a set of chapters, this dissertation provides deep and broad accounts of science and engineering learning pathways in and out of classrooms. This work informs the ways in which informal, formal, and hybridized learning spaces can create opportunities for new forms of local

constitution and engagement in science and engineering practices that support science-linked identity development for all youth.

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Dedication

For Rowan

Chapter 1: Introduction

Although learning occurs in pathways across time and settings, we often put the burden on learners to coordinate their own learning across social settings over extended time periods (Banks et al., 2009; Bell et al., 2012; Lee, 2007). In this dissertation, I leverage a social practice focus to consider approaches for connecting learning across settings in order to address inequities in access to science and engineering practices. I attempt, as others have done, to produce rich accounts of how the sociomaterial arrangements of different settings provide or hinder access to learning opportunities. Specifically, I consider how opportunities for connected or extended learning pathways, in which youth take part in “learning that is interest-related and pursued across multiple settings,” might be navigated by fifth-grade students (Penuel, 2014, p.1).

A broad diversity of social settings have the potential to be locations where learners’ everyday repertoires of practice and identities merge with those of the learning setting to encompass a broader range of science practices and practice-linked identities than is traditionally recognized, promoting interest and engagement in environmental science for all learners. Thus, it is imperative that studies of learning focus on what Gutiérrez (2008) describes as horizontal learning—traversing borders and boundaries and highlighting the variety of situated contexts individuals engage in as they move throughout their social worlds in cultural learning pathways (Bell et al., 2012).

Herrenkohl and Mertl (2010) and others argue that learners have access to constellations of valued ways of knowing, being, and doing that can be resources for understanding the world (e.g. Gutiérrez et al., 1999). Hybridity theory provides a lens with which to examine how facilitating access to and merging of these resources can create spaces for deep engagement in learning (Calabrese Barton & Tan, 2009; Moje et al., 2004). Several attempts to create access

and equity in science education have recently focused on hybrid learning spaces as an organizer of learning and a theoretical lens, showing promise as a tool for examining the cultural and socioeconomic contexts that frame learning experiences. By creating hybrid spaces that not only validate, but rely on youth resources outside of school or other formal learning environments, hybrid learning spaces have the potential to create opportunities for youth to take on new forms of authorship, authority, and identity in relation to science, bridging the gap between how youth organize their participation in the world and in science.

Most research in this area, though it draws on resources from many settings across youth's lives, focuses on what can be drawn on and contributed to learning and identity development in only one setting. However, several studies point to a need to better understand learning experiences as "points on a trajectory," where each setting is delineated by porous boundaries (Leander, Phillips & Taylor, 2010). Leander et al. (2010) argue that learning experiences should be conceptualized not as "containers," but as "nexuses of relations" that acknowledge learning as a process over time and space (p. 336).

While there are a number of studies that describe the cross-setting nature of STEM (science, technology, engineering, and math) learning, STEM learning across settings has only recently emerged as a design goal (Penuel, 2014). Within this new territory, this dissertation focuses on the social and material features of places, the available social positions, and the actions that are related to learning and identification in order to provide much needed empirical evidence of the ways in which learning is organized as youth participate in coordinated learning across settings (Bell et al., 2012). The conclusions and design implications presented here will inform educational design efforts seeking to develop and support learning as it might occur across time, places, and communities.

Overview of the Dissertation

As an environmental educator, I became interested in how science education can be brought to bear on the concerns of young people and their communities—an issue that is often insufficiently addressed through the narratives of environmentalism, particularly for historically marginalized youth. My interest in addressing the overlapping inequities in science education and environmental justice through designing for environmental science and engineering across settings lies in the premise that these two fields are uniquely suited to address the everyday concerns of youth and their communities. Environmental science is directly and readily relevant to everyday concerns of health and well-being. Engineering provides not only a valuable context for learning science, but also promotes problem-solving strategies that can be used to address personally- and community-relevant issues that can empower youth to make a difference.

My research focuses on access to and participation in environmental science and engineering learning, especially for youth from groups historically underrepresented in science, including African-Americans, Latinos/as, women, and others. I am generally interested in issues of social justice and access to science that allow youth to become informed and active citizens, and I seek educational experiences that allow youth to see how science and engineering might be a useful way to address the concerns and realities in their lives, including issues of environmental justice (e.g. Tzou, Scalone, Bell, 2010). Like Calabrese Barton, Tan, and Rivet's (2008) study of girls in science, I am particularly interested in "how cultural and socioeconomic contexts frame...science experiences" (p. 72).

With this in mind, the purpose of my dissertation project is to examine science and engineering learning spaces as potential sites of intentionally designed hybridity and coordination along a cultural learning pathway that both affords and constrains learning for

culturally and linguistically diverse youth. This study focuses on elementary school students from non-dominant communities as they took part with their class in a coordinated set of environmental science and engineering experiences across multiple settings over the course of a school year. I followed students across a number of sites: their classroom, a residential outdoor education experience, a Superfund site, an education center at the source of the city's drinking water, and City Hall and the Mayor's office. My research questions address the kinds of learning and identification processes that occur for youth as they engage in science and engineering practices in and across these different settings. I am particularly interested in how hybridized learning spaces, those which draw on the resources learners bring from multiple settings to disrupt typical boundaries of science learning, create opportunities for new forms of local constitution and engagement in practices that lead to science-linked identity development for youth.

Structure of the Dissertation

This dissertation consists of three separate analysis chapters, which are meant to be independent of each other, but draw from overlapping data sources. The first analysis chapter reports findings from the Science Activity Survey (SAS) data, to examine the different meanings that young people have for science in relation to the social practices in which they might engage. The implications of this study point to opportunities for broadening young people's recognition of science in their lives by focusing youth learning experiences on authorship and production of science-related investigations. The second chapter describes a cross-setting approach for supporting and investigating student learning of environmental science in a fifth-grade classroom. In this design-based research project, researchers worked in partnership with a fifth-grade teacher and her students in a linguistically and culturally diverse school in a large urban

district to design and implement a coordinated set of environmental science lessons in and out of school. The analyses highlight both the potential and the challenges of working in a research-practice partnership to coordinate learning across settings by describing the powerful outcomes for youth in light of some of the complexities that arise. Finally, the third analysis chapter analyzes an enactment of an engineering design curriculum unit in a fifth-grade classroom—as part of a larger, three-year design-based implementation research study. This chapter highlights the images of engineering portrayed by an engineering design curriculum unit and the teacher, and the affordances and challenges of these portrayals as they supported students to engage in engineering design work as the unit was enacted.

Methods and Location of Study Design in a Tradition of Research

To examine learners as they move within and across a coordinated set of science and engineering experiences, the data in this dissertation draws from multiple methods including online surveys, semi-structured interviews, video recordings of participant observations, student work, and ethnographic fieldnoting. I use a sociocultural approach grounded in ethnography and design-based research methods to address the ways in which the experiences in their fifth-grade year shape the positionings available to youth in relation to science and engineering.

My approach is grounded in sociocultural perspectives in education, which argue for a broad account of learning that attends to the social, cultural, and historical processes that guide interactions in learning environments (e.g. Herrenkohl & Mertl, 2010). Sociocultural research often focuses on the argument that accounts must also broaden the definition of what counts as central or full participation, in that traditional views often ignore the many gray areas where marginalized learners might interact, thereby leaving their participation and process of becoming unrecognized by a traditional definition of learning (Calabrese Barton & Brickhouse, 1996;

Calabrese Barton, Tan, & Rivet, 2008). Therefore, a qualitative study design which illuminates a broader view of youth participation in science and engineering is appropriate for examining what it means to be or not to be a member of a learning community (e.g. Walford, 2008).

Design-based research.

Design-based approaches recognize a broad conceptualization of learning that includes identity and interest (Cobb et al., 2003, p. 9). This study, in which learners negotiate the merging of learning resources across settings to potentially develop science-linked identities, benefits from this approach because of the attention to “negotiation of domain specific norms-- such as what counts as a “good” scientific question in a classroom” (Cobb et al., 2003, p. 10). In line with this broad definition of learning, Cobb et al. (2003) conceptualizes the approach of design experiments to learning spaces as attending to ecologies, requiring examination of interrelated, layered features.

Ethnography.

Because my research questions explore how youth engage in practices and are positioned in relation to science and engineering, an ethnographic approach makes sense as it allows researchers to “look for mutually understood sets of expectations and explanations that enable [them] to provide cultural interpretations about what is occurring and what meanings we may reasonably presume are being attributed by others present” (Wolcott, 1997, p. 335). This study is a team ethnography, with multiple ethnographers working as participant observers both in the classroom and on field trips. In this process, we worked to develop shared meanings and protocols in an effort to create more robust accounts of practices (Erickson & Stull, 1998). Additionally, the research group I am a part of has a long history at the elementary school where the majority of this study is focused, having conducted a multi-year child ethnography centered

in this school. The knowledge base generated by this long term study and the resulting analyses serves as a way to understand the context more deeply.

Researcher Positionality

First, it is important to note that I have been professionally and personally in the local environmental education community for the last 10 years. I currently maintain what I would characterize as an insider/outsider status there in that I have many personal and professional ties with several organizations throughout the region, as well as deep familiarity and allegiance with the philosophies and goals of the programs included in this study. Much of my own identity as a professional educator and graduate student researcher is rooted in my experiences with environmental education organizations in the area.

Additionally, I find it important to reflect on my social location and thus my perspective as a researcher to gain insight into issues of privilege and power in learning settings and in my relationship with the people who participate in my study. To start, I am a white, middle-class, educated, heterosexual, married woman, all qualities which give me some measures of privilege. Through critical reflection as an educator and a researcher, I am aware that I am a part of the dominant culture in most ways. I am not cultureless, nor am I part of a culture that is objective, neutral, or emotionless in any endeavor. This is true for the culture of science, where those qualities are very heavily touted. I am both ‘multicultural’ and ‘gendered’ (Maher & Tetreault, 1997). This point, that the categories used by the dominant culture to describe others actually encompass all of us, influences my awareness of the interpretations I create about others. It reflects the reality that identities are embodied and situational. Demographic categories, including gender, socioeconomic status, race, and ethnicity, must be recognized as limiting of who people can be recognized as and instead must be understood as “narrative descriptors of

participants' backgrounds" (Gutiérrez & Rogoff, 2003, p. 23) in order to better capture how learning occurs for everyone. In this study, I bring an awareness of any "norms" taken for granted and based on a predominantly male, White culture, and instead act inclusively to capture a broad set of experiences and ways of being in the world (Carlone & Johnson, 2007; Ginorio & Martinez, 1998).

As my professional role has shifted from educator to researcher, I consider what Alcoff (1991) describes as "the problem of speaking for others" (p. 6). This problem is derived from two places: the location of the speaker, especially in relation to those they are speaking for, and the potential for the discursive context to increase or reinforce dangerous stereotypes. Because white people often see themselves as cultureless, they sometimes believe they can speak for all people (Kahl Jr., 2011). I avoid assuming that "the class, race, and gender position of the 'knower' is ignored or presumed irrelevant" (Maher & Tetreault, 1997, p. 325). As a graduate student researcher, I am in a position of power to produce knowledge about other people. Maher and Tetreault (1997) say that, "such domination is often couched in the language of detachment and universality, wherein the class, race, and gender position of the "knower" is ignored or presumed irrelevant" (p. 324). Using interpretive research methods like the ones I outlined above will help to make explicit my role in the communities of practice included in this study. I recognize that my position in relation to the participants in my research must be attended to and as Alcoff (1991) argues, truth and meaning are affected by my social location (p. 6). My voice has the potential to overlap, overshadow, or cover entirely the voices of the participants in my work. In addition, the discursive context matters, as I write and speak to particular audiences with multiple agendas, including my own. This context also includes the literary and research traditions in which I work, based on the work of my academic and intellectual ancestors. I have a

responsibility to do my best to use my position to create more room for more voices. To do this, I will a mix of emic and etic approaches in my research, especially ethnographic approaches which prioritize participant accounts, while also attempting to interpret these perceptions in tandem with my own ideas about what it means for making education more equitable.

In the end, Alcoff (1991) states that it is sometimes possible to speak for others without reinforcing socially constructed hierarchies (p. 29). In this study, I hope to contribute to the development of “strategies for a more equitable, just distribution of the ability to speak and be heard” (Alcoff, 1991, p. 29). One way of addressing some of these issues in my study is to consider youth voice, or youth views about their learning experiences, including how science is taught, the relevance they see of environmental science to their present and future goals, and implications for environmental education or activism in their communities. This approach is in line with my goal of examining hybrid learning spaces and identity development. Additionally, Durrant argued that “[g]iving students voice provides them with the power to create change” (as cited in Kahl Jr., 2011, p. 1935). I believe this is especially important for issues of environmental justice and educational equity in environmental science and Chapter 3 highlights the features of the design intervention that facilitated this.

Limitations and Assumptions

A common critique of design-based research is the view that it is arrogant to assess need and prescribe change for a community where the researcher is an outsider (Barab, Thomas, Dodge, Squire, & Newell, 2004). Working with classroom teachers and other instructors whom I had not worked with before required time upfront and throughout the year to build relationships and listen to learn about the strengths and needs of each of the educational settings. In this study, I am situated as a researcher as both observing and creating stories within already existing

communities of practice through my own interactions with participants, which required sensitivity and clear objectives for the process from the beginning.

These research approaches also assume that teachers, instructors, and youth will trust me enough as a participant observer, to talk and act in front of me as they normally would, and to tell me the truth about their interpretations of participation in each learning setting. Though I attempted to spend enough time in these communities of practice to develop positive relationships with adults and youth, it is possible that they still saw me as an outsider or a person of authority, and I felt this partly contributed to some students' reticence to talk with me extensively in interviews. This may have been especially difficult for youth who saw a larger gap between their everyday ways of being and the culture of school and science. It is possible that I was interpreted by them to be part of the conflict they feel with school or other learning settings and it is possible they did not trust me enough to present their actions or perspectives fully and honestly. To address this, I took a cultural historical approach to this study, as described by Gutiérrez and Rogoff (2003). In addition to positioning youth as capable and valuable contributors to science and school, I also attempted to make "first guesses about patterns and [seek] confirmation or disconfirmation" by member checking, reviewing my thoughts and hypotheses with adults and youth iteratively throughout the study to avoid misinterpretation or assumptions about practices, behaviors, norms, and goals (Gutiérrez & Rogoff, 2003, p. 23). The bulk of the member checking I did was through the semi-structured interviews with youth over the course of the year.

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Chapter 2: Youth Conceptualizations of Science across Their Lives

This chapter examines the different meanings that young people have for science, using the Science Activity Survey (SAS), an ecologically grounded survey and interview protocol. The goal of this study was two-fold. The first goal was to further develop an existing analytic tool and protocol (the Science Activity Task or SAT)—adapting it from a time-intensive interview method to an online survey (SAS) that could be more broadly administered—that can be used to understand how science is characterized both for individuals and communities. The second goal was to better understand how to leverage the conceptions and experiences of young people to design science learning environments that are more personally relevant. A survey was given as part of a larger year-long ethnographic design-based research study of multicultural, multilingual children in a metropolitan area in the Pacific Northwest, in one urban and one suburban community. Survey responses surface and describe young people’s constructions of science and the prevalence of science-related activities in four social venues from their everyday lives—in school, at home, in their communities, and through media activities. In follow-up interviews, a subset of focal students reflected on and expanded their responses. These were linked to ethnographic accounts of their experiences in informal and formal science learning experiences across a school year—as reported in Chapters 3 and 4.

This study stems from previous work focused on “analyzing the prevalence and social construction of science in the everyday activities” (Zimmerman & Bell, 2012, p. 1) of young people through the SAT, an ethnographic interview protocol. The development of the SAT was motivated by three driving needs of the field. First, to contribute to the field’s understanding of the mechanisms that lead to a documented decline in scientific interest as young people move

into adolescence by examining the meaningful and interesting connections that can be made from young peoples' lives to science. Second, to address extend the framework traditionally imposed on understanding children's views, by accounting for young people's voices and a broader range of everyday life activities. Finally, to develop a method that addresses gaps in existing tools by adequately focusing on the multidimensional nature of science, while giving full consideration to the holistic developmental contexts that influence young people.

The original SAT and the SAS, which is presented here, both emerged out of ethnographic research focused on how young people take part in various science activities across settings during a longitudinal study of the children, their families and classrooms (Bell et al., 2013). Zimmerman and Bell (2012) oriented the questions of the ethnographic interview to focus on 'When is math or science?' (McDermott & Webber, 1998) and conducted analysis using a developing theoretical model of the extended cultural learning pathways of young people across the settings of their lives in domains like science and technology (Bell, Tzou, Bricker, & Baines, 2012). The design and analysis focused on three related concepts: activities, practices, and learners' collection of resources. Resources, which are referred to as 'assets,' are the things in young people's lives that could be leveraged for science learning. The authors argue that this activities/practices perspective contributes to the field by creating an inventory of the activities that young people identify as related to science. Additionally, they suggest that examination is needed of the socio-material arrangements of science-related activities in order to understand the tools used by young people in their practices and the relevancies of those practices to science practices.

In the present study, the SAS retains the open-ended format of the SAT, allowing for multiple meanings of science to be expressed in relation to a range of everyday practices. In

order to better characterize young people's conceptualizations of science in activities across the venues of their lives, I redesigned the game-like protocol of the SAT into an online survey with the intent of reaching a larger number of young people still with the goal of not essentializing their activities.

Theoretical Framework

Science learning experiences in school have not traditionally centered on the lives of science learners. We specifically know from previous research on extended learning pathways that many young people explore science-related interests outside of school and engage in related learning agendas, but that these do not typically get leveraged in curriculum and instruction in formally or informally designed settings (Bell et al., 2012). Additionally, young people themselves do not always recognize the activities and pursuits in their lives as being science-related.

The value placed on school science as the only "real" culture of science ignores the assets and experiences provided by everyday practices of science, which leads to a cultural narrative that includes problematic assumptions of when science is and who does science (McDermott, 2012; Stevens, 2012). For example, Stevens (2012) points out the symbolic capital afforded to people who are recognized by themselves or others as science-oriented. He describes these people as "more often than not seen as smart and allocated social opportunities, usually through the educational systems, on that basis" (p. 4). It follows that those who are not seen as smart or science-oriented are not afforded the same opportunities. Moreover, school science is often disconnected from the work of professional science (Lemke, 2001; Stevens, 2012), which actually has many parallels to the sense-making practices of everyday science (Nasir, Rosebery, Warren, and Lee, 2006). These disconnections create artificial and undesirable barriers for

learners, making science seem elite, difficult to navigate, or inaccessible all together, not only in the collective cultural narrative, but also practically speaking with respect to the interests and concerns of everyday life (McDermott, 2012; Stevens, 2012). Some youth also encounter oppositional accounts of science which are inaccurate across the communities in which they participate (Bang & Medin, 2010). All of this likely contributes to a drop off in interest and identification of young people in science, especially around middle school (Tai, Lie, Maltese, & Fan, 2006).

This drop off is one of the consequences of the dominant perspective on science, in how it gets defined and by whom and for what purposes. McDermott (2012) encourages a confrontation of the assumptions that go along with the emphasis placed on school science as the only legitimate form of science practice. The analytical tool described here was originally developed by drawing on McDermott and Webber's (1998) recommendation that research in math and science education must focus on what moments of everyday life gets counted as scientific or mathematical, including who decides and to what end.

As Penuel (2014) reminds us, research that yields a deeper understanding of the ways in which young people engage in science in practice and when they see science in their everyday lives is important because "such research can serve to identify specific interests and experiences of communities that can be developed within diverse institutions devoted to supporting learning, including schools" (p .16). In other words, highlighting and leveraging the points of overlap in everyday activities and "official" science activities can provide meaningful access to science learning for those who might not otherwise be engaged (Nasir et al., 2006).

To address the problem of a drop of in young people's interest in science, the aim of this study is to better understand how youth define science in the activities across their lives and

identify the areas where science has the potential to be recognized, both for youth and for designers of learning environments (Bell et al., 2013). I refine an analytic tool and protocol that will help surface young people's contributions to collective definitions of science in ways that can broaden our understanding of what "counts" as science. This broader definition may then be used as a means to reconceptualize how we engage youth (Esmonde et al., 2012; Stevens et al., 2005; Stevens, 2012). To this end, I first seek to identify, categorize, and contextualize young people's conceptions of science in and outside of school and over time in ways that can be leveraged in order to understand the stances, dispositions, characterizations, and knowledge that leads learners to engage in an extended cultural learning pathway (Bell et al., 2012)—or becoming 'activated,' a state of ignited and persistent engagement that enables success in a variety of learning experiences (Moore, Bathgate, Chung, & Cannady, 2011). In this way, the SAS is intended to illuminate the activities youth participate in that might serve as opportunities for growing competences and/or new learning opportunities.

Additionally, this study seeks to fill gaps in the research on the settings, interactions, and events where science takes place, including how to identify assets young people carry from setting to setting that can provide access or navigation assistance in science (e.g. McDermott & Webber, 1998; Stevens, Wineburg, Herrenkohl, & Bell, 2012). Bell et al. (2013) describe these points of continuity (knowledge, practices, boundary objects, etc.) as the outcomes of rich STEM (science, technology, engineering, and mathematics) learning experiences which are afforded or constrained by the social and material resources available within situated moments of activity, as well as by the mechanisms that create bridges or barriers across settings and experiences.

And finally, I seek to identify curricular or other connections that can be made from setting to setting. This kind of *connected learning* is an emerging focus of learning sciences

research, especially within research in the sector of young people and digital media (Ito et al., 2013). Intentionally designed learning opportunities across settings can provide spaces for young people to pursue meaningful personal interests with the support of friends and family in ways that have implications for present and future community, academic, or professional engagement (Ito et al., 2013). In a related line of work, Bell et al. (2013) recommend, for example, that school science curriculum be made to *overlap* with the lives of young people in meaningful ways, building on prior interests and identification in relation to science and drawing on young people's resources in ways that align with the disciplinary learning goals.

This work seeks to inform the design of learning environments which open up available scopes of possibility for young people by stabilizing situational interest so that "people [can] come to participate in specific forms of social practices" in central or legitimate peripheral ways (Bell et al., 2012, p. 9; Lave & Wenger, 1991). Additionally, opening up available scopes of possibility for youth can be scaffolded by nurturing both interest and competent engagement through a focus on the development of *competent outsiders* who can use science in their everyday lives for meaningful personal and community goals (Feinstein, Allen, & Jenkins, 2013, p. 314). As Feinstein et al. (2013) assert, there is little evidence to support assumptions that the current policy climate focused on the practices and knowledge of professional scientists is the central tenant of science literacy for all. Redesigning learning environments to address the everyday needs of all people who must evaluate and interpret conflicting arguments, assess the needs of their communities, and make decisions for themselves and their families has the potential to yield a powerful form of scientific literacy, making science for all a reality.

It is important to note that this study does not assume that all practices will be or should be strongly related to science, nor is this required for promoting scientific literacy in and across a

wide range of settings across youths' lives. The science-relatedness of any given activity is context dependent and situated. The intent in this paper is to establish a baseline for different kinds of activities in terms of how youth view the activities in their lives, both in prevalence and science-relatedness.

In summary, expanding our view of young people's engagement in, interest in and identification with science and science activities allows us to create environments that more actively engage them in the practices of science (e.g. Driver et al., 1985). In this study, I aim to contribute to a research base that informs our ability to draw on young people's everyday cultural practices, connect prior interests and/or develop new interests in ways that are related to science over time, especially as youth move into adolescence.

By examining the following research questions, the purpose of this study is to: 1) refine an analytical tool and protocol intended for broad use that will identify the ways in which young people conceptualize science in relation to everyday practices across the settings of their lives, and how they participate (or do not) in these activities included in the survey; 2) create a conceptual model that enables us to relate the ways in which young people characterize science in their lives with their engagement in social practices across settings; and 3) derive design implications for learning across settings that use these science-related connections to youths' life practices as points of leverage to activate learning in STEM (Moore et al., 2011) and help them develop science-related identities (Bell et al., 2012). I use a mixed method approach to situate the narrative accounts of individual case study youth in a broader data set and thus gain ecological validity by triangulation (e.g. Erickson, 1986; McDermott, 2012).

Research Questions

1. In what activities do fourth- through sixth-grade children (10–12-year-olds) participate across the venues of their lives? How do they see that these activities are related to science?
2. What science-related definitions and educational assets are developed within youths' activities across the venues of their lives?

Subjects and Methods

Subjects

The Science Activity Survey reflects an adaptation of the Science Activity Task, an ecologically grounded interview protocol based in the ethnographic fieldwork of a longitudinal study in the community of Granite Hills (pseudonym). Granite Hills is a culturally and linguistically diverse neighborhood in an urban area in the Pacific Northwest. Sixty fifth-graders from a school that will be referred to as Granite Elementary enrolled in this study in Fall 2013, although the researchers have engaged in a decade-long partnership with the school staff and community. Granite Elementary was the site of the original ethnographic research engaged in by Bell and colleagues (Bell et al., 2013).

In addition, 78 students from Holly Hills Elementary enrolled in the study during their sixth-grade year, in Fall 2013. Holly Hills is located in a suburban area approximately 25 miles from the Granite Hills neighborhood. While the demographics of the student body at Holly Hills Elementary reflect a less culturally and linguistically diverse student body than that of Granite Elementary, the schools' students represent 25 countries and about a third spoke a language other than English at home. The district is the 11th largest in the state and encompasses several suburban cities and some parts of unincorporated county. See Tables 1 and 2 for demographics as reported by the two school districts.

Granite Elementary Student Demographics (as of Oct. 2012)	
Free/Reduced Lunch	63%
Black	14%
Hispanic	20%
Asian/Pacific Islander	49%
White	11%
Multiracial	7%
ELL	35%
Special Ed	8%

Table 2.1. Granite Elementary student demographics, as reported by the district.

Holly Hills Elementary Student Demographics (as of Oct. 2012)	
Free/Reduced Lunch	17.3% (district wide)
Black	3%
Hispanic/Latino	18%
Native Hawaiian/Other Pacific Islander	0
Asian	18%
White	51%
Multiracial	10%
Transitional Bilingual	5% (district wide)
Special Ed	13.9% (district wide)

Table 2.2. Holly Hills Elementary student demographics, as reported by the district.

The fifth-grade classrooms at Granite and sixth-grade classrooms at Holly Hills were invited to participate in the broader study that this chapter is a part of because of their commitment and focus on science literacy for their students. It is important to note this in a time when accountability pressures in mathematics and language arts lead to a general dearth of science education in elementary education, especially for historically marginalized learners (NRC, 2012). The young people who participated in this survey were consistently and deeply engaged in science instruction in their classrooms on an almost daily basis, in a way that is probably atypical for most students at these grade levels. This study then highlights the science conceptions and practices of youth who had deep opportunities to learn about science in school, as all youth should.

The Science Activity Survey

The SAS protocol designed for this study draws from Zimmerman and Bell's (2012) ethnographic interview SAT protocol, which was implemented in a conversational manner with a

small number of case study youth participating in a multi-year, team ethnography. In the ethnographic interview protocol, Zimmerman and Bell drew from fieldnotes and content logs from school, home, and community settings to construct a comprehensive list of young people's activities. Researchers identified activities that young people participated in or discussed during ethnographic observations, and then classified activities into like categories while also attending to social structures, expectations, rules and tools used. Finally, researchers selected the final 36 activities by accounting for activities that 1) were said to be important by children and their families; 2) were seen as science-related by children, their families, teachers and researchers; and 3) that spanned all researchers' accounts. They then tested and refined the list outside the research project (see Zimmerman & Bell, 2012, for more details).

To revise the SAT to efficiently reach a larger number of young people and help better understand characterizations of science across communities, I redesigned the game-like format into an online survey using an online survey host. (In the SAT, the activities are listed in a grid format and game pieces are used to mark activities in which youth participate. The game pieces vary in size to mark the extent to which youth participate in each activity.) A major goal of the online survey format was to reach a larger number of young people without essentializing the activities of young people's everyday lives. To make the survey manageable for young participants, I worked with teachers to narrow the list of activities presented from 36 to 21. To narrow the large number of activities to a manageable number for an online survey, I surveyed three teachers in the region: one from a less diverse, higher socio-economic neighborhood, one from Holly Hills, and one from Granite. I compiled the teachers' rankings of the activities they felt matched their students' everyday lives to create one online survey which was used in both schools in this study (Table 3).

C2	Going to an afterschool program or club	M24	Going online or using the internet
C3	Talking with friends	M25	Watching a movie at home or in a theater
C4	Fishing, camping, snorkeling, hiking, boating	M26	Listening to music on the radio, computer, mp3s
C5	Playing soccer, basketball, football, other sports	M29	Watching cartoons or comedy on TV
C7	Playing on the playground, like tetherball	M30	Reading stories or comics (fiction)
H10	Doing experiments or playing around with things at home	S31	Observing things in school science
H14	Playing a musical instrument or singing		
H16	Playing videogames	S32	Talking about science in your school classroom
H17	Taking care of pets (feeding, walking)		
H18	Talking with parents and family	S33	Doing math in school
H20	Drawing, knitting, painting, crocheting	S36	Conducting experiments in school
H22	Making origami stars, airplanes, paper-folding		

Table 2.3. Activities included in the SAS, organized into four sectors: community, home, media, and school. To retain consistency in the data between the two studies, the shorthand designations assigned to each activity (e.g., C1, H18) were retained. Because of this, there are gaps in the numbering of the items included in the SAS.

Structure of the Science Activity Survey. As in the original SAT protocol, young people completed the SAS in the classroom in two phases. In Phase 1, young people indicated how frequently they participated in the set of activities: ‘a lot,’ ‘sometimes,’ or ‘do not do.’ In Phase 2, young people were presented with the same list of twenty-one activities and asked to indicate how related to science the activities were: ‘closely related to science,’ ‘somewhat related to science,’ or ‘not related to science.’ The survey then asked young people to elaborate on their answer by typing a sentence or two into a text box explaining their selection (Figure 1). As in the original implementation of the SAT, young people were asked first about their activities without mentioning that the second phase would discuss science, in order to ensure that they would focus on the prevalence in their lives separately from considering the science-relatedness of each activity.

Section 1:

Talking with friends



3. How frequently do you do this activity?

- A lot
- Sometimes
- Do not do

Prev

Next

Section 2: Science

Talking with friends



24. How related to science is this activity?

- Closely related to science
- Somewhat related to science
- Not related to science

Tell us why you chose that answer:

Figure 2.1. An example of a survey items from Phases 1 and 2.

Data Collection and Analysis

Survey implementation. The SAS was implemented in participants' classrooms in their fifth- or sixth-grade year. The dataset included pre- and post-data for 128 fifth- or sixth-graders. Sixteen students took only the pre- or the post-survey. Unless otherwise noted, the analysis presented here is of post-survey data—since there was little change from pre to post. 135 students took the post-survey, 63 from Granite and 72 from Holly Hills.

The survey took young people between 15 and 50 minutes to complete. The pre- and post- versions of the survey were identical. The purpose of the pre/post design was to observe any changes over the school year as students were engaged with teachers uniquely committed to elementary science instruction, but was not designed to be tied to any specific instruction. Youth participants took the pre-survey in fall 2013 and the post-survey in May or June 2014, near the completion of the academic school year. After completing the survey, nine consented fifth grade

students at Granite Elementary were selected as case study students. These students were selected based on observations of the classroom at the beginning of the year to form two small group tables in the classroom that included a variety of demographic backgrounds and a broad range of demonstrated interest and excitement for school and science instruction. The case study students were interviewed by researchers using open-ended follow-up questions similar to those used in the original interview protocol. This allowed us to ask probing questions about young people's survey responses, focusing on their short explanations of the science-relatedness of each activity, and allowed us to clarify any answers we found confusing or unclear. The interview data set included 147 single-spaced pages of follow-up interview transcripts from the nine participants. Data from two of these students was dropped from the study after they were observed copying text from the survey question into the response boxes instead of answering the survey questions.

Analysis. To understand which activities young people participate in the most and those they see as most related to science, I did several sets of analyses.

Ordinal scale responses. First, I scored the participants' rankings for the prevalence of particular types of activities in their lives and their perceptions of the relatedness to science from Phases 1 and 2 of the survey (0 = Do not do/Not related, 1 = Sometimes/Somewhat related, 2 = A lot/Closely related). As in Zimmerman and Bell (2012), I also multiplied the rankings (prevalence X science-relatedness) for each activity to get a 'science and activities' score. I created visual representations of data for subgroups (e.g., pre-, post-, school, class, gender) and for individual case study students in order to determine variation and consistencies within and between groups. Finally, for all comparisons of individuals or subgroups, I conducted Mann-Whitney U-tests (Mann & Whitney, 1947) to determine any statistically significant differences in

the data sets. There were no statistical differences between the pre- and post-survey. For this reason, unless noted otherwise, the post-survey data is used throughout this chapter to explain how young people reported the prevalence of these activities in their lives and how they viewed these activities as being related to science.

Open-ended responses. To characterize and examine the prevalence of young people's definitions of science in activities, I conducted qualitative and quantitative analysis of the open-ended survey responses. In collaboration with another graduate researcher, I used a sample of 10% of the student responses to develop a preliminary coding scheme of the definitions of science students were using in their written responses. The initial coding scheme was reviewed by others in our research group and their feedback informed revisions. We then coded a larger sample of about 75% of students' responses before reviewing and revising the coding scheme once more, writing full working definitions for each code with exemplars, which guided our final coding. Participant responses were coded as 'N/A' if they did not respond to the question. The code 'Not enough information' was applied if coders agreed there was not enough information to determine the meaning of the response. These responses were dropped from the data set. We conducted an inter-rater reliability test, discussed any discrepancies, and came to further agreement. We made minor changes to the working definitions of each code for clarity and finally coded all responses using the final coding scheme.

To examine the prevalence of young people's definitions of science, I then conducted a quantitative analysis of the open-ended responses. I created visual representations of the prevalence of codes by activity and for individual participants and subgroups. For all comparisons between individuals and subgroups, as well as for pre- and post-survey differences,

I conducted a Mann-Whitney U-test, or other tests where more appropriate, to determine any significant statistical differences.

Case studies. Finally, to exemplify themes developed from analyses of the survey data, I consulted fieldnotes and content logs, in addition to teacher interviews and student work for case study participants. I used excerpts from surveys and other case study data to illustrate examples of young people's conceptualizations of science across their lives.

Findings

The SAS is intended to gauge how young people participate in specific activities across the social settings of their lives and how related to science they view these activities. The data allows characterization of the degree to which the student population—and any individual—engage in the focal activities, as well as how they perceive them to be related to science. Additionally, I sought to identify how young people's participation in activity shifted over the course of the school year by situating case study data in a larger data set as a way to understand shifts in individual learners' identities, especially in relation to science. What I found instead was that though there were some shifts in individual case study students over the course of the year, the study group as a whole remained relatively stable in their participation in activities and their perceptions of science across those activities over the course of the year. Because of this, I focus on summarizing and characterizing the aggregate data in order to better understand science in the lives of young people more generally. There were no statistically significant differences between the pre- and post-survey or between subgroups (boys/girls, by classrooms, by school) for any of the analyses I conducted, so the findings here are based on a report of the aggregate data that seemed stable over the course of the academic year.

The findings are presented in two parts. In the first part, I summarize the data by describing the extent to which young people participate overall in the activities selected for the SAS and how they see these activities as related to science. In the second part, I examine how young people conceptualize science across activities by categorizing their explanations of how activities are related or not related to science. Additionally, I examine activities in broad social settings (or venues), focusing on community-based, home-based, media-based, and school-based activities more closely to understand how young people participate in and conceptualize science within the contexts of common activities.

Research Question 1: In what activities do fourth- through sixth-grade children (10–12-year-olds) participate across the venues of their lives? How do they see that these activities are related to science?

In Phase 1 of the SAS, youth reported how they participate in a range of activities: a lot, sometimes, or do not do. In Phase 2, young people considered when and how activities are related to science and explained their responses. Table 4 describes the means and standard deviations for each activity in relation to prevalence and science-relatedness. The activities are ranked in order from most to least science-related. *Going online or using the internet* (M24) is the only activity that was in both the top 25% for science-relatedness and prevalence in youths' lives.

Activity	Prevalence Mean (0-2)	Prevalence Standard Deviation	Related to Science Mean (0-2)	Related to Science Standard Deviation
*S31: Observing things in school science	1.31	0.59	1.94	0.30
*S36: Conducting experiments in school	1.03	0.57	1.93	0.34
*S32: Talking about science in your school classroom	1.22	0.57	1.91	0.33
*H10: Doing experiments or playing around with things at home	1.03	0.66	1.85	0.45
*C4: Fishing, camping, snorkeling, hiking, boating	0.82	0.68	1.18	0.75

Activity (cont.)	Prevalence Mean (0-2)	Prevalence Standard Deviation	Related to Science Mean (0-2)	Related to Science Standard Deviation
*^M24: Going online or using the internet	1.70	0.47	1.15	0.68
^S33: Doing math in school	1.88	0.33	1.11	0.73
M30: Reading stories or comics (fiction)	1.44	0.54	0.90	0.65
C2: Going to an afterschool program or club	0.81	0.76	0.89	0.63
C5: Playing soccer, basketball, football, other sports	1.42	0.63	0.88	0.72
M25: Watching a movie at home or in a theater	1.31	0.54	0.84	0.68
^C3: Talking with friends	1.73	0.52	0.83	0.64
^H18: Talking with parents and family	1.47	0.60	0.81	0.62
H14: Playing a musical instrument or singing	1.19	0.82	0.75	0.77
H16: Playing videogames	1.40	0.68	0.73	0.72
C7: Playing on the playground, like tetherball	0.94	0.56	0.70	0.70
^M29: Watching cartoons or comedy on TV	1.51	0.66	0.69	0.69
H17 : Taking care of pets (feeding, walking)	1.09	0.86	0.68	0.66
^M26: Listening to music on the radio, computer, mp3s	1.68	0.53	0.64	0.71
H22: Making origami stars, airplanes, paper-folding	0.70	0.70	0.63	0.67
H20: Drawing, knitting, painting, crocheting	0.90	0.71	0.49	0.62

Table 2.4. Means and standard deviations for each SAS activity. * Top 25% most science-related activities. ^ Top 25% most prevalent activities.

Activities young people engage in across social settings. In contrast to the previous study (Zimmerman & Bell, 2012), there were no activities in which all young people reported full participation. Most young people said they take part in *Doing math in school* (S33) (84%) and *Talking to friends* (C3) (72%), followed closely by *Going online* (M24) (68%) and *Listening to music* (M26) (67%). The only activity in which all of the young people reported participation as either ‘A lot’ or ‘Somewhat’ is *Doing math in school* (S33). *Making origami* (H22) is the

activity youth participate in the least, ranked just below *Fishing, camping, snorkeling, hiking, boating* (C4) and *Going to an afterschool program* (C2).

Activities young people associate with science across social settings. Three of the top four activities that young people associate with science share a focus on science in school. Most young people indicated that the fact that these activities were described as ‘science in school’ made them inherently science-related. Of the activities youth participate in most, only *Going online* (M24) is rated by young people as highly related to science. *Observing things in school science* (S31) (88%) and *Conducting experiments in school* (S36) (87%) are closely ranked at the top, followed by *Talking about science in your school classroom* (S32) (84.8%) and *Doing experiments or playing around with things at home* (H10) (84.3%). All other activities trail these by a wide margin in science-relatedness. *Fishing, camping, snorkeling, hiking, boating* (C4) (35%) and *Going online* (M24) (29%) ranked the highest of the remaining activities. *Drawing, knitting, painting, crocheting* (H20) (6%) ranked the lowest. These findings are similar to those in Zimmerman and Bell’s (2012) study, where youth rated *Observing in school science* (S31) and *Doing experiments or playing around with things at home* (H10) as the most science-related activities.

Variability in the prevalence and science-relatedness of youth activities. The variation in youths’ participation in activities and their conceptualization of how they may be related to science is important for understanding fundamental aspects of the phenomena of interest. While mean scores describe the central tendency for how prevalent or science-related an activity is in relation to other activities, the standard deviation describes how much divergence there is among the youth population with respect to any given activity. This can be due to fundamental cultural variability in the social lives of youth and families based on contemporary

or historical differences. It can be also be due to differences in theoretical interpretations or meanings culturally associated with activities across individuals or sub-populations.

Understanding the heterogeneity of human experience in relation to learning and education is a crucial perspective for promoting equity and social justice (Lee, 2008; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001).

The wide variability of how youth see some activities as related to science fits with the findings of the previous SAT study: youth hold a broad variety of images of science (Zimmerman and Bell, 2012). In one example, as shown by Table 4, young people's perception of the prevalence of *Doing math in school* (S33) has the least variability (0.33). This finding makes sense, as doing math in school is a primary focus for all elementary school classrooms. In another example, *Taking care of pets* (H17) shows the most variability (0.86) of the activities listed in the survey. Again, these findings make sense, as not all youth take care of pets at home.

The data in Table 4 also demonstrate that some activities are much more variable than others in terms of how young people see them as related to science. Some activities are seen by youth as related to science in more stable ways (or more generalizable ways) than other activities. For example, the top four most science-related activities also have the least variability ($SD \leq 0.45$), which means that these rankings had the most agreement from young people in the study.

Other activities, such as *Taking care of pets* (H17) (.66) and *Fishing, camping, snorkeling, hiking, boating* (C4) (.75) show wide variability in science-relatedness. This indicates that some youth see activities such as these as more related to science than the mean score shows, and others see it as much less related. Bell and colleagues (Bell et al., 2013; Bricker & Bell (in review), Bricker & Bell, 2014; Zimmerman, 2012; Zimmerman & Bell, 2012) have

published extensively on ethnographic case studies of youth who related science ideas and practices to a wide variety of out of school activities. In one example, Penelope, who was deeply engaged in a variety of animal care practices, related those practices to science if they included attempts to learn more about the animals (Zimmerman, 2012; Zimmerman & Bell, 2012). In another case, April described fishing as closely related to science because of the opportunity to engage in scientific inquiry to learn about animals (Zimmerman & Bell, 2012). These case studies provide evidence of a fundamental variation in the ways that youth perceive science in some activities. This variation then is at least partly dependent on life context and history: some youth may rate activities as more closely to science if the purpose of the activity is more closely related to engaging in science practices rather than just interacting with science content or tools. In light of the evidence that some youth have strong, generative associations with science in these activities, this data shows that there may be opportunities to leverage these activities as points of access to scientific concepts and practices for a broader number of youth.

The prevalence of science across youths' lives. To understand the relationship between the prevalence of activities in youths' lives and how related to science they see those activities, I plotted the distribution of average scores from Phases 1 and 2, shown in Figure 2. The x-axis describes young people's view of the prevalence of each activity in their lives. The y-axis describes how related to science young people see each activity. As in Zimmerman and Bell (2012), I multiplied the rankings from Phases 1 and 2 to get a 'science and activities' score for each activity. The top five activities are marked in the scatterplot by a red square and include *Observing things in school science* (S31) and *Doing math in school* (S33), followed by *Conducting experiments in school* (S36), *Going online* (M24), and *Talking about science in your school classroom* (S32). Together, these activities illustrate where science is most prevalent in

young people's activities. Though the change was not statistically significant, the five activities maintained their top ranking, but changed slightly in order of ranking from pre- to post-survey. *Talk about science in your school classroom (S32)* showed the more increase from pre- to post-survey.

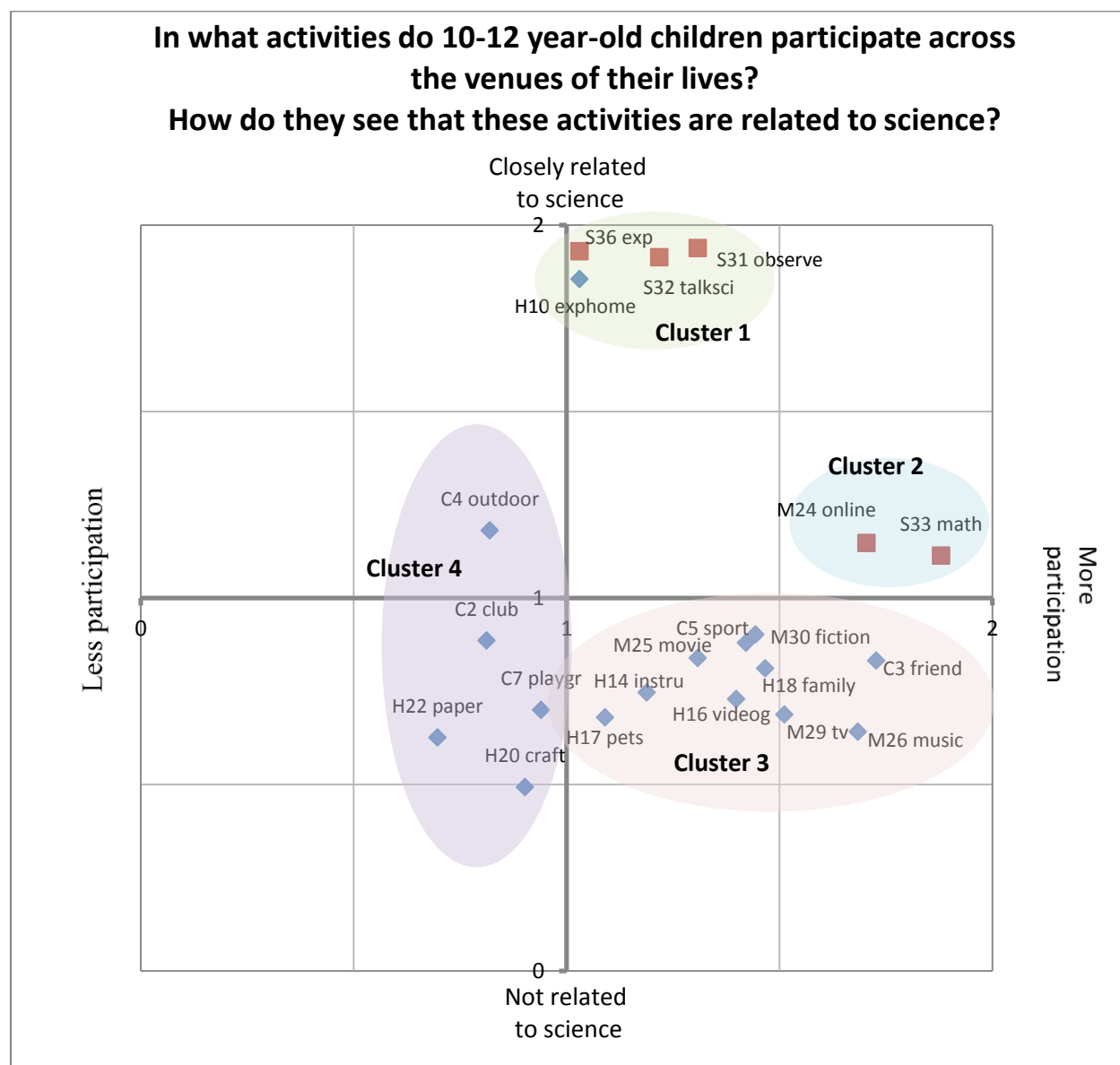


Figure 2.2. The distribution of average scores young people applied to the activities included in the Science Activity Survey.

This distribution shown in Figure 2 makes clear that in general there is very little overlap between the activities young people engage in a lot and those they see as most closely related to

science. This finding is consistent with Zimmerman & Bell (2012). Home and media activities are seen as less science-related than those that occur in school or in the community. For example, in the post-survey ReyMaya rated 13 of the total 21 activities as those she did frequently. However, she only ranked one activity as highly related to science, *Going to an afterschool program or club* (C2), but reported it as an activity she did not engage in.

The activities included in the survey can be grouped into roughly four clusters in terms of how young people participate in them and how they see them related to science. Cluster 1: *High science, low prevalence*: At the top of the chart, Cluster 1 represents activities youth rated as very closely related to science and which they participate in sometimes, high on the y-axis. These activities include classroom activities, as well as *Doing experiments at home* (H10). Cluster 2: *High prevalence, low science*: Cluster 2 includes activities that youth participated in the most, but only count as somewhat science-related, just above the x-axis. This cluster includes *Doing math in school* (S33) and *Going online* (M24). These are the two activities youth report participating in the most, but only regarded as somewhat science-related. Cluster 3: *Intermediate prevalence, lowest science*: Just below the x-axis are activities in which youth participate, but which they consider not related to science. This cluster includes primarily home-based activities and media activities. Cluster 4: *Low prevalence, low science*: There are several activities youth reported that they do not participate in much, found to the left of the x-axis. These include activities like origami, outdoor activities, and going to an afterschool program.

Discussion for Research Question 1: Activities and science

The data reported in this section summarizes how youth see science in their lives generally: primarily as science in school, or in out-of-school activities that are focused on experimentation or other practices that youth recognize as scientific. *Doing experiments or*

playing around with things at home (H10) was the only activity descriptor outside of school that explicitly used the word “experiment”—which likely shaped their interpretation of it. Young people often made a related connection in their explanations of the science-relatedness of the activity. For example, one young person said, “experiments are pretty much always scientific.” Another said, “I think it is closely related because if you play around with things it might make you ask questions and wonder if you changed something what it would do.” Young people also commonly used phrases like exploring, asking questions, learning new things, learning from mistakes, and trying things out when describing how doing experiments at home was related to science. Young people demonstrated their view that any activity that involves these practices, whether in or out of school, is closely related to science. The activities that youth do not do as much, shown in Cluster 4, include home- and community-based activities that may represent more niche activities particular to some young people, but not others based on personal or family interest and access. I will discuss this further in the analysis of the survey data for home- and community-based activities.

While fifth-grade students at Granite had a deep and broad experience with science in their classrooms, we know from previous research in past years at this school that science in the lower grades is not as comprehensive. It is also important to note that during the year of the study both schools engaged in a more rigorous science curriculum than may be typically implemented in these grades. At the time of this study, two of the three fifth-grade teachers at Granite were also involved in a multi-district, multi-year program which engaged practitioners with the *Next Generation Science Standards* (NGSS, 2013) to implement focused improvements for science learning. At Holly Hills, the sixth-grade teacher who taught science for all sixth graders was a studying for a master’s degree focused on promoting social and ecological change

through formal and informal education and was also at the forefront of implementing NGSS practices in her classroom. At both Granite and Holly Hills, we observed talk in science class as a common and scaffolded scientific practice in the classroom, so it is unsurprising that by the end of the year youth ranked *Talk about science in your school classroom* (S32) more highly in both prevalence in their lives and science-relatedness.

The clusters of activities youth participate in (or do not) and their relative relation to science provide information about how youth might be identified by themselves or others. Sociocultural perspectives account for learning as the transformation of participation within ongoing activity, or communities of practice (Gutiérrez & Rogoff, 2003; Lave & Wenger, 1991; Nasir, Roseberry, Warren, & Lee, 2005; Rogoff, 1997). Participation in various repertoires of practice not only serves as resources for learning, but also “help define who a person is, in terms of their social identity, in any given situation” (Bell, Lewenstein, Shouse, & Feder, 2009, p. 75). From this perspective, it is productive to consider identities as being practice-linked, which foregrounds the relationship between the activities people participate in and the development of identity by emphasizing the social and cultural contexts of learning (Nasir & Hand, 2006). At the individual case unit of analysis, some shifts in participation can be seen. For example, Eddie, a case study student, identified only a few activities as science-related. At the end of the year, he designated almost all of the activities on the survey as science-related, which was in line with other outcomes for him described in Chapter 3. The aggregated data presented here does not detail how young people might be shifting toward more central participation in practices; it does provide an image of how they spend their time, from their perspective, and the kinds of identities that might be available to them through those practices. From this representation, we can see that young people from these two community groups may be identified by themselves or others as

active family members and friends, music-lovers, and mathematicians. At the population level, they are more likely to have practice-linked identities around playing videogames and doing science in school than in outdoor activities like fishing, or crafts like paper-folding. In this way, the survey data allows for a closer examination of the activities that might be leveraged in order to broaden young people's opportunities across their lives to take part in, and recognize and identify with science. For example, as I will describe further later in this chapter, it is helpful to understand the variable ways in which young people characterize the science-relatedness of an activity like *Doing math in school* (S33), which they spend a lot of time doing, but perceive as only somewhat related to science. Even if young people reported that they did not engage in activities personally, they did describe activities across a range of venues as at least somewhat science-related or with the potential to be science-related, which means that a wide variety of activities could be leveraged in engaging young people in developing science-linked identities.

Research Question 2: What science-related definitions and educational assets are developed within youths' activities across the venues of their lives?

In Phase 2 of the survey, young people described the science-relatedness of each activity and explained their answer in a, open-ended, short response format. The themes that emerged represent definitions of science, as justifications that young people used to describe activities as being related to science to differing degrees and in different ways. These themes, ranked in Table 5 in order of overall prevalence in the data, describe how young people see science in specific ways in the activities across their lives and what specifically about an activity or set of activities counts as science.

Theme	Description	Exemplar
Learn content	The activity includes learning about, or consuming, science	Reading a book is science-related if it has “fun facts or ideas with science in it”
Everyday activities	The activity is for fun, to relax, for purposes other than learning or doing science	“Sports are created for fun, not so much learning.”
Scientific practices	The activity includes doing science, engaging in practices of science such as carrying out experiments	“You can observe how your animal changes throughout your caring.”
Activity as science	The activity uses or includes science-related tools, products, or phenomena	“...Music is a sound and can be studied.”
Investigation	The activity includes a specific question that is asked that describes a scientific investigation to be carried out	“How many times will a tetherball go around in one minute?”
Disciplinary	Activities are either related to science or to another discipline, but cannot be both	“It is art, not science.”
It is science	No further explanation is needed, this activity is the definition of science	“It is actually science.”
Other	Miscellaneous explanations that cannot be characterized by other codes	“I do this.”
School science is science	No further explanation is needed, school science is the definition of science	“Observing things in science class is definitely science!”
Interdisciplinary	Activities can be related to more than one discipline, such as math and science	“Without math, science would be impossible, and vice versa.”
Scientists do this	The activity is the same as what scientists do	“...Experiments prove things and that is what all scientists try and do.
Using science materials	The activity includes using materials that are science-related	“...you are experimenting with stuff like chemicals.”

Table 2.5. Young people’s definitions of science in activities across their lives, ranked in order of prevalence.

Young people primarily see science as opportunities to *Learn content* or to participate in *Science practices*, or as including an activity that is dependent on or related to scientific phenomena in some way (*Activity as science*). The *Framework for K-12 Science Education* (NRC, 2012) laid out a vision for NGSS and science education broadly that integrates the content and process (practice) dimensions of scientific work. *The Next Generation Science Standards* (NGSS, 2013) mark a shift in science education to emphasize that “science is not just a body of

knowledge that reflects current understanding of the world; it is also a set of practices used to establish, extend, and refine that knowledge” (NRC, 2012, p. 26). Engagement in scientific practices is especially important for providing opportunities for the development of an identity as a competent learner of science (Bell et al., 2009; Brickhouse, Lowery, & Shultz, 2000; Calabrese Barton, Tan, & Rivet, 2008; Lave & Wenger, 1991; Nasir & Hand, 2006; NRC, 2012). Because the memorization of scientific content has been a more common pedagogical focus in science education than learning and applying content (i.e., conceptual and theoretical ideas) through engagement in scientific practices, in this study young peoples’ descriptions of learning about science were coded as *Learn content* unless they explicitly described engaging in scientific practices.

Young people also commonly identified activities in the survey as *Everyday activities*, those with purposes other than to learn. Some activities are seen as science-related specifically because the activity provides an opportunity for carrying out an *Investigation*. Other definitions of science concern science as either disciplinary only or interdisciplinary, in that an activity can either be only science-related or can be related to other disciplines as well. These definitions were commonly invoked to describe *Doing math in school* (S33) as either not science because it is math not science (*Disciplinary*) or as science because math and science are linked to each other in some way (*Interdisciplinary*). *School science is science* or *It is science* reflect explanations young people gave to describe activities that they consider inherently related to science or school science and thus requiring no further explanation. Some activities are described as science because they are similar to what scientists do (*Scientists do this*) or include specific materials (*Using scientific materials*), such as chemicals or test tubes. Finally, outlier responses

that did not fit into the other categories were grouped into one category (*Other*). The prevalence these definitions of science across the survey data are reported in Figure 3.

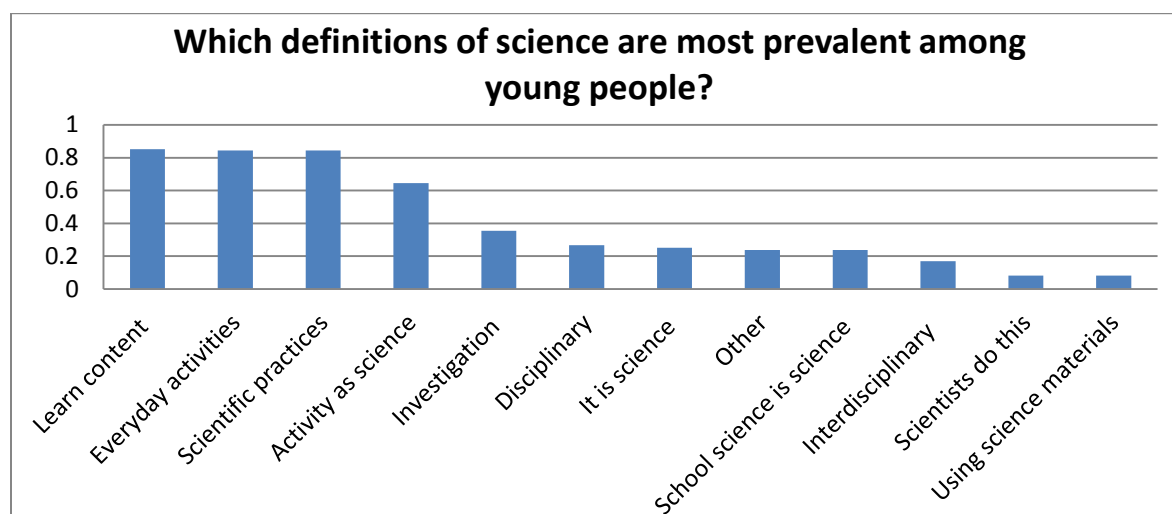


Figure 2.3. Distribution of definitions of science. Results reported as percent of youth who used a definition of science at least once in their survey responses.

Young people's definitions of science show remarkable consistency across the two schools and between the pre- and post-survey within each school, according to the survey. There are no statistically significant differences in how young people define science between schools or from pre- to post-survey. One explanation is that the images portrayed here are more broadly pervasive images of science of a culturally shared level. It is also possible that young people at Granite and Holly Hills elementary schools may have very similar responses because their schools and their student communities are so similar. The two schools are geographically close to one another, in and just outside of the same large city in the Pacific Northwest. They also have similar student populations in many ways (e.g. several languages spoken at home, high student diversity). Additionally, both sets of classrooms involved in the study had a strong science focus during the year of the study. Future research could clarify the usefulness of their survey in determining variation across school communities or other subgroups by comparing school communities with more geographic, socioeconomic, or curricular differences. Alternatively, the

lack of difference between the two schools and over the school year could mean that the SAS is not sensitive enough to distinguish the perspectives of specific communities of young people from others.

Venue	Leading definitions of science			
	Learn content	Scientific practices	Activity as science	Everyday activities
Community				
	0.24	0.22	0.21	0.20
Home	Scientific practices	Everyday activities	Learn content	Activity as science
	0.26	0.26	0.18	0.14
Media	Learn content	Everyday activities	Activity as science	Scientific practices
	0.49	0.27	0.16	0.05
School	Scientific practices	Learn content	It is science	School science is science
	0.52	0.16	0.12	0.08

Table 2.6. Leading definitions of science for each venue. Results reported as percent of youth responses for each venue.

Finally, the leading definitions of science that youth have in each venue varies greatly, as shown in Table 6. School-based activities are clearly the place where youth see themselves engaging in scientific practices, while media-based activities are mostly about learning content. The most prevalent definitions of science found in home-based activities are both scientific practices and everyday practices. Community-based activities show a pretty even distribution of definitions of science and everyday activities. These results will be discussed further in the analysis of each venue.

Young people’s most prevalent definitions of science across activities. Here, I focus on how young people conceptualize activities in relation to the three most prevalent definitions. There are striking contrasts in how young people perceive activities as either opportunities to perform *Scientific practices* or as *Everyday activities*. I also demonstrate how youth see little overlap in activities that are opportunities to perform *Scientific practices* or to *Learn content*.

Scientific practices vs. Everyday activities. The terms ‘everyday’ and ‘scientific’ are commonly understood in popular parlance to denote opposing ends of a dichotomy. As described in Warren et al. (2001), everyday activities are informal, subjective, and ambiguous while scientific activities are often framed as formal, objective, and precise. In this view, doing science involves discourses and practices that are distinct from those used in everyday activities. Science classrooms have traditionally embraced this view by separating the everyday practices of youth from those privileged in the science classroom, especially for historically marginalized youth, in ways that can also be viewed as deeply problematic and flawed (Warren et al., 2001). This everyday/science dichotomy phenomenon is reflected in the SAS data in that young people who participated in this study recognize *scientific practices* and *everyday activities* as mutually exclusive by definition. Youth associate *scientific practices* most closely with school activities (38%) and with doing experiments at home (H10) (35%). *Everyday activities* are most likely to be associated with other home activities (43%), or with media (31%) or community activities (25%). This analysis demonstrates that the youth in this study hold a prevalent, canonical view of science as a set of particular practices that usually occur in formal educational settings, such as classrooms.

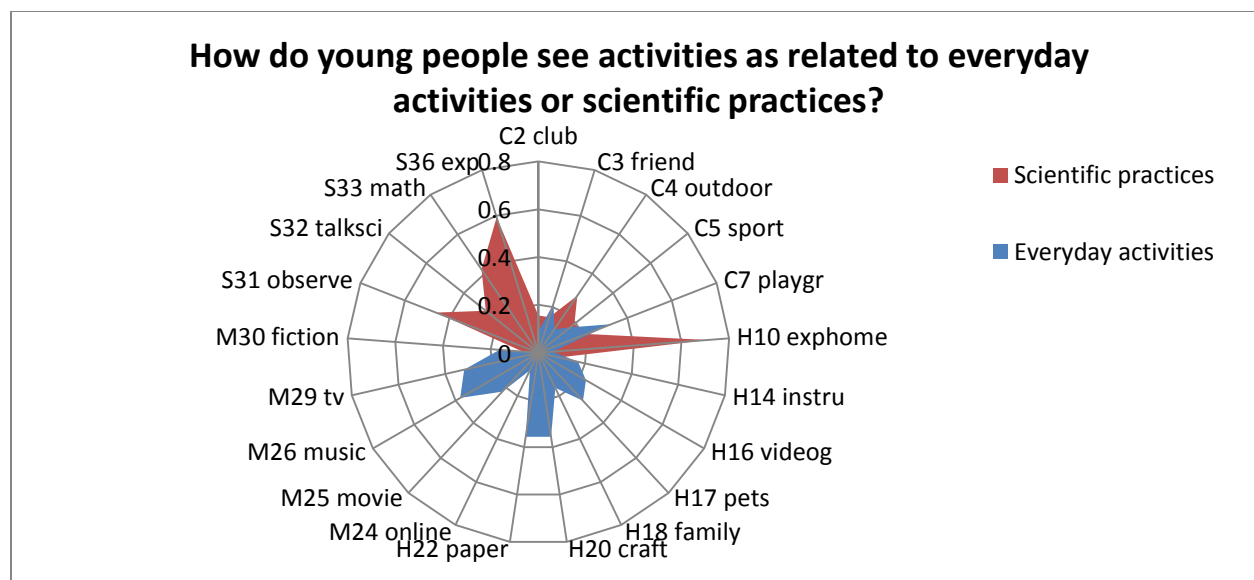


Figure 2.4. Activities that include scientific practices compared to those that are everyday activities. Results reported as percent of youth responses for each activity.

The data represented in Figure 4 show the prevalence of the two thematic codes across the activities embedded in the survey. Young people more often define science-relatedness as being about scientific practices in school and during home experimentation while they define other activities as being related to everyday forms of science. The lack of overlaps in the thematic definitions of youth This supports the need for more extensive work in classrooms and in other settings of young people’s lives to value what Warren et al. (2001) call the heterogeneous view of sense-making. In this view, young people’s everyday practices are valued and leveraged to engage them in making sense of scientific phenomena, broadening perceptions of what counts as, and who can participate in, science. A student community with a more heterogeneous, or expansive, view of science would define activities from across the social venues of their lives as being defined by scientific practices.

Scientific practices vs. Learn content. The *Framework for K-12 Science Education* (NRC, 2012) describes scientific practices as an intertwining of knowledge and skills, but youth in this study primarily described the two as separate. In this study, learning content is taken to be

the canonical view of science as obtaining or memorizing knowledge, while scientific practices are focused on the ‘doing’ of science.

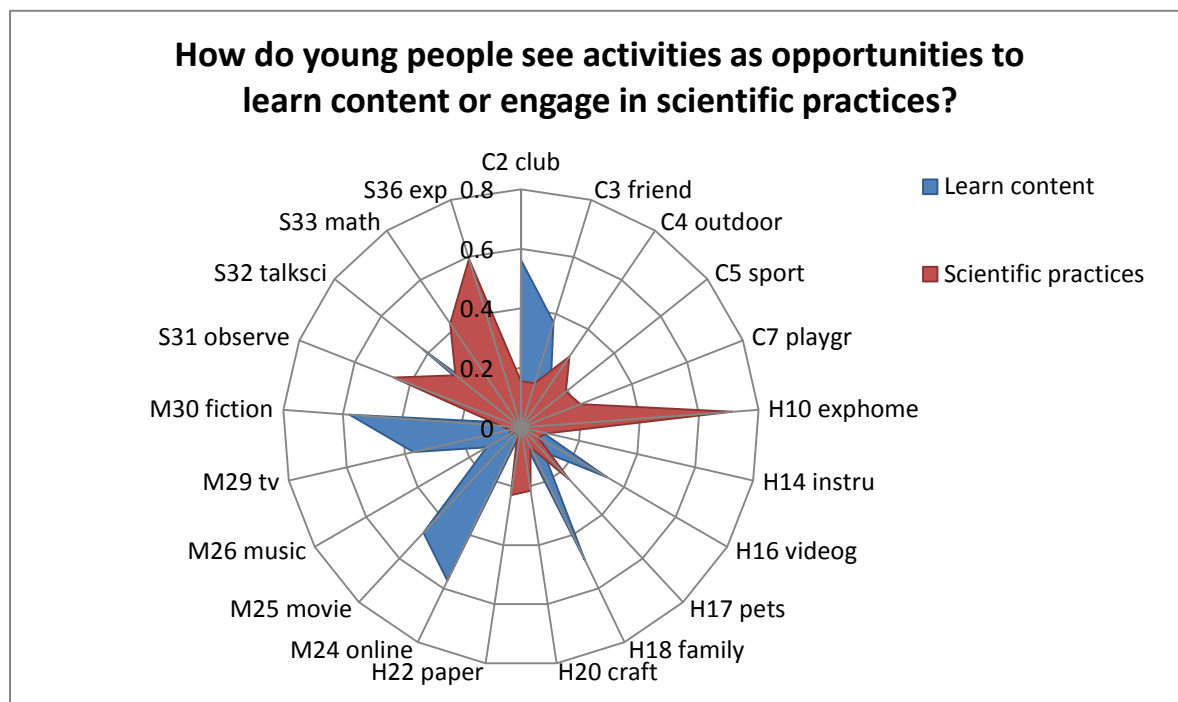


Figure 2.5. Activities that include scientific practices compared to those that include learning science content. Results reported as percent of youth responses for each activity.

In the SAS data, it is clear that young people see a separation between engaging in the practices of science and learning science content—at least in terms of their leading definitions used in a short-response format. According to youth, scientific practices are more prevalent in school activities than learning science content, which demonstrates that young people associate school activities as opportunities to engage in the doing of science as they leading way to define science and are less likely to say that school centers on learning science content. This is consistent with the finding in Zimmerman and Bell (2012), that young people only considered school-based activities to be science related “when the activities included inquiry practices” (p. 21). Since both schools make extensive use of commercially-available science kits for their curriculum, it makes sense that students associate the doing of science with school. More

textbook and memorization focused school environments might not lead students to define science from an engaging in practices frame.

The representation in Figure 5 also shows that young people see out-of-school activities as opportunities to learn about content but not to engage in scientific practices. In this way, the science they see in activities outside of school seems to be more about encountering or finding science-related information than acting as active producers of knowledge—although some of the instances for practices referenced could have been knowledge production efforts (e.g., producing a report, informing a decision). The authors of the *Framework* (2012) argue that direct experience with scientific practices is crucial to understanding scientific knowledge and how scientific work is done (p. 30). The findings here point to two educational implications or opportunities. The first opportunity is to make explicit to youth how engaging in the practices of science are a way to learn about and explain scientific phenomena. The second opportunity is to incorporate scientific practices into activities where young people say they encounter science already in afterschool programs, in family conversations, in videogames, and in media activities such as reading, watching movies, and going online. Building on the prior comparison as well, this highlights the need to help youth see the relevancy ‘scientific practices’ as they engage with science content in disparate settings and activities—and to recognize their sense-making practices in those moments as being related to science practices. According to the *Framework*, this would provide a more authentic venue for youth to engage in the doing and learning of science in ways move them toward more central participation in science (NRC, 2012), and thus science-linked identities (e.g. Bell et al., 2009; Lave & Wenger, 1991).

Science within broad social settings. In order to better understand how youth define science in relation to specific social settings, I closely examine how participants in the SAS

reported the prevalence, and the science-relatedness, of the activities in the four broad social settings presented earlier: community, home, media, and school. In each of the following four sections, I summarize young peoples' perceptions of the activities in one social setting. I examine the relationships between prevalence, science-relatedness, and definitions of science, and interpret these relationships in light of research on science learning. Table 7 reports the median and mean scores for the prevalence and science-relatedness of all activities, for comparison with the findings for each social setting.

	Prevalence	Science-relatedness
Median	1.31	0.84
Mean	1.27	1.03

Table 2.7. Median and mean scores for all activities.

To help to situate the findings from the SAS more deeply in the lives of youth who participated in the study, I present data from case studies of two individual youth: Eddie, a Mexican-American boy, and ReyMaya, an African-American girl. I chose these two students because while they were classmates and took part in most of the same activities, they had different experiences across their fifth grade year and different perspectives on science in their lives. I include select analytical details of Eddie and ReyMaya's perspectives on their survey responses and their fifth-grade year. I triangulated details from the analysis of their survey and interview responses with classroom interactions and observations to better understand how youth demonstrate their perceptions of science across their lives. Where appropriate, I also include details from other young people's survey responses in order to illustrate a particular finding.

Science within Community-based Activities. Young people variably engage in a multitude of community activities, including visiting museums and other informal learning institutions, playing on the playground, exploring the natural world, and participating in afterschool programs (Bell et al., 2009). This section examines how young people participate in and conceptualize science within the context of common community activities which were included in the survey.

Community-based Activities	Ranked prevalence among community activities (0-2)	Ranked science-relatedness among community activities (0-2)	Leading definitions of science
Talking with friends (C3)	1 (1.73)	4 (0.83)	Learn content Everyday activities
Playing soccer, basketball, football, other sports (C5)	2 (1.42)	3 (0.88)	Activity as science Scientific practices
Playing on the playground, like tetherball (C7)	3 (0.94)	5 (0.70)	Everyday activities Activity as science
Fishing, camping, snorkeling, hiking, boating (C4)	4 (0.82)	1 (1.18)	Scientific practices Activity as science
Going to an afterschool program or club (C2)	5 (0.81)	2 (0.89)	Learn content Scientific practices

Table 2.8. Community-based activities summary. Activities are ranked based on the average reported scores for prevalence of the activities in youths' lives and on the average scores of science-relatedness.

Conceptualizations of science in community-based activities. From young peoples' point of view, community-based activities can be places where science exists, but these activities are not in their everyday experiences. The three most prevalent community-based activities, shown in Table 8, are the three least related to science. The most science-related activities are the ones youth participate in the least.

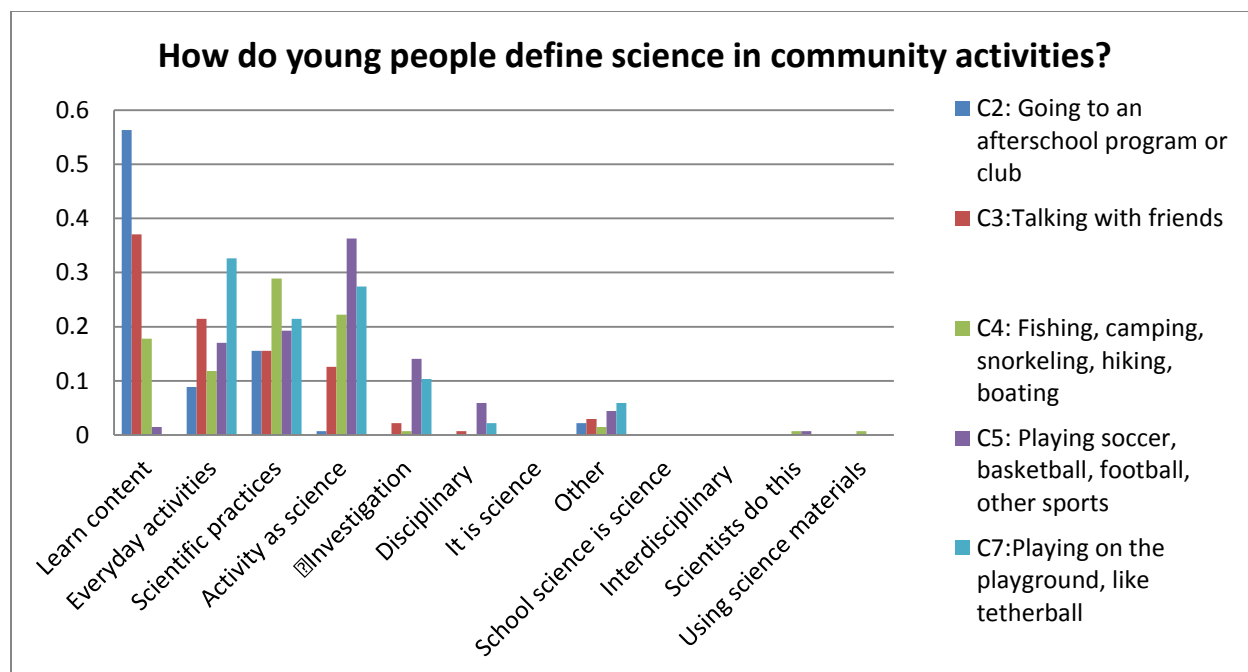


Figure 2.6. How young people see community-based activities as related to science. Results reported as percent of youth responses for each activity.

In community settings, as shown in Table 6, youth see community activities as evenly related to *Learn(ing) content*, *Everyday activities*, *Scientific practices*, and *Activity as science*. However, young people are slightly more likely to describe community activities as opportunities to *Learn content* (24%) or to do *Scientific practices* (22%). They engage in these forms of science primarily when they *Talk with their friends* (C3) (if their conversation is about science) or in *Afterschool programs* (C2), as shown in Figure 4. *Outdoor activities* (C4) and *Playing on the playground* (C7) are where youth primarily see opportunities for engaging in scientific practices.

Eddie's and ReyMaya's responses about their participation in these activities were typical of the study group in these ways, though ReyMaya reported an increase with respect to playing on the playground at the end of the year. In our research team's observations at both schools, most young people played on the playground with regularity, so the report of low participation in this activity may be due to young people who may have focused on the surface detail of the item

(i.e., the tetherball example). This is a common issue of surface level effects associated with the working of survey items.

The activities youth participate in the least, *Fishing, camping, snorkeling, hiking, boating* (C4) and *Going to an afterschool club* (C2). These signify activities that young people either have little interest in or access to in their everyday lives. These results are not surprising in that the outdoor activities included here require family interest and access to gear and materials needed to do those activities successfully and safely. Young people can only participate in these kinds of outdoor activities with access to specific resources and involvement from adults. This may be in contrast to activities like self-organized sports. In the same way, afterschool programs or clubs are more often attended by youth from families of higher income status because of the resources required to attend, which many of the young people at Granite and Holly Hills do not have. Additionally, it may be that young people at these schools have responsibilities at home that preclude their attendance at afterschool programs or clubs, including caring for family members or contributing to the family business. The ethnography conducted by the research team provides evidence that this may have been the case for youth growing up in this community (Bell et al., 2013).

Neither Eddie nor ReyMaya participated in either outdoor activities or afterschool programs during the year of this study. Eddie noted that he had previously participated in an afterschool program on robotics and was looking forward to participating in the no-cost afterschool programs offered at the middle-school he would move to next year. Most young people (56%), including Eddie and ReyMaya, characterized *Going to an afterschool program* (C2) as related to science if it is known to be a 'science club', where they might learn about science or do science activities (Figure 4). This reflects a very homogeneous view of science that

youth have of some community-based activities. For other activities their view of science is more heterogeneous. In other words, some activities are primarily seen by youth as related to science in only one way, while others can be related to science in a number of ways.

For example, youth commonly use one of three views of science to describe the science-relatedness of *Fishing, camping, snorkeling, hiking, boating* (C4), as shown in Figure 4. Young people see these outdoor activities as science-related because those activities represent an opportunity 1) to learn science content, 2) to use scientific practices, or 3) because the activities themselves include scientific phenomena. Young people commonly see these outdoor activities as opportunities to carry out an investigation, or they related the activities to nature, which many, including Eddie and ReyMaya, described as inherently science.

About 20% of young people's responses characterize community-based activities as *Everyday activities* (Table 6). This designation reflects that these are activities young people consider to be something they do with no explicit learning goals or pedagogical intent, but with a variety of other goals. Science-related definitions, including *Activity as science, Learning about content*, and *Scientific practices* accounted for 67% of the young people's responses about community-based activities. Regardless of how youth rated the prevalence of community-based activities, they described many as *potentially* science-related, if for example, one was talking to their friends about science or what they did in science class. This example helps to account for why *Talking with friends* (C2) was most often coded by youth as related to science because of the opportunity to *Learn content*. Another frequent occurrence was young people who pointed out that trying out new strategies when playing games is similar to practices they might use when doing science. Young people said these activities are not usually related to science, but they could be if participants did specific science-related practices, such as ask questions, try things

out, or learn about content. For example, ReyMaya talked about playing on the playground as related to science because “you can try it and part of science is to try new things.”

Finally, it is interesting to note that two community-based activities, Playing sports (C5) and Playing on the playground (C7), are recognized by about 10% of young people as opportunities to carry out both formal and informal investigations (Figure 4). For example, one young person said, “it can help us learn about how sports can affect the health of a human compared to someone who doesn’t do many sports.” This points to an opportunity to engage youth in authentic science investigations that are relevant to their everyday lives, through activities they are already doing.

Summary of young people’s perspectives on community-based activities. Previous research shows that youth learning happens in a variety of ways in the context of community-based practices (Bell et al., 2009). Youth spend time and learn with others in community environments that are educationally designed, such as museums and afterschool programs, and those that are self-directed, such as playing outside or on the playground.

To summarize community-based activities, young people generally see those that they participate in the most as the least science-related and those that are the most science-related are those they participate in the least. This is an issue of recognizing science within everyday activities (e.g., sports) in that some youth see the relevant connections, but the overriding image of science from school likely keeps them from making this association.

Youth participants in this study view community-based activities as related to science in two areas: 1) outdoor recreational activities that can involve science or 2) educational experiences designed to focus on science. From the perspective of young people, outdoor recreational activities can be related to science for a variety of reasons; however afterschool

programs are only related if the focus is explicitly on science. This could be because young people understand afterschool programs as being “designed” spaces with a specific intent depending on the program, whereas outdoor recreational activities are generally self-directed and flexible, leaving them open to exploration, investigation, and learning about the natural world.

Therefore, the finding here is that youth see some activities as very broadly connected to science whereas others only fit into young people’s view of science in a particular way. This finding has important implications for the ways that young people are engaged in science through activities. For example, it is possible that because the outdoor activities described here are so broadly connected to science in the view of young people, they have great potential to be a bridging point for engaging youth in science. This is supported by the research about out-of-school programs focused on investigating and learning about the natural world (Bell et al., 2009).

Further, this analysis shows the disconnect between the community activities youth engage in the most and those that they view as related to science: the two activities young people rated as most closely related to science are not in the top half of activities in which they frequently engage. Additionally, young people view certain community-based activities as science-related even if they themselves do not participate in those activities. As I further describe in subsequent sections, this is an important finding to note as it implies two possible explanations for how youth interact with science in community-based activities and more broadly across their lives. First, youth see science even in community-based activities that are not a part of their daily lives. Second, as I will show in most home- and media-based activities, youth do not identify science in many areas of their own lives. These two possible explanations have implications for both increasing science in the lives of youth and broadening youths’ views of science. Recognizing how youth define science in their everyday activities may highlight leverage points

where adults and youth can build on the potential for science in specific activities in specific ways. Alternatively, introducing youth to new activities they do not currently participate in but see as science-related might be another avenue of increasing where young people see science in their lives. In other words, even activities they do not participate in can potentially be leveraged to engage youth in science.

Science within Home-based Activities. Prior research, including Zimmerman and Bell (2012), has documented the ways in which youth often engage in important science-related activities such as building, mixing, and creating in home settings. For example, research on the everyday lives of youth has shown rich examples of the kinds of science-related activities youth take part in at home. Bricker and Bell (in review) describe the story of Sam, a fourth-grader, who spent the majority of his time out of school engaged in sustained building projects from kits, resourced primarily by his family. While Sam saw his building-related practices at home as being related to science, the data presented in this study shows that not all youth see the connection between their home-based activities and science. This section examines how young people participate in and conceptualize science within the context of home-based practices.

Home-based Activities	Ranked prevalence among community activities (0-2)	Ranked science-relatedness among community activities (0-2)	Leading definitions of science
H18: Talking with parents and family	1 (1.47)	3 (0.81)	Learn content Everyday activities
H16: Playing videogames	2 (1.40)	4 (0.73)	Learn content Everyday activities
H14: Playing a musical instrument or singing	3 (1.19)	5 (0.75)	Activity as science Everyday activities
H17: Taking care of pets (feeding, walking)	4 (1.09)	6 (0.68)	Everyday activities Scientific practices
H10: Doing experiments or playing around with things at home	5 (1.03)	1 (1.85)	Scientific practices Everyday activities/ Learn content (tied)
H20: Drawing, knitting, painting, crocheting	6 (0.90)	2 (0.93)	Everyday activities Scientific practices
H22: Making origami stars, airplanes, paper-folding	7 (0.70)	7 (0.49)	Everyday activities Scientific practices

Table 2.9. Home-based activities summary. Activities are ranked based on the average reported scores for prevalence of the activities in youths' lives and on the average scores of science-relatedness.

Conceptualizations of science in home-based activities. As with community-based activities, the two most prevalent home-based activities are among the least science-related of all of the activities in the survey (Table 9). *Talking with parents and family* (H18) was often described by young people as an opportunity to talk about science content: *Learn content* represented 50% of youth responses for this activity (Figure 5). This is primarily because young people recognized the potential for talking about science in conversations at home. However, it is also often described as an *Everyday activity* (16%) that does not include science. For example, one young person said it was not related to science: "...like most of the times when you talk to your family, it's to tell them about how you did in school or just like talk to them like about what you're gonna eat. You don't really ever talk about, like, well I don't. I don't really talk about science." Youth generally saw these conversations at home as just a part of their everyday activities unless explicitly about science classwork or content.

The remaining home-based activities, such as *Playing a musical instrument* (H14) or *Taking care of pets* (H17) signify hobbies that require specific interest or resources to participate in on a regular basis (Table 9). This finding is consistent with the lower-ranking community-based activities, where there may be similar barriers to youth participation and corresponding variability in participation and recognition as science.

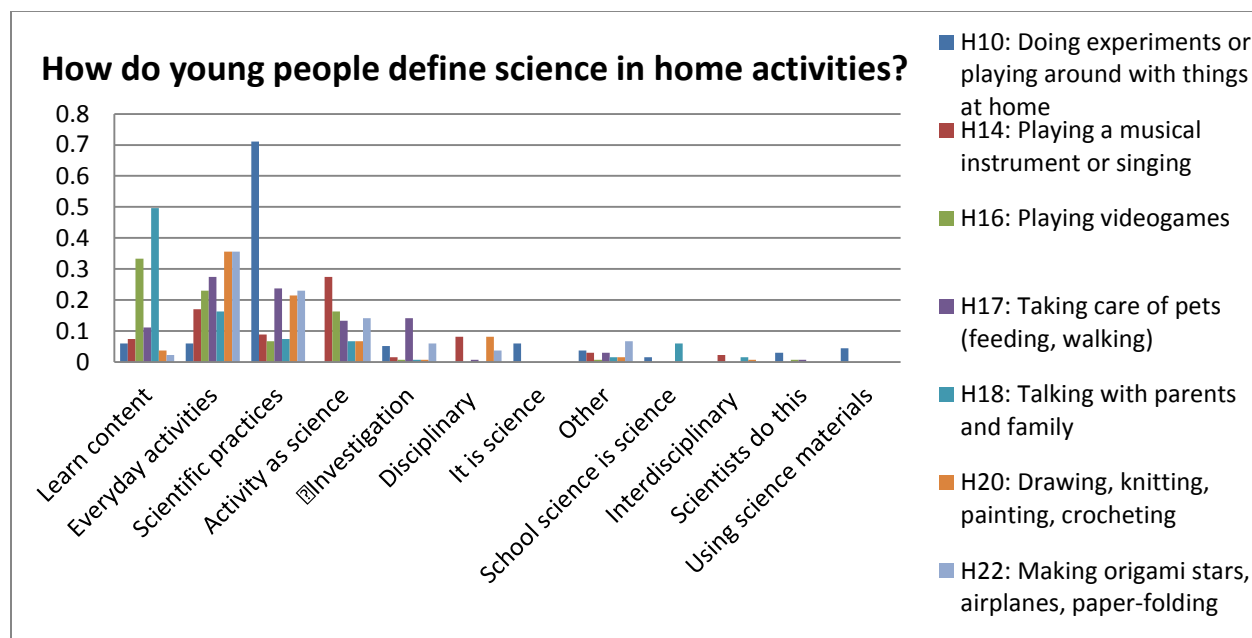


Figure 2.7. How young people see home-based activities as related to science. Results reported as percentages of youth responses for each activity.

As shown in Table 6, youth generally see the home-based activities they take part in the most as not very related to science. Broadly, young people consider most home-based activities to be *Everyday activities* (26%), not closely related to science. The most prevalent definition of science is opportunities to do *Scientific practices* (26%), primarily because of young people's engagement in *Doing experiments* (H10) at home. Some activities, such as *Talking with parents and family* (H18) are sometimes seen as opportunities to *Learn Content* (18%) if one is talking about science. Young people see *Doing experiments at home* (H10) as the most science-related home activity and the only activity outside of school that is one of the most science-related of the

overall activities in the survey (Table 4). From young people's perspectives, this activity usually entails mixing things together, asking questions, observing, and/or finding new things. Nearly three quarters of youth describe *Doing experiments at home* (H10) as science-related because it includes doing *Scientific practices*, as shown in Figure 5. For example, one young person said, "You are making something. You are making a hypothesis about how the experiment will react to whatever you are doing." This example highlights young people's definition of science as inquiry involving knowledge work—as opportunities to engage in scientific practices to seek answers to questions they have about the world.

At the end of the year ReyMaya talked about the experiments she often did at home and how she saw those as somewhat related to science. She described mixing foods and liquids together at home to see what would happen or how they would taste. She described these activities as obviously related to science "because you're doing science." ReyMaya saw these activities as informal experiments in which she used scientific practices tried things to out to learn something new.

It is possible that the phrase 'Doing experiments' signifies to youth that the activity is science related, as it did for ReyMaya, because experiments are in integral part of science in her view. For many youth, experiments are central to a definition of science itself. As shown in Figure 5, small percentages of youth described *Doing experiments at home* (H10) as either *It is science* (6%) (and thus needs no further explanation), as an opportunity to do *Investigations* (5%), or to *Use science materials* (4.4%). These numbers may seem insignificant, but it is worth noting that young people did not describe any community- or media-based activities in these ways. This implies that youth see more and broader opportunities at home to do science than in

other places outside of school. Youth see opportunities at home for doing investigations through experiments or even in activities such as taking care of pets.

The two home-based activities young people participate in most are *Talking with parents and family* (H18) and *Playing videogames* (H16), as shown in Table 9. In our classroom observations, youth made daily references to games such as Minecraft. Both ReyMaya and Eddie indicated that they participate in these activities a lot. Most often, young people describe videogames as an *Everyday activity* (33%), unrelated to science. However, youth who do see *Playing videogames* (H16) as connected to science primarily characterize the relationship in one of two ways. Some youth see it as science-related if one is playing a specific game that provides an opportunity to *Learn content* (23%), as ReyMaya said. Other youth see videogames as science-related because they involve or rely on scientific phenomena (e.g., in the physics of the construction work associated with Minecraft), and thus are inherently science-related (*Activity as science*: 17%). Several other home-based activities are also seen by youth as related to science in this way, such as *Playing a musical instrument or singing* (H14) (27%).

Finally, it is particularly interesting to note that several home-based activities are described by young people as including practices similar to those that take place in science. Though not all youth participate in these activities, many see arts, crafts, and music as opportunities to try things out, learn technique, or ask questions. For example, though *Making origami* (H22) was one of the least science-related activities in the survey (Table 4), several youth described it as including practices similar to those used in science, such as measuring angles, using geometry, following directions, or making models. In another example, ReyMaya noted that she regularly uses drawing to make conceptual models in science class. Overall, though youth typically do not see most activities in this category as closely related to science,

they clearly see 1) the potential for science as a fixture of home practices, and 2) the science-related similarities in home practices.

Summary of young people's perspectives on home-based activities. Prior research shows that family activities, such as dinner table conversations, are full of rich scientific topics and scientific forms of discourse (Bell et al., 2009; Bricker & Bell, 2014; Goodwin, 2000; Zimmerman & Bell, 2012). However, Callanan et al. (2012) point out that parents and families often have many competing goals for participating in any activity. Specific learning goals may be included, or activities may just be for fun, to spend time together, or to complete necessary tasks, like grocery shopping. For these reasons, and when compared with the formal discourses of science classrooms, informal activities at home may not be recognized as science-related. In light of this, the results presented here on home-based activities are not surprising. Participants in this study view home-based activities to be primarily everyday activities that do not include any learning or inquiry goal. These activities, such as talking with family or playing videogames, are usually only counted as science-related if they have a focus on science content in some way.

The home-based activities that youth do see as science-related are most related in terms of doing scientific practices (Table 9). *Doing experiments at home* (H10), and to a lesser extent, art activities like *drawing* (H20) and *origami* (H22), include practices that are the same or similar to those youth see in science. In terms of implications for broadening opportunities for youth to engage in and recognize science in their lives, these findings are important because they support previous work that has emphasized the importance of building on what youth are already doing, as youth recognize the potential for science in their current activities (Calabrese Barton et al., 2008; Zimmerman & Bell, 2012). There are many ways in which home-based activities could be bridged or drawn upon to do science. STEM activities that are designed to include art (STEAM)

for the purposes of doing science or engineering, or that include construction from novel materials, could have powerful effects on youths' recognition of science in their everyday lives (Kim & Park, 2012).

Science within Media-Based Activities. The ways in which youth engage in media-based practices is varied and well-documented. Ito et al. (2013) recently reported on their examination of how digital media can be used to foster learning that is personally meaningful, supported by important people in learners' lives, and connected to academic, career or civic participation. This section examines how young people participate in and conceptualize science within the context of common media-based activities.

Media-based Activities	Ranked prevalence among community activities (0-2)	Ranked science-relatedness among community activities (0-2)	Leading definitions of science
M24: Going online or using the internet	1 (1.70)	1 (1.15)	Learn content Activity as science
M26: Listening to music on the radio, computer, mp3s	2 (1.68)	5 (0.64)	Everyday activities Activity as science
M29: Watching cartoons or comedy on TV	3 (1.51)	4 (0.69)	Learn content Everyday activities
M30: Reading stories or comics (fiction)	4 (1.44)	2 (0.90)	Learn content Everyday activities
M25: Watching a movie at home or in a theater	5 (1.31)	3 (0.84)	Learn content Everyday activities

Table 2.10. Media-based activities summary. Activities are ranked based on the average reported scores for prevalence of the activities in youths' lives and on the average scores of science-relatedness.

Conceptualizations of science in media-based activities. Media-based activities are the most prevalent of any group of activities in youth's lives, according to the survey. However, these activities are generally seen by young people as the least related to science. Of media activities, youth engage most in *Going online* (M24), which they see as the most science-related, and *Listening to music* (M26), which they see as the least science-related, as shown in Table 10.

The most prevalent definitions of science describe media activities as opportunities to *Learn content* (49%) or as *Everyday activities* (27%) (Table 6). Young people engage in these forms of science primarily in when they go online or use the internet (if they are looking for things about science) or when watching movies (if they are about science), as shown in Figure 6.

Young people often describe the science-relatedness of media-based activities as dependent on how one uses the media or the intent behind their use. For example, young people primarily see their online activities as related to *Learn(ing) content*, as they use the internet to do research for school projects both at school and at home (Figure 6). Eddie counted this activity as science because “you’re searching for things like animals or dinosaurs.” This practice is something we observed in classrooms on a regular basis. One young person made clear the distinction between online use that is science-related and that which is not: “this could be about science that is if you were looking up a science topic. if [sic] you’re watching nyan cat on youtube, it’s not science at all...” For Eddie and others, the intent with which one consumes information through media informs its relationship to science.

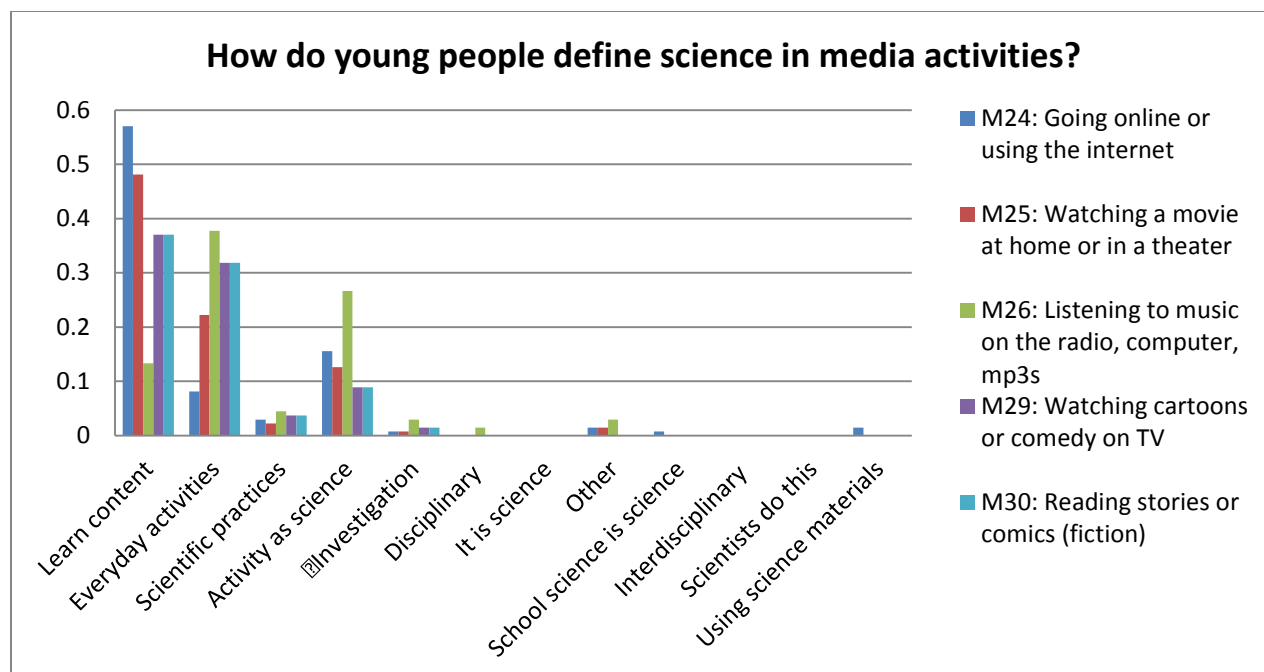


Figure 2.8. How young people see media-based activities as related to science. Results reported as percent of youth responses for each activity.

Most youth we interacted with in the two schools had at least some form of interest and access to media-based activities. Some young people, like ReyMaya, relied entirely on smartphones for internet access at home. *Going online* (M24) is the only activity in the survey which young people ranked as both the activity they participate in the most and the most science-related (Table 4). Young people often see online activity as science-related for the same reason they view videogames as science-related: because computers are technology, and thus involve or rely on scientific phenomena (*Activity as science*: 16%). As one young person said, “you need science to power your internet.”

Very few young people see media-based activities as opportunities to engage in *Scientific practices* (4.5%) (Figure 6). This is clearly an area where having a critical frame when interpreting and making decisions on science-related information would amount to a basic scientific literacy and would be important to promote. Most are characterized as an *Everyday activity*, unrelated to science.

Summary of young people's perspectives on media-based activities. The survey data reported here reflects the well-documented fact that youth have increasingly abundant access to various forms of digital and physical media. While there are concerns about the downsides of intense engagement in media, there are also increasing opportunities for youth to enter into extended learning pathways in areas that are of interest to them (Ito et al., 2013). For this reason it is important to identify how youth recognize media-based activities as opportunities for engagement in science learning and possible points of leverage for designing science learning environments.

Overall, young people participate in media-based activities more than other activities in their lives. It is important to note that with the exception of *Going online* (M24), young people view media-based activities as only somewhat related to science compared to other activities (Table 4). This points to another way in which there is a disconnect between the lives of young people and science. The activities they do the most are often the least science-related, in their view.

One possible conclusion from these findings is that young people tend to view media-based activities as opportunities for consuming information rather than producing it. It is also possible that the SAS did not provide youth with sufficient ways to describe media production activities. In other activity areas, young people described engaging in practices similar to or included in doing science, such as asking questions, trying things out, and creating things. Media-based activities seem to lack these kinds of practices for the youth who participated in this survey. However, we know that previous research has shown that young people who make the shift from consuming to producing media content show powerful forms of engagement, learning, and positioning. For example, Ito et al. (2013) tell the story of Tal, a sixth-grader who developed

an interest in writing about the game Minecraft. Buttressed by social supports and encouragement from teachers, peers, and family, Tal’s writing about gaming led to social recognition as an expert and extended engagement in creative writing. In order to increase these kinds of experiences for youth in relation to science learning, design considerations could include helping youth to see media-based activities as opportunities to authentically engage in scientific practices such as communicating their work to others.

Science within School-Based Activities. A rich body of research informs science curriculum and instruction in schools, including the recently released *Framework for K-12 Science Education* (NRC, 2012) and the accompanying *Next Generation Science Standards* (NGSS, 2013). These documents highlight the goals for science education in schools as two-fold: to engage all youth in science that is meaningful and relevant to their everyday lives and communities; and to inspire and prepare young people to pursue careers in STEM fields. This section examines how young people reported participating in and conceptualizing science within the context of common school-based activities.

School-based Activities	Ranked prevalence among community activities (0-2)	Ranked science-relatedness among community activities (0-2)	Leading definitions of science
S33: Doing math in school	1 (1.88)	4 (1.11)	Scientific practices Learn content
S31: Observing things in school science	2 (1.31)	1 (1.94)	Scientific practices It is science
S32: Talking about science in your school classroom	3 (1.22)	3 (1.91)	Learn content Scientific practices
S36: Conducting experiments in school	4 (1.03)	2 (1.93)	Scientific practices It is science

Table 2.11. School-based activities summary. Activities are ranked based on the average reported scores for prevalence of the activities in youths’ lives and on the average scores of science-relatedness.

Conceptualizations of science in school-based activities. School-based activities represent the most science-related activities in young people’s lives, in addition to *Doing*

experiments at home (H10). Additionally, young people report spending a lot of time doing science and math in school, more so than any sector other than media-based activities (Table 4). Their participation is in line with our observations at both schools, and is unsurprising because of our selection of science-focused classrooms for this study.

The two school-based activities young people see as most closely related to science are *Observing things in school science* (S31) and *Conducting experiments in school* (S36), as shown in Table 11. When asked about this, both Eddie and ReyMaya described conducting the water quality tests they did as part of an ongoing study of their local watershed as examples of using scientific practices.

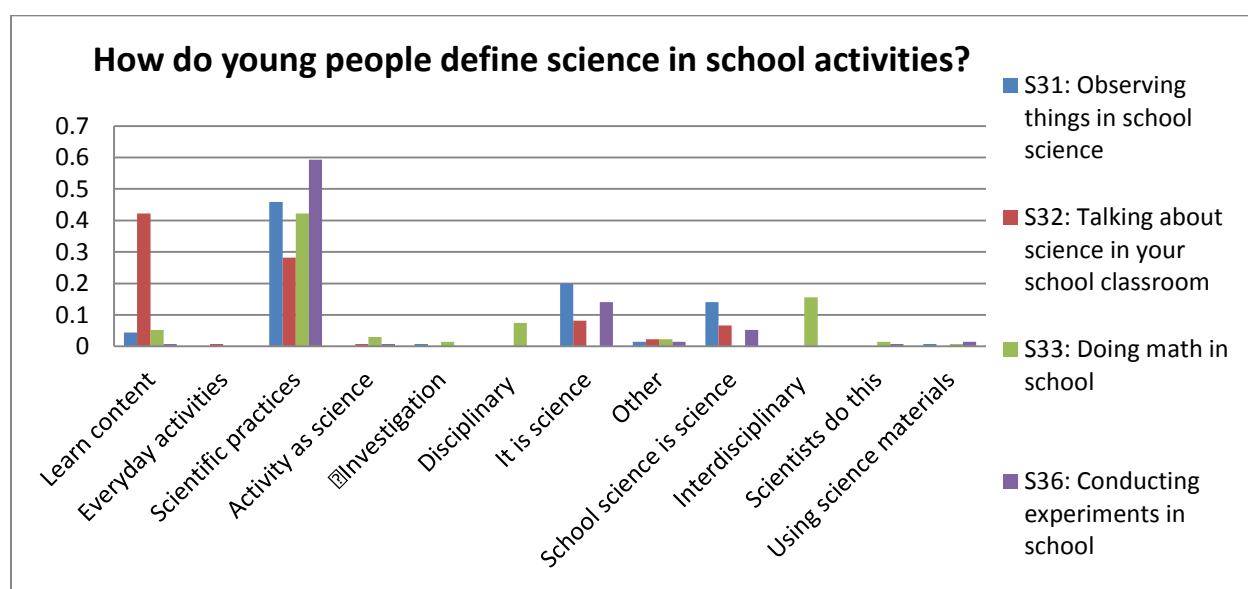


Figure 2.9. How young people see school-based activities as related to science. Results reported as percent of youth responses for each activity.

Unlike home-based activities, which showed a broad distribution of definitions of science, young people have a more specific view of science in school (Table 6). Primarily, youth recognize school-based activities as opportunities to engage in *Science Practices* (52%), more so than in any of the other areas of their everyday lives. Young people engage in scientific practices

in school primarily when they carry out experiments or make observations in class, but also sometimes when they do math or talk about science in school.

Young people characterized *Talking about science* (S32) as an opportunity for *Learn(ing) content* (42%)—which is an important realization from perspective that disciplinary learning is primarily accomplished through discourse and sense-making (Figure 7). They also recognized it as a necessary practice for engaging in science. For example, one youth said, “When you are talking about science in school you are making predictions, thinking what the steps are, and conclusions and using to interpret data you collected from an experiment.” In this way, youth described actually doing science in their classrooms. About a quarter of young people described talking about science as an integral practice to carrying out and making sense of investigations (*Scientific practices*: 28%).

While *Doing math in school* (S33) was the least science-related of the school-based activities, it is interesting to examine how young people connected it to science or not (Table 11). A large proportion of young people stated that there is a relationship between doing math and doing science because mathematical practices are similar to *Scientific practices* (41%). These young people often described the interdisciplinary nature of doing math and science, with many youth considering math to be an integral practice of doing science. For example, one young person put it this way: “you have to have math to do most complicated science and you are figuring out things.” However, youth also commonly described math and science as separate things. Doing math in school (S33) was one of the activities with the highest variability in youths’ conceptualization of science-relatedness ($SD = 0.73$) (Table 4). Further investigation of these responses would yield further understanding of how and when youth see math and science as inextricably linked or not.

The data for school-based activities add a unique piece to how we understand young people's perspectives on science in their lives (Figure 7). Young people's perspectives on science in school highlight what they see as an inherent relationship between doing science and being in school. Though these responses account for a small percentage of youths' responses to school-based activities (*School science is science*: 7.6%; *It is science*: 12.5%), it is important to note that some youth explain their views on school science activities by equating school science with the definition of science itself. As one young person described, "If it is school science then of course it is related to science because you're being taught science!" Another said, "It's science class so it is science." Typically, young people felt that the fact that these activities were so obviously a part of science meant that they did not warrant further explanation. The only other activity in the survey that was described in this way by any young people was Doing experiments at home (H10), as discussed earlier.

Summary of young people's perspectives on school-based activities. This study started just as the vision of the *Framework* and the NGSS were being introduced in classrooms. These documents represent a shift toward integration of scientific ideas and practices to support science learning. The classrooms in which this study took place were at the forefront of implementation and all of the teachers were particularly focused on engaging students in the practices of science as outlined by the *Framework* and the NGSS. For this reason, it makes sense that the young people in the study understand science in school to be about the 'doing' of science, not just learning about content. They see themselves as actively engaged in investigations, asking questions, collecting data, and working collaboratively to find answers. This is in line with what we observed in both schools and supports the same findings in the previous SAT study (Zimmerman & Bell, 2012). Additionally, the responses in this section demonstrate a view which

may widespread amongst young people: that science exists primarily in school-based activities. These results are unsurprising given pervasive perspectives on science as within the purview of professionals and educators. As demonstrated in Table 4 beginning of this chapter, classroom science activities, as well as *Doing experiments at home* (H10), are rated as far more highly related to science than any other activities in the survey. These findings point to an opportunity to broaden conceptualizations of science, not just for young people, but in the messages they receive from their teachers, families, community members, peers, and likely the media, about who can do science and where and when science is in their lives. One way to address this is to create more overlap between school and the other activities in youth's lives (Bell et al., 2013; Penuel, 2014). By leveraging out-of-school activities, practices, and discourses youth engage in by themselves or with others, we might broaden their view of when science is (McDermott & Webber, 1998).

Discussion

The goal of this study was two-fold. The first goal was to further develop a protocol that could be used at a larger scale to understand the prevalence of science-related activities in two communities where youth had rich opportunities to engage in science in their classrooms. The second was to better understand how to leverage the conceptions and experiences of young people in science across their lives. By examining fifth- and sixth-graders' definitions of science, this study built on Zimmerman and Bell (2012) to understand young peoples' stances on science and the ways they positioning themselves relative to science and science learning more generally. These definitions of—and social positionings in relation to—science can be considered assets, or resources, that mediate learning across settings (Rogoff, 1997; Zimmerman & Bell, 2012). Situating this work in cross setting learning research, such as the Cultural

Learning Pathways Framework (Bell et al., 2012) points to specific design implications for learning within and across environments that support extended learning pathways in science for young people based on the disciplinary ‘kinds of people’ and socio-material practices present across specific settings and pursuits. The findings here help identify the activities that can further develop growing competencies or provide new learning opportunities in science, informing how youth can be supported to build practice-linked identities.

Young People’s Views of Science across Settings

As in Zimmerman and Bell (2012), young people in this study strongly associated specific ways of engaging with science with certain activities and practices. These distinctions were strongest when comparing how youth defined everyday activities and scientific practices. Media and most home activities were seen primarily as everyday activities that had no pedagogical intent and little relation to science. For most young people, school constituted the overriding image of science, especially in terms of when and where scientific practices happen.

In the SAS, young people often described the ways in which activities had the potential to be science-related, even if they did not report participating in those activities. Activities that included practices that youth saw as similar to those in science, such as “trying things out” in sports or crafts, were the primary activities youth saw as science-related. For example, many young people described science-related practices like trying different techniques to see how many times the tetherball can go around on the playground. This emphasizes the importance of building on what youth are already doing where they see the potential for science.

Additionally, young people saw some activities as being focused on learning scientific content specifically and others as opportunities to engage in scientific practices, including designing investigations. Opportunities to learn about content were generally related to activities

where youth see themselves consuming information and limited to a few activities including afterschool programs, reading, watching movies, going online, talking with family or in science class, and perhaps most surprisingly playing videogames.

The young people in this study saw science less broadly across settings and activities than the participants in Zimmerman and Bell's (2012) study, in that there were no activities youth participated in often that they also regarded as related to science. They also saw themselves as participating in science-related activities less frequently overall than the youth in the previous study. Other than doing math, young people in this study did not rate school activities as those they participate in the most. This is surprising given that the two sets of classrooms that participated in this study had a particularly strong focus on science. I think this might be an artifact of the survey method used for this study. Students took the survey in the context of school while in Zimmerman and Bell (2012) the interview was conducted in the home. Perhaps the students took the opportunity of being asked about school/non-school settings as an opportunity to think more about the other in each of these cases.

Young People's Views of Science within Social Settings

The social settings across youths' lives vary greatly in terms of how youth see each as related to science, as shown in Table 6. While youth do not necessarily regard a social setting, such as home, to be a place where science happens, they do often see individual activities in which they see themselves engaging in scientific practices, using scientific tools, or learning content. In this section, I explore the importance of the similarities and differences across venues.

School. The findings in this study demonstrate that youth consider school science to be the primary place where science takes place because of the particular discourses, practices, and

the sociomaterial arrangements of the science classroom, such as specialized talk, tools and specifically sanctioned behaviors. This portrayal of science is problematic, particularly for marginalized youth. Previous work points out that the culture of the science classroom is distinct from other venues of youth activity and can be inaccessible because of the conflicts that can arise between youths' everyday practices and those of a formal setting (Aikenhead, 1996; Moje, Collazo, Carillo, & Marx, 2004; Phelan, Davidson, & Cao, 1991). The findings of this study show that youth take up a narrative of scientific practices as related to school and not to most everyday activities in their lives. The challenge then is not just that youth may struggle to move to full participation in school science, but this storyline about who, when, and where science is narrows their view of ways in which they can participate and therefore their scopes of possibility in relation to science. This is problematic because the message youth are taking up is that science is restricted to a specific time and place which they may not be able to fully access, thereby restricting their participation in science not just in the classroom, but narrowing their view of it across their lives. This limitation has the potential to affect their ability to navigate science learning and interests across broader personal, academic, political, and economic contexts. While we must leverage youths' everyday definitions of and practices in science (Bell et al., 2013; Zimmerman & Bell, 2012), we must also decode these environments and make the sanctioned practices and discourses explicit in order to give young people the tools they need to navigate the field in ways that are meaningful to them (Delpit, 1988). Science learning needs to be expanded off of those moments situated within moments of schooling. Opportunities to increasingly recognize when science is in young peoples' lives will help to broaden and to deepen the sociocultural resources they can leverage across settings.

Community. Community-based activities were not a common setting for youth to recognize science in this study. The primary finding about community-based activities was that “designed” spaces, like afterschool programs, warranted a more narrow definition of science, whereas activities that were considered open-ended, like outdoor activities are more broadly perceived by youth to be related to science. As discussed briefly earlier, this has important implications for the design of community-based programs or learning settings that can provide opportunities for youth to engage in personally- and community-relevant science. Afterschool programs, religious youth programs, museums and other informal spaces in the community have the potential for youth to come into contact with science and with others in their community (NRC, 2009). Prior research has shown, however, that youth do not always associate science learning with such settings and practices even when they are present—in contrast to art practices and learning, for example (Martell, 2005). Community-based programs or settings that are youth-driven or at least informed by the choices and commitments youth make in their lives can provide opportunities for young people to be positioned as scientific leaders or experts. There are a number of examples of these kinds of programs that have demonstrated positive outcomes for youth as they take on new roles, appropriate new identities and develop extended learning pathways in science (e.g. Calabrese Barton & Tan, 2009; Gutiérrez & Vossoughi, 2010).

Home. Given the similar findings in Zimmerman and Bell (2012), it is not surprising that in the SAS study young people did not recognize most home activities as science-related. Activities like family conversations (as well as activities in other settings) have many competing goals and the rich discourses of everyday life are not always recognized as scientific. Across the two studies, young people said they do not talk with their families about science much. However, previous research (Warren et al., 2001) has shown that young people’s everyday discourses and

other practices include productive sense-making repertoires that are similar to those used in scientific activities and could be leveraged in science class. Young people's conversations at home with their families are shaped by a different set of discourses, practices, and sociomaterial arrangements than those in the science classroom. In this way, young people may see these conversations in contrast to what they experience in school. Callanan et al. (2013) say that "everyday experiences with science are embedded in a messy world, and usually not the central focus of activity, as they might be in classrooms" (p. 45) and thus not recognized by young people specifically as science. This lack of recognition points to opportunities for both educators and parents to act as brokers for young people's involvement in science, by leveraging the practices of one setting in another. For example, youths' everyday talk and practices can be acknowledged and utilized in the classroom. However, parents and families can also act as important brokers in young people's lives, supporting and broadening their interests outside of school in ways that help youth recognize and navigate opportunities for doing science (Barron, Martin, Takeuchi, & Fithian, 2009; Penuel, Lee, & Bevan, 2014).

Media. Media activities were reported as the most common activities youth participated in and the least related to science in their view. Across the two studies, young people most often see media activities as opportunities to consume information or as a research tool. Previous research has demonstrated the powerful nature of supporting youth to become contributors to authentic endeavors, especially in relation to the production of media (Ito et al., 2013; Penuel, Lee, & Bevan, 2014). Penuel, Lee, and Bevan (2014) argue that by positioning youth as capable of not just consuming but producing knowledge, opportunities are created for youth to participate in the cultural practices and to be recognized for practice-linked identities that lead to possible futures (Holland, Lachiotte, Skinner, & Cain, 1998). This study demonstrates how much time

youth already spend engaged in media activities and supports the argument for creating media-related opportunities for youth to take part in authentic and personally-meaningful work where they can engage with science concepts and in key scientific practices.

Conclusion

To meet their present and future goals, learners negotiate their participation in various contexts, or communities of practice, every day as they move throughout homes, schools, neighborhoods, and communities (Banks et al., 2007). A better understanding of the social and cultural contexts where young people do or do not see science can shed light on how best to support youth to build extended learning pathways in science and take on associated practice-linked identities. This study demonstrates that while young people see science as primarily related to the science classroom, they often see the potential for science in other activities- if those activities provide opportunities to carry out scientific practices, such as asking questions and planning investigations.

This study aimed to develop a survey research protocol for examining young people's conceptualizations of science in a way that was less time and intensive in terms of personnel than ethnographic interviewing. The implementation of the online survey, as well as the follow-up interviews with a small subset of young people, accomplished much of this goal while pointing to several opportunities for future work. This study presents a new representation for visualizing the overall data (Figure 2) that makes clear the relationships between the activities youth participate in and those they see as science-related. Additionally, the science definitions typology allows for a mapping of youth's view of science in and across venues and practices.

Finally, this study provides clarity on a new method for investigation of science in the lives of youth. In terms of future work, to better account for science-linked identities in stories

about everyday and family practices, the follow-up interviews could include adapted versions of a self-documentation task (Tzou & Bell, 2010), the Math-in-a-Minute protocol (Esmonde et al., 2012) or Barron et al.,'s (2012) techno-biography interview. Adaptations of protocols like these have the potential to produce richer, more nuanced accounts of science across the lives of youth. Additionally, the analysis presented here leaves out detailed individual case studies, which may allow for a deeper focus on the “ways people interact with material resources and other participants as they combine to assign individuals to available identities” as learners engage in a process of approaching more central participation in or across particular communities (Bell et al., 2009, p. 75). The survey approach did allow for a characterization of the life activities and science-related definitions for a broader range of youth in ways that allow for quantitative analysis. The resulting findings here can be used to design future studies that further examine the ways in which youth engage with media and the opportunities that can be leveraged for positioning them as contributors to authentic endeavors in ways that engender recognition of science-linked identities. The survey could also be used to explore qualities of youth activities across different grade bands and communities—and longitudinally over time. It is worth noting that the list of activities included in the SAS should not be understood as a stable set of activities relevant to the lives of all youth. One focus of future iterations could be to ask youth to identify an activity they participate in a lot or consider closely related to science that was not included on the survey, in order to continually refine understandings of the activities that youth engage in across their lives.

In summary, youth participate in disparate practices and hold somewhat variable ways of relating science to those pursuits. The SAS can be used to examine young people's conceptualizations of science at the individual and community level and inform the development

of new opportunities for science-related learning pathways in ways that support more expansive and productive views of how science relates to the sense-making practices and topics associated with the specific, variegated situations and interests of different cultural communities. This should help youth and adults in their lives support more meaningful science learning for them across venues and pursuits in relation to developing life goals and interests.

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Chapter 3: Designing for Environmental Science Learning across Settings

In a democratic nation facing global issues of climate change, energy use, health care, environmental sustainability, and other complicated issues and debates rooted in science, we rely on an informed citizenry to make countless personal and family decisions in their everyday lives. As a society, we recognize both the importance of science, technology, engineering, and mathematics (STEM) literacy (NRC, 2012) and that K-12 science education is essential for all learners regardless of their position in the modern workforce. However, profound issues of equity and access to science education for all learners still exist, shown most clearly in the well-documented achievement gaps for learners from non-dominant communities including African-American, Hispanic/Latino, and female students (NRC, 2012), as well as the lack of adequate representation in science-related higher education and careers (BEST, 2004; NRC, 2011). Engagement of all learners in meaningful, sustained science learning—particularly environmental science learning—is an equity matter: youth from non-dominant communities must be engaged in assessing and acting on environmental issues because they are most likely to be affected by those issues (Tzou, Scalone, & Bell, 2010). Prior research has shown that educators must leverage the cultural values, resources, and expectations of youths' everyday lives in order to engage all youth successfully in science education and promote a wide range of future possibilities (e.g. Bell, Bricker, Tzou, & Baines, 2012; Calabrese Barton, Tan, & Rivet, 2008). By doing so, educators and youth can create opportunities for the development of new possible selves and positions in relation to science, leading to science-linked identities, deeper engagement in science-related trajectories, and increased representation of non-dominant communities in science-related careers.

Formal venues of science education, such as schools, are often recognized as challenging contexts for learners—especially those from non-dominant communities—because the specific practices, discourses, texts, and values of academic science and formal learning environments often require or encourage youth to set aside their everyday ways of being. More specifically, youth must learn to dismiss “what and how they have come to know in the world, or to reframe what and how they know in terms of problems to be solved” (Moje, Collazo, Carillo, & Marx, 2004, p. 46). Science learning settings are typically socially and materially constructed in ways that privilege specific power and knowledge structures—often those associated with white, middle class discourses and values. Deep engagement with these issues requires navigational knowledge of the assumptions and values in play that may not be apparent to all learners, or that are not always compatible with the everyday lives of youth, especially those from non-dominant communities (Calabrese Barton et al., 2008). These environments force learners to create new ways of engaging in learning that align with the dominant culture (Calabrese Barton et al., 2008; Delpit, 1988; Lee, 2007). Marginalized learners are more likely to find a move to full engagement in a science learning setting difficult or inaccessible as they struggle to negotiate the valued practices and identities in play (Aikenhead, 1996; Moje et al., 2004; Phelan, Davidson, & Cao, 1991). While these tensions exist in all disciplines of science, environmental science—as a politically-contested discipline—is a specific field where tensions particularly arise between learners’ everyday repertoires of practice and the expectations of formal academic setting in ways that can either afford or constrain learning. Therefore, environmental science education (ESE) is an important context for understanding how youths’ everyday and formal science practices might merge and become coordinated, resulting in personally-relevant engagement in the practice and learning of science.

Environmental science is a discipline that has the potential to connect to the everyday practices and realities of youths' lives (Calabrese Barton et al., 2008; Tzou et al., 2010). It is also particularly applicable to the lives of youth from non-dominant ethnic, cultural, or socioeconomic groups (Calabrese Barton et al., 2008; Tzou et al., 2010) because young people who live in marginalized areas are more likely to experience environmental degradation and the related health issues, such as increased asthma rates from industrial pollution (National Resources Defense Council, 2006). Access to meaningful engagement in science practices in the range of places where marginalized groups are affected by environmental concerns is a social justice issue. It is necessary to prepare a modern citizenry for tackling these environmental issues that disproportionately affect poor people and people of color. Specifically, science education should seek to “help youth see the places in which they live, learn, play, and work as places in which they can enact positive social change” (Tzou et al., 2010, p 105).

Environmental science recognizes culturally specific practices and identities that are often misaligned with the everyday lives of youth from non-dominant communities (Tzou et al., 2010). For example, conversations about environmentally-friendly transportation choices may not be productive or even accessible for some youth because of institutional constraints such as the unavailability of neighborhood bus service. This is just one example of the multitude of barriers these communities face in environmental science education that educators and researchers must work to break down. Meaningful engagement in environmental science requires relating learning experiences to the everyday issues and concerns of youth and their communities in order to solve problems and further interests. This might include investigating the economic, political, and environmental contexts that dictate decisions about neighborhood bus service, interviewing residents about the implications, researching opportunities to influence decision

processes, and then authoring texts centered on youths' findings and opinions to be presented to authentic audiences.

Though environmental science education is often located in the science classroom, the discipline of environmental science commonly takes place in settings outside of the classroom, such as waste disposal sites, public community meetings, rural or urban rivers, and in the places where youth live and visit. A broad diversity of social and physical settings have the potential to be hybrid spaces where learners' everyday repertoires of practice and identities can be merged with those of a learning setting to encompass a wide range of practices and practice-linked identities, promoting interest and engagement for all learners (e.g. Bell et al., 2013; Gutiérrez, 2008).

This chapter focuses on a year-long research practice partnership in which university researchers and informal and formal practitioners engaged in co-design and implementation of an environmental science unit. The focal problem of practice for the co-design project was to address equity in environmental science learning. We designed a coordinated set of lessons to connect environmental science learning across the school year by leveraging classroom activities and out-of-school field trips. The specific goals were to support student engagement in authentic scientific practices and personally- and community-relevant science concepts, and to support opportunities for student authorship and the development of science-linked identities. To better understand how to engage in co-design for these goals, this study was guided by the following research questions:

1. How do non-dominant elementary youth engage in science practices and identity work in and across a range of settings?
2. What instructional design features contribute to environmental science learning across settings?

In this study, Ms. Jones, a fifth-grade teacher, was particularly interested in and enthusiastic about engaging her students in a multi-month investigation of a local Superfund site: an industrialized river near their school. Superfund sites are those designated by the Environmental Protection Agency (EPA) as hazardous waste sites requiring cleanup to protect human and environmental health (EPA, 2014). Briefly, the Superfund river at the center of this chapter is an industrialized, urban estuary, known by government and corporate agencies as a waterway (EPA, 2015). It was and continues to be an important home area and fishing ground for several Native American tribes, one of which is still fighting for federal tribal recognition, as well as recent immigrants from countries such as Vietnam and Laos. In the early 20th century, the river was straightened, dredged, and concretized to make it navigable for ships and hospitable to building. The area surrounding the river became the industrial core of the city, leading to high contamination levels in the river sediment, water, and marine life, and the subsequent Superfund designation (EPA, 2015). Over the last ten years, several agencies have been involved in developing and executing a clean-up plan (EPA, 2015). The plan has been controversial in several ways, including how much money to spend, how long it should take, how the contaminants should be removed, treated, and disposed of, and what constitutes a clean environment (Smith, 2011).

To engage students in these issues, Ms. Jones planned for students to carry out several related scientific investigations, engage with various stakeholders in the issues, and draw on local watershed learning experiences that would situate the social and scientific issues of the Superfund site. While the topic was teacher-driven, Ms. Jones engaged in a number of strategies to promote student agency within the issues under consideration. For example, Ms. Jones began the unit by having students do background research and generate their own questions of interest

that would be used to drive the unit. The primary strategy for connecting learning across settings in this study was the use of a mobile application designed to support cross-context inquiry by engaging students in scientific practices such as collecting and analyzing data and writing explanations.

The focus of this study, environmental science education across settings, requires examination of boundaries in science learning. It is therefore appropriate to adopt an approach based in theories of hybrid learning spaces. In this context, hybrid learning spaces are those that acknowledge the learning resources students draw from both inside and outside of formal learning environments to disrupt and expand boundaries of science. This focus of this study therefore centers on how “everyday resources are integrated with disciplinary learning to construct new texts and new literacy practices that merge the different aspects of knowledge and ways of knowing offered in a variety of spaces” (Moje et al., 2004, p. 44) in order to better understand how to expand the boundaries of science learning to include all learners.

Why Design for Environmental Science Learning across Settings?

Studies that focus on learners both in and across contexts allow a unique perspective on the situatedness of learning, as well as on how learning gets translated across settings (Dreier, 2009; Gutiérrez, 2008; Rogoff, 1997). Dreier (2009) contends that participation in one setting must be linked to participation in another setting in order to demonstrate development. In this way, studies of this kind allow examination of the broad networks that afford and constrain participation in activities of interest to learners. Furthermore, Bell et al. (2012) argue that to understand and promote interest and expertise development requires looking at the pathways of youth across settings and time as they negotiate varying cultural practices, purposes, and value systems. This attention to life-wide learning leads to disruption of the boundaries between spaces such as home and school (e.g. Banks et al., 2007; Leander & McKim, 2003).

Further studies of learning across settings will contribute to our understanding of the extended learning pathways that lead to the development of science-linked identities, further exploration, and potential career opportunities by creating ‘interventions across settings,’ a growing trend in this work that seeks to create opportunities for youth to engage in disciplinary practices in relation to their own interests and everyday practices (Penuel, Lee, & Bevan, 2014). Bell et al. (2013) argue that attending to extended learning pathways and designing for STEM learning across settings is particularly important both to account for the varied learning pathways that can broaden our understandings of how all people learn science and to expand participation in STEM practices.

There are several reasons to study the design of environmental science learning across settings as a way to understand how to broaden participation in science through the development of engagement and identity. I extend two conclusions from Tzou et al. (2010) to build the argument for using hybrid learning spaces to organize and study environmental science education. First, the authors argue that ESE needs to create pathways that connect youths’ lives to the places where environmental education happens (see also Bell, Bricker, Lee, Reeve, & Zimmerman, 2006). One way to do this is to examine the sociocultural practices that make up youths’ everyday lives that inform and mediate the way they develop environmental science-linked identities, as well as the privileged practices that define engagement in formal learning settings. Once youth practices have been identified, they must be leveraged as valid and necessary points of entry into environmental science. This includes experimenting with practices that can merge youths’ everyday lives with the valued practices in a given learning setting (Moje et al., 2004), while also reevaluating the explicit and tacit goals in those settings.

Second, an effort needs to be made to facilitate the questioning of environmental narratives and people's position in relation to the environment in order to provide opportunities for youth to reposition themselves and gain access to addressing environmental issues (Tzou et al., 2010). The authors recommend starting with relevant youth narratives to design instruction that will reposition youth in relation to practices that will make full participation in environmental science possible, including empowering youth to take action to meet their goals.

To this end, Penuel, Lee, and Bevan (2014) put forth two premises that support designing for equity in STEM learning across settings:

1. STEM learning is life-long, life-wide, and life-deep.
2. Promoting equity and diversity in STEM learning requires:
 - a. Expanding access to new opportunities for learning;
 - b. Providing opportunities for continuing and deepening learning; and
 - c. Designing learning opportunities that deeply connect with and reflect (and therefore invite) the lived experiences of children and young people. (p. 2)

Guided by these premises, this study aims to expand access to new science learning across a coordinated set of activities that allow for continued and deepening learning. By centering on a local, community-relevant environmental issue, this study engaged fifth-grade students in scientific practices and identity work in order make explicit a multitude of ways to see and do science in their community. In this chapter, I begin by arguing for how the design of environmental science learning across settings can: 1) promote engagement with scientific concepts and practices, and 2) provide resources for development of science-linked identities. I then describe the strategies used to address these goals, the key outcomes from a subset of events, and the lessons learned from this project.

Design across settings to promote environmental science learning

The *Next Generation Science Standards* (NGSS, 2013) mark a shift in science education from the coverage of multiple, disconnected topics to a focus on the intertwined nature of

disciplinary core ideas, cross-cutting concepts, and practices of authentic, disciplinary science and engineering. The NGSS offer a focused set of core ideas that enable learners to access science “as science learners, users of scientific knowledge, and perhaps also as producers of such knowledge” (NGSS, 2013, p. 31). Cross-cutting concepts are those that span multiple scientific domains, such as patterns or cause and effect. Engagement in authentic practices is defined by the coordination of the knowledge and skills learners use to engage in the actual doing of science, through engagement with tools, discourses, and opportunities for sense-making.

Practices. Authentic scientific practices are those that resemble the activities of professional scientists engaged in research, and include activities such as designing and carrying out investigations, using models, and constructing explanations and arguments (Dunbar, 1995; Latour & Woolgar, 1986). Classroom science tasks necessarily cannot recreate the complex activity of authentic research in its entirety, but most do not provide sufficient opportunities for practices like scientific reasoning (Chinn & Malhotra, 2000). How access to disciplinary practices is shaped has implications for young peoples’ understandings of scientific concepts, practices, and the nature of the scientific enterprise in general. In the National Research Council consensus volume *Learning Science in Informal Environments* (2009), the authors summarize research that demonstrates the difficulty many children and adults have in understanding the nature of contemporary science as: socially-constructed, revised in the face of new evidence and thus an ongoing process rather than an established set of facts, inclusive of a variety of methods, and made up of different types of scientific knowledge of varying certainty (p. 109). As discussed in Chapter 2, there is also evidence that young people’s prevailing images of science are limited to what they do in school science. It is difficult for young people to see science in many of the other activities and settings in which they take part.

Designing for environmental science learning across settings can expand access to disciplinary practices in two ways. First, previous work in science education has shown that informal environments have unique potential to provide access to science in ways that differ from school, resulting in connection to youth's everyday interests, alignment with their everyday lives, and access to authentic practices that would otherwise be unavailable to youth (Bell, Lewenstein, Shouse, & Feder, 2009; Luehmann, 2007). Second, designing for learning across settings means that all spaces have the potential to be hybrid spaces of connected and divergent learning, meaning that practices and identities from one setting can be recognized by educators and learners and leveraged as a resource in other settings to support learning (Gutiérrez, 2008; Moje et al., 2008; Penuel, Lee, & Bevan, 2014). This study seeks to both expand potential sites of environmental science learning and recognize these sites as important contexts for understanding how youths' everyday and formal science practices might be bridged and coordinated with formal learning environments, resulting in personally-relevant engagement in the learning of science both in and out of school.

Place-based education emphasizes the importance of rooting education in place in order to connect what happens in schools to the local community (Smith & Sobel, 2010). Ideally, engaging youth in authentic practices outside of the classroom and out in their communities creates "opportunities that allow children to become change agents in their own communities is likely to inspire a taste for such involvement and encourage the formation of the social capital and sense of common identity so essential to the maintenance of a democratic society" (Smith & Sobel, 2010, p. 37). Though understudied, place-based education has the potential to position youth as members of their local social and natural communities and provide opportunities to

apply what they have learned to contribute to solutions for real-world problems (e.g. Ginorio, Huston, Frevert, & Bierman, 2002).

Opportunities to learn in places outside of school have the potential to provide student access not only to a variety of authentic field science practices such as collecting water quality data from a stream behind their school, but also access to community members and professionals who are involved with environmental issues. For example, in the study presented here, youth interacted with several stakeholders with differing views on the clean-up of a polluted site, ranging from a community-based activist organization, the government regulatory agency, and one of the corporations responsible for the pollution. These interactions have the potential to broaden and deepen the narratives of what it means to do science in a wide range of contexts and how it might connect with young people's interests. Furthermore, these interactions have the potential to make explicit the intersections and tensions of complex scientific and social issues, as well as the work scientists, engineers, and community members do to collaboratively answer questions, design solutions, and meet a variety of social and environmental needs. In this way, engaging learners in environmental science in the places where it takes place is one way to make issues of social justice explicit, some of which may directly impact learners' home communities.

Identity. Previous sociocultural research has established identity as an integral aspect of learning. Wenger (1998) says that "because learning transforms who we are and what we can do, it is an experience of identity" (p. 215). This view of the inextricable nature of identity and learning assumes that learning science can change learners' identities, but also how they are in the world at large (e.g. Brickhouse, 2001; Calabrese Barton & Brickhouse, 1996; Calabrese Barton & Tan, 2009; Carlone, 2004). This change is possible because identity is not made up solely of individual traits, but rather is influenced by the social processes and situated contexts in

which learners participate (Wortham, 2004). In other words, identity is constructed and reinforced through what Holland and Lave (2001) refer to as a process of “thickening” in complex social interaction, in which individuals bring previous beliefs, histories, and assumptions to assign, take up, reject or embrace prevailing storylines about themselves and others in a given setting (Harré, Moghaddam, Cairnie, Rothbart, & Sabat, 2009). Identity is taken to be not just what youth say about themselves in relation to science, but also includes their moment-to-moment interactions with social and material resources, all of which combine to afford or constrain the availability of practice-linked identities (Bell et al., 2009). This manifests as who we are and what we care about “[as] individuals form and re-form themselves and their relations within and across communities” (Nasir & Hand, 2006, p. 467).

References to identity describe the types of person one can be in a given setting; that is, what is available and desirable in the moment (e.g. Carlone, 2004). Prior research has established that one way to address the barriers to engagement in science education is to examine how youth develop science-linked identities. The ways in which individuals engage in cultural practices influence how they take up, get assigned, or reject various identities (Eisenhart, 1996; Harré et al., 2009). In one example, Brickhouse, Lowery, & Shultz (2000) build on Lave’s (1992) model of identity development in communities of practice to examine science learning as how youth see themselves as science-oriented people and thus take part in scientific activities in ways that are meaningful to them. In moment-to-moment interactions, youth are positioned by themselves and others in particular ways in reference to science, often as people who “do” or “do not do” science. This binary often excludes learners who do not fit stereotypical views of who does science, both from the perspective of the individual and of others. For example, many girls become disinterested in science in middle school due to stereotype threat, because they do not

identify themselves as the kind of people who “do” science (Taasoobshirazi & Carr, 2008). Other populations are also excluded from this binary logic of identification and affiliation with the domain.

When learners view what happens in formal science education as being systematically disconnected from their everyday lives, it can result in issues of identity conflict where learners find themselves disinterested in or unable to access science-linked identities. In other words, some learners do not see science as a desirable or accessible resource that contributes to who they are or who they want to be in the future. People try to engage in activities they see as part of who they want to be and avoid activities they perceive to be misaligned with who they see themselves as. This highlights how the practices learners participate in might contribute to who they want to be (Calabrese Barton et al., 2008; Nasir & Hand, 2006).

Bell, Tzou, Bricker, and Baines (2012) draw on Nasir’s (2012) definition of identity resources in a setting “that individuals choose to either take up or not based on their own personal identities and narratives” (p.18). The authors describe how access to these resources is variable and can afford or constrain learning and identity formation. In one example, Latino youth were volunteering at a community service day through an environmental justice organization. The event organizers positioned these youth outside of the “community service” narrative as “other” –illustrated by how the event organizers positioned the young people in stark contrast to other participants (e.g. speaking to the youth in Spanish as opposed to the English used to communicate with other participants; giving the group much harder manual labor jobs). Issues of identity conflict can be productive if efforts are made to make explicit, incorporate, and merge divergent practices to create a “productive hybrid cultural space” that can include all learners (Moje et al., 2004, p.43). The setting of a community service day on a farm had the

potential to position youth as advocates and activists. However, the roles and responsibilities available to the youth, and therefore the available scopes of possibility for action and the subsequent learning outcomes, were outside of meaningful activity and limited to identities in relation to “otherness.” This work speaks to the multiple and sometimes competing social expectations, storylines, and actions that afford or constrain aspects of youths' cultural learning pathways, as learners engage in cultural practices across spaces in ways that stabilize their interests and identities and meet personal goals (Bell et al., 2012). This perspective on learning can make power structures explicit, and inform design that can destabilize and expand traditional boundaries of learning that limit notions of who can “do” science and what “doing” science looks like.

Student-collected data and authorship. Penuel, Lee, and Bevan (2014) highlight identity development as an important facet of designing for equitable learning opportunities across settings. One way to create generative hybrid spaces across learning settings is to position all youth as producers, or authors, of new knowledge and contributors to authentic endeavors (e.g. Bell et al., 2012; Calabrese Barton, Tan, & Rivet, 2008; New London Group, 1996; Penuel, Lee & Bevan, 2014). Authorship is more than just communicating information, carried out by collecting and reporting data; it is about meaning-making. Youth must be engaged in asking and answering questions that help them address issues of relevance to them and their communities: questions that make explicit how decisions that affect them get made (such as where bus service goes), by whom, and with what consequences. Science must be recognized as socially situated to make explicit not just the research practices scientists use to do their work, but the political, economic, and environmental contexts that shape the work they do and the impact it has on

society. This includes attending to how actions are situated in a social context and thus change across physical and social settings (Calabrese Barton et al., 2008).

Opportunities for marginalized youth voices to be heard—especially by audiences in positions of power—is especially important for recognizing and positioning youth as competent and developing experts. This recognition work can support the development of new possible selves as youth “try on” various identities in relation to science, leading to science-linked positionings, deeper engagement in science-related trajectories, and increased representation of non-dominant communities in science-related careers (Carlone & Johnson, 2007; Nasir, 2012).

The design-based research study described here sought to engage youth in scientific concepts, practices, and identity work. To this end, the design centered on two practices: student-collected data and authorship. In the design of learning across settings, student-collected data can be considered a boundary object, that which “can fulfill a specific function in bridging intersecting practices” to establish “continuity across sites” (Akkerman & Baker, 2011, p. 134). Youth collected and shared data with each other from several different investigations and sites that informed subsequent investigations later in the year. Iteratively engaging in these practices across settings then served to connect learning across settings by providing multiple, overlapping opportunities for boundary crossing, in which youth “face the challenge of negotiating and combining ingredients from different contexts to achieve hybrid situations” (Engestrom, Engestrom & Karkkainen, 1995, p. 319) in order to meet their goals.

Design-based Research

This study takes a design-based research approach to address environmental science learning across settings. Design-based research aims to examine how to support learning, while also creating theory about learning through collaborative, iterative design (Bell, 2004; Cobb,

Confrey, diSessa, Lehrer, & Schauble, 2003). This approach is a useful methodology for studying learning across settings because design-based research aims to “orchestrate innovative learning experiences among children in their everyday learning contexts as well as to simultaneously develop new theoretical insights about the nature of learning” (Bell, 2004, p. 244). This means that design-based research can attend to both the intentional coordination of learning across settings, while also creating knowledge about learning as it happens. This approach allows for observation on longer time scales, shifting the focus from short-term cognitive changes to an ecological view that attends to the roles, purposes, attitudes, understandings, and relations to each other and to practice (Rogoff, 1997), as well as to how “co-construction of a community’s various practices and individual development support the changing nature of participation” (Gutiérrez & Rogoff, 2003, p. 20). Design-based research emphasizes the situated nature of values, norms, and practices, but also allows for empirical study of how these translate across time and settings (Bell, 2004, p. 248).

Additionally, design-based research allows for an ethnographic approach, using participant observation protocols to trace learning pathways both within and across situated learning settings. Ethnographic approaches allow for a focus on what it means to be or to not be a member of a learning community for youth across settings (Walford, 2008), potentially illuminating a broader view of youth participation in environmental science in this study.

This work was conducted as a long-term co-design model, in which I and another graduate student worked in partnership with practitioners in both formal and informal learning environments to design for environmental learning across settings. Ms. Jones, a fifth-grade teacher at Granite Elementary, was our primary partner and her class served as the focus of this

study; however, this study also involved engagement in co-design and collaboration with several other practitioners and disciplinary experts.

Ms. Jones's Fifth-grade Class at Granite Elementary

In this chapter, I investigate the claims for the potential of designing to support student learning in environmental science across settings through a design research partnership. This project took place over the 2013-2014 school year is a part of an ongoing team ethnography focused on science learning in and out of school. During the year of this study, she was in her 14th year of teaching, with seven years in her current position at Granite Elementary School. Ms. Jones had been (and continues to be as of this writing) a long-time research partner with the LIFE Center and the UW Institute for Science and Math Education. Concurrent with her involvement in this partnership, Ms. Jones also participated in a multi-district effort designed to launch implementation of the NGSS by creating a network of practitioners and engaging in co-design of science kit adaptations.

Granite Elementary School is an open-concept school and Ms. Jones regularly invited additional adults into her classroom. At any given time there were as many as four or more adults in the room, including Ms. Jones, the two graduate researchers on this project, a student teacher, an undergraduate intern, and one or more instructional aides. The students in Ms. Jones's class were a very linguistically and culturally diverse group. During the 2013-2014 school year, there were 25 languages in addition to English spoken throughout the school.

As mentioned in Chapter 2, it is important to note that based on our observations, instructional time for science in fifth-grade at Granite Elementary is much greater than typically occurs in most elementary schools. The students in Ms. Jones' class engaged in science class for an hour almost every day during the 2013-2014 school year. They completed three commercially

available district science kits, went on several science-related field trips and engaged in the investigations described in this study over several months.

Over the course of a school year, Ms. Jones' fifth grade class participated in coordinated activities in a residential environmental learning field program, local ecosystem exploration field trips, and in science activities in their classroom. Across these settings, youth interacted with a variety of adults, including their teachers, parent chaperones, field instructors, volunteers, and disciplinary experts. Because each of these settings relied on the merging of repertoires of practice that originate in other environments, each was considered a potentially generative hybrid learning space.

Methods

Data Collection

Observations. The data corpus used in this study of the classroom and field trip interactions included audio and video recordings of eighty days of instruction (usually one hour a day over ten months, but also included several day-long and one multi-day fieldtrip), fieldnotes, email exchanges between the teacher and researchers, and planning documents. During classroom observations, two video cameras were set up, one focused on each table of case study students. One of the two cameras was also positioned to easily capture large group discussions at the front of the classroom. For each interaction we had in the classroom, on field trips or with the teacher or students, we wrote detailed field notes, which we wrote up more fully immediately afterwards, including conceptual memos. Data analysis included developing content logs of the videos of small group work and large group discussion for all days of instruction. I selected a subset of days to examine closely in this chapter, based on conceptual interest, for repeated viewings of the videos and the creation of analytical narratives. By reviewing the narratives and

the literature, I determined themes that I used to develop the analytical structure I describe below.

Interviews. Each case study student was interviewed formally, at five points over the school year, using a semi-structured protocol. The aim of the interviews varied across the year, but generally sought to capture students' interpretations of science in their lives as they engaged in science practices across settings and to check researcher understandings. The focal teacher was interviewed formally three times by me or by other members of our research team.

Interviews with the teacher focused on her teaching background, her perceptions of science and engineering in her classroom, the impacts of the professional development and her participation as co-designer, and the backgrounds and classroom experiences of the case study students.

Additionally, I and other researchers had many informal conversations with the teacher over the school year and those conversations became part of our fieldnotes.

Student work. Analysis of student work in this chapter focused primarily on the investigations students conducted using the mobile application, Zydeco. This included student-collected data and claims, evidence, and reasoning statements for nine Zydeco investigations over the school year. For each investigation question, a rubric was developed for research purposes and students' claims, evidence, reasoning (CER, McNeill & Kajcik, 2012) statements were evaluated. Other student work analyzed in this chapter included graphic organizers created as a class, student science notebooks, student-generated background research and questions about the Superfund site, and their final service learning project, a book about the Superfund site that they created to educate the Mayor.

Data Analysis

Youth engagement in practices and identity work across environments. The first research question, focused on how youth engaged in science practices and identity work in and across a range of settings, required an analysis of how the design afforded or constrained the practices and identities made available to youth in and across settings. This study attends to the ways access to disciplinary practices and identities is shaped by the sociomaterial arrangements, actions, and positions available in a setting, which afford or constrain scopes of possible action for youth (Bell et al., 2012). This includes a focus on the affordances and constraints of situated events for youth to *carry out ongoing and overlapping investigations*, and to *collect, represent, and share data from a variety of sources*. I pay particular attention to how individuals and groups were positioned in events both implicitly and explicitly, the kinds of persons that were foregrounded, and the storylines that were leveraged in positioning. To this end, I asked the following questions: What practices and identities were available to youth in each of several situated events? In what ways did youth take up the focal practices (or not)? What identity work was accomplished through meaning-making in these practices? What sociomaterial arrangements provided opportunities for youth decision-making, contributions to authentic endeavors, and recognition as the “kinds of persons” who use and contribute to science? In this way, I examined the social and material resources, available positions, and stances across situated events that influenced new ‘scopes of possibility’ for individuals in relation to science concepts and practices.

Coordinating learning across settings. The second research question, focused on how to design for connected learning across settings, required analysis of the attempt to coordinate disciplinary practices and identity work across a complex investigation in multiple settings over

nine months. In this study, I focus on authoring and public presentation as the primary opportunities for coordinating the focal disciplinary practices of this study (*carrying out investigations and collecting, representing, and sharing data*), and identity work across settings. I asked the following questions: How did the practices in one setting inform practices in another setting, to coordinate learning across settings? How did situated and coordinated events provide opportunities for youth to be centrally positioned in activity as authors? Specifically, what kinds of positions did participation in practices over time and across settings make possible?

Strategies for Promoting Environmental Science Learning Across Settings

Before engaging in co-design with Ms. Jones, I developed a draft study design that centered on the question: How do we determine the health of water in our community? The aim was to engage students in activities that would help answer the question not only by developing explanations of scientific phenomena, but also by investigating human interactions with the natural environment and the social and scientific contexts that determine the definition of clean water. Specifically, the set of coordinated activities in this study centered on an ongoing exploration of a local Superfund site, a river in the heart of a large city in the Pacific Northwest. Based on the literature presented in this chapter, the original broad research design intended to connect learning experiences across settings guided by the following questions:

1. What are our everyday practices relevant to environmental science and how can we draw on these, in class and on field trips?
2. What opportunities can there be for youth to share authorship, give performances, and gain recognition?

3. What are and how do we deal with prevailing narratives around people and environmental science (environmental justice)? What are the connections and contradictions between how we know and how others know about the world?

In the emergent study design, the design features that were intended to address these questions were foregrounded to varying degrees, with more depth in some areas that I will highlight in the analysis presented here. For example, while students had multiple opportunities to challenge and disrupt the typical structures and expectations of the classroom by asking critical questions of disciplinary experts, their everyday practices were not as foregrounded as intended in the original design. In a complex study design, it was inevitable that some design features would figure more prominently than others.

Conjecture maps describe the theoretically salient features of learning environments in relationship to the intended outcomes (Sandoval, 2014). The conjecture map presented here (Figure 1) describes how the conjectures for this study are embodied by particular design features in and across settings, which create mediating processes that lead to the desired outcomes—in this case, described the six strands of learning in informal (and formal) environments (Bell et al., 2009). The conjecture map allows for evidence for or against those statements. This study focuses on how students engaged in four practices:

1. Coordinating learning across settings
2. Carrying out ongoing and overlapping investigations
3. Collecting, representing, and sharing data from a variety of sources
4. Authoring and public presentation

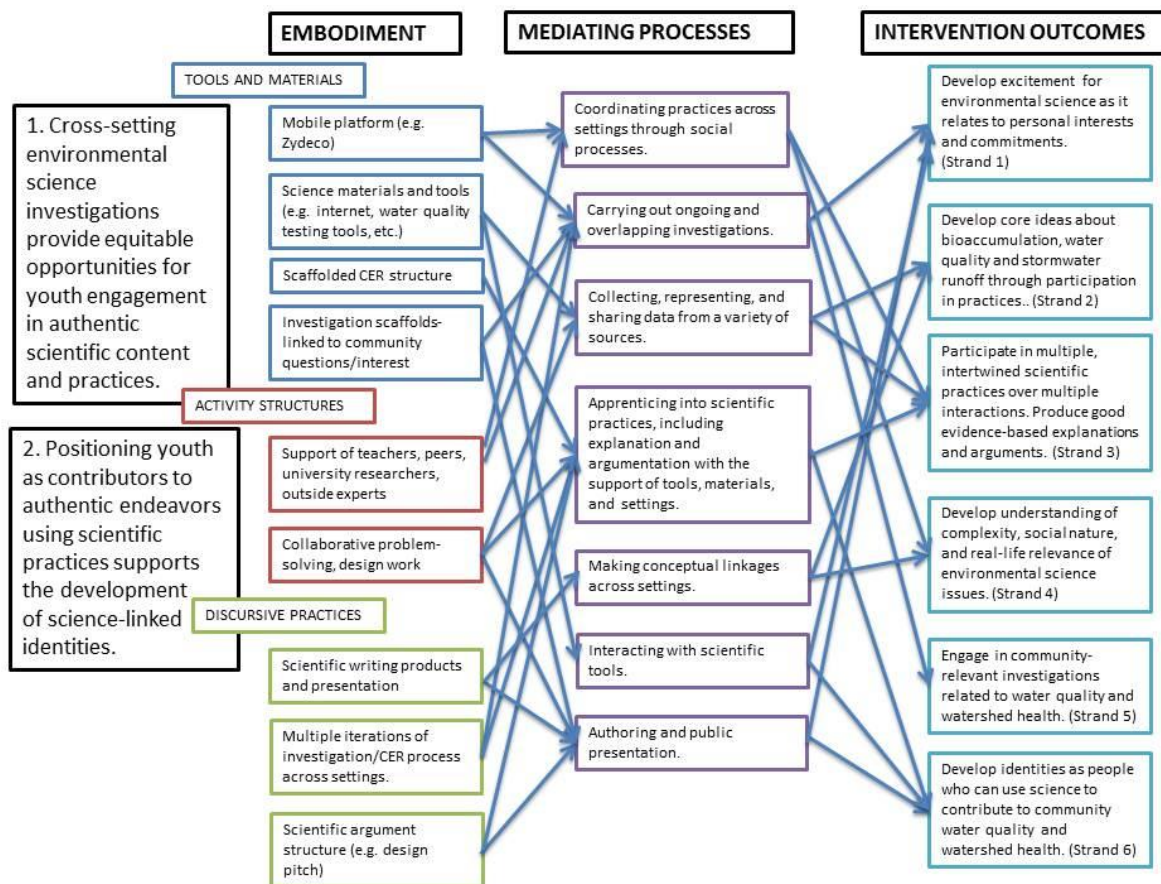


Figure 3.1. Conjecture map for study design for environmental science learning across settings.

Further, Table 1 illustrates the design strategies employed in this study to meet the desired outcomes in relation to the six strands of learning science in informal (and formal) environments (Bell et al., 2009). For example, to address Strand 4, in which learners “reflect on science as a way of knowing; on processes, concepts, and institutions of science, and on their own process of learning about phenomena” (Bell et al., 2009, p. 4), the design strategies included investigating a community issue, evaluating sources and comparing stakeholder views, engaging in scientific writing, and making and receiving feedback on public presentations (Table 1). This table is meant to summarize the ways in which the goals outlined in the conjecture map (Figure 1) were attended to in slightly more detail, within and across settings, and over time.

	Strand 1 Interest	Strand 2 Knowledge	Strand 3 Reasoning	Strand 4 Reflection	Strand 5 Practices	Strand 6 Identity
Learners...	Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world.	Come to generate, understand, remember, and use concepts, explanations, arguments, models and facts related to science.	Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world.	Reflect on science as a way of knowing; on processes, concepts, and institutions of science, and on their own process of learning about phenomena.	Participate in scientific activities and learning practices with others, using scientific language and tools.	Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science.
Desired outcomes	Develop excitement for environmental science as it relates to personal interests and commitments.	Develop core ideas about bioaccumulation, water quality and stormwater runoff through participation in practices.	Participate in multiple intertwined scientific practices over multiple iterations. Produce good evidence-based explanations and arguments.	Develop understanding of complexity, social nature, and real-life relevance of local environmental science and environmental justice issues.	Engage in community-relevant investigations related to water quality and watershed health.	Develop identities as people who can use science to contribute to community water quality and watershed health.
Investigation Sequence: Local Superfund site investigations across settings	<p>1. Focus:</p> <ul style="list-style-type: none"> Student-collected data on mobile platform <p>1. Design Strategy:</p> <ul style="list-style-type: none"> Student-collected data on mobile platform Field trips Public presentation 	<p>2. Focus:</p> <ul style="list-style-type: none"> Watershed health wastewater treatment <p>2. Design Strategy:</p> <ul style="list-style-type: none"> Student-collected data Various stakeholder perspectives CER scaffold Using models Design challenge 	<p>3. Focus:</p> <ul style="list-style-type: none"> Qualitative and quantitative data on watershed health and water treatment <p>3. Design Strategy:</p> <ul style="list-style-type: none"> Student-collected data CER scaffold 	<p>4. Focus:</p> <ul style="list-style-type: none"> Scientific information comes in various forms and media Science is social CER Engineering design <p>4. Design Strategy:</p> <ul style="list-style-type: none"> Compared stakeholder views Evaluated sources Investigated community issues Public presentation and feedback Scientific writing 	<p>5. Focus:</p> <ul style="list-style-type: none"> CER Argumentation Engineering design <p>5. Design Strategy:</p> <ul style="list-style-type: none"> Mobile platform Scientific tools and tests Outside experts and officials Group roles/ collaboration Shared data and results Public presentation and feedback Design challenge Scientific writing 	<p>6. Focus:</p> <ul style="list-style-type: none"> Engagement in authentic practices Authorship <p>6. Design Strategy:</p> <ul style="list-style-type: none"> Group roles/ collaboration Shared data and results Public presentation and feedback Field trips

Table 3.1. Cross-setting design features and goals.

To describe the strategies use to promote environmental learning across settings in this study, I first describe the signature tool used for the coordination of learning across settings and then briefly outline the flow of activity over the year.

Signature Tool for Coordination of Learning across Settings. Penuel (2014) argues that designers of cross setting interventions must not only consider the guiding principles that are appropriate for use in different settings, but also identify what Penuel calls ‘signature tools’ that can coordinate learning with consideration for the “the multiplicity of purposes and structures of activity that can be supported in those settings” (Penuel, 2014, p.3). To facilitate the design strategies for this project, we used Zydeco, a mobile platform designed specifically for youth to carry out scientific investigations outside the classroom, as the signature tool to enable boundary crossing from setting to setting (Quintana & Lo, 2014). Zydeco facilitated boundary crossing by allowing students to carry boundary objects across settings in and out of the classroom, in the form of investigations, questions, data, and results.

In Zydeco, a user creates a driving question and learners use a tablet computer to collect multi-modal data: pictures, video, audio, text which is then saved to the cloud and accessible to everyone signed into that investigation. Users write a title each piece of data they collect and use conceptual labels to organize their data in relation to the question. Notes such as explanations about why a piece of data is useful can also be added in the data collection or analysis stage. Users can then sort the data, conduct analysis, develop a claim in response to the driving question, select the most relevant pieces to support their claim, and add their reasoning.

In this study, Zydeco supported the connection of science concepts, student data collection and engagement in other practices such as explanation and argumentation across formal and informal designed settings. This was primarily done through student collection of

data on fieldtrips with some preliminary analysis at the site of data collection (such as comparing water quality indicators to the color chart on the test package to record data). Organizing and full analysis of data happened back in the classroom. Zydeco proved to be engaging to students, allowed them to collaboratively capture the novel experiences and phenomena on field trips in ways that could be accessed and processed later.

Activity flow. As is the case with many co-design partnerships, we began the school year with a general plan, which was adapted and refined on a daily basis as the year went on. The coordination of lessons evolved over the course of the year to fit new opportunities (such as the last minute availability of a fieldtrip), topical news stories (such as the water contamination issues on the Elk River), and constraints (such as planning for culminating projects at the end of the school year). A complete description of the coordinated set of activities students engaged in over the school year can be found in Table 2.

	Learning Settings	Connected Learning Strategies	Intended Goals
	<p>^contributed to Culminating Event #1: Stormwater design challenge</p> <p>*contributed to Culminating Event #2: Mayor's Office presentation</p>	<ul style="list-style-type: none"> • Student-collected data • Resourcing Identity • Sense-making of content • Authorship 	
1.	Classroom: Students used mobile platform to collect data for an initial investigation called "About Us," in response to the question, "Who are we?" (September 2013)	Student-collected data Resourcing identity	Practice using mobile platform and develop excitement for using it as a tool for collecting information, sense-making, and presenting. Focus on: Strands 1, 6
2.	^Fieldtrip: Students attended 3-day residential camp, Forest Grove. Students participated in team-building, recreational activities, and science lessons. Students used the mobile platform to collect data about how the Living Machine wastewater treatment system works. (September 2013)	Student-collected data Resourcing identity	Bring student-collected data back to classroom from field. Focus on: Strands 5, 6
3.	^Classroom: Students organized and analyzed the data from the Living Machine wastewater treatment system data from Forest Grove camp. They used the data as evidence for writing CER statements in response to the investigation question, "Does the living machine clean water? How do you know?" (October 2013)	Student-collected data Resourcing identity Sense-making of content Authorship	Analyze student-collected data from field in the classroom. Focus on: Strands 3, 5, 6
4.	Classroom: Students used mobile platform for seven investigations as part of the Land and Water district science kit curriculum. (December 2013-February 2014)	Student-collected data Sense-making of content	Practice using mobile platform to collect data and write CER to answer investigation questions in classroom. Develop increasingly sophisticated CERs. Focus on: Strands 2, 3
5.	*^Classroom: Background research: Students consulted a number of sources, including maps, videos, websites, and radio reporting. In addition, three guest speakers (disciplinary experts) came from three stakeholder organizations in the Superfund clean-up process. (February-March 2014)	Student-collected data Resourcing identity Sense-making of content	Practice doing background research, reading and interpreting text and other media, generating questions, and interacting with stakeholders. Focus on: Strands 3, 4, 5, 6
6.	*^Fieldtrip: Students conducted water quality field tests of the Superfund river at a local park. (March 2014)	Student-collected data Resourcing identity	Bring student-collected data back to classroom from field. Focus on: Strands 2, 4, 5, 6
7.	^*Fieldtrip: Students toured the Superfund river with community-based activist group. (April 2014)	Resourcing identity	Situate issues of water quality and environmental justice in the places where these occur. Focus on: Strands 2, 4
8.	*Fieldtrip: Students attended an education program about the city's water supply at a watershed education center located near the source of the city's water supply. They then conducted water quality field tests of a lake near the watershed education center. (April 2014)	Student-collected data Resourcing identity	Bring student-collected data back to classroom from field. Focus on: Strands 2, 4, 5, 6
9.	*Classroom: Students analyzed the water quality data and compared the data from the watershed education center investigation to their research on the Superfund river. Students compiled what they learned about the Superfund site into a book that argued for increasing awareness of the environmental issues. (April 2014)	Student-collected data Resourcing identity Sense-making of content Authorship	Analyze student-collected data from field in the classroom. Focus on: Strands 2, 3, 5, 6
10.	* Culminating Event #1: Fieldtrip: Students presented their book to the Mayor at his office and asked him to help them increase signage for the river in order to increase awareness of the environmental issues. (May 2014)	Student-collected data Resourcing identity Sense-making of content Authorship	Student public performance and presentation of product through culminating event. Focus on: Strands 1, 2, 3, 4, 5, 6
11.	^Field trip: Students toured a municipal wastewater treatment system and collected data about how it works in parallel to what they collected on the Living Machine. (May 2014)	Student-collected data Resourcing identity	Bring student-collected data back to classroom from field. Focus on: Strands 2, 4, 5, 6
12.	^ Culminating Event #2: Classroom: Students used what they learned about wastewater treatment and water quality to design a storm drain treatment system in response to what they learned about current pollution issues. They then wrote a CER about the most important parts of their design in relation to keeping pollutants out of the watershed. (May 2014)	Student-collected data Resourcing identity Sense-making of content Authorship	Culminating project in which students used what they learned about water quality, watershed health, and wastewater treatment for an engineering design challenge. Focus on: Strands 1, 2, 3, 4, 5, 6

Table 3.2. Flow of activity for year-long study, including strategies for connecting learning and intended outcomes in each setting.

In this study, students carried out investigations and engaged with data in order to build two emergent, culminating arguments- one about why and how public awareness of the Superfund river should be raised (Mayor's Office), and one about the most effective way to clean stormwater before it gets to the river (Stormwater Design Challenge). These were both complex social and scientific arguments, requiring students not only to understand the scientific concepts of watersheds, water quality, pollution, and bioaccumulation, but also the complex social concepts behind environmental justice, industrial pollution, tribal fishing rights, etc. This design for learning across settings focused on providing opportunities for students to collect scientific and social evidence to build their culminating arguments.

Briefly, students began the school year with an introductory activity on the mobile platform, in which they gathered data in the form of pictures around their school to collaboratively answer the question, Who are we? They then attended Forest Grove camp for three days and collected data about the wastewater treatment system on site, the Living Machine, which they organized and analyzed back in class. The Living Machine is an alternative system in that it uses plants and bacteria to treat water onsite, in contrast to traditional chemical-based municipal systems.

In December 2013, the class started their investigations with a commercially available science kit, Land and Water, which was the focus of the curricular adaptations Ms. Jones co-designed in the district partnership study. During Land and Water, Ms. Jones wanted students to have several opportunities to practice writing CERs in Zydeco. In the end, Zydeco was a tool for organizing seven investigations. In February 2014, Ms. Jones introduced the investigations students would do to learn more about the local Superfund site. To start, students did background research in order to generate research questions about the Superfund site, and a subset of

questions for the three disciplinary experts presented to the class. The disciplinary experts each represented stakeholder organizations in the clean-up efforts of the Superfund site: a non-profit activist group representing the community, one of the corporations found to be a responsible party in the contamination, and the governmental agency responsible for overseeing the clean-up process.

Students visited the Superfund site on two occasions, one at a nearby park to conduct water quality tests and again to take a boat tour of an extensive length of the river led by the community activism group. Students conducted another set of water quality tests on a fieldtrip to the watershed education center located at the source of the city's drinking water. Students analyzed the results from their data collection, wrote CERs, and created a book about the Superfund site, which they presented to the Mayor in a plea to raise public awareness of the site. Finally, students toured and collected data at a municipal wastewater treatment center. This data, in combination with what they learned about the Living Machine wastewater treatment system at Forest Grove camp and the stormwater pollution issues at the Superfund site, was used in a final engineering design challenge. In this culminating project, students designed a storm drain to treat pollution in stormwater.

Findings

In the analysis presented here, I focus on a subset of student activities that built toward the class visit to the Mayor's office (culminating event #1). I describe the key events that led up to the students' production and presentation of the book they made to educate the Mayor about the Superfund site and to make a case for raising public awareness of the river and the associated environmental justice issues. My claim is that the design for learning across settings provided opportunities for students to be recognized in new ways as knowers, users, and authors of

science. I will focus on a selected subset of events to illustrate aspects of within- and cross-setting learning experiences. Using descriptions and transcripts of classroom activity, this analysis demonstrates how positioning students to engage with authentic practices, settings, content, and data provided opportunities for important identity work that shaped the way students were viewed by themselves and others. I highlight how these events and the subsequent outcomes played out for two case study students, Eddie and Katy, in different ways. I use these cases to hypothesize about strategies for designing to support learning across settings in ways that promote student engagement in scientific practices and disciplinary identification. I cannot claim that the experiences highlighted here were consistent across the classroom, but clear patterns did emerge in the ways that opportunities to engage in epistemic practices and identity resources were made available across settings.

Case Studies

Eddie. Eddie's parents both came to the U.S. before he was born and his family spoke Spanish at home. Eddie's youngest brother was 18 months old at the start of this study and Eddie had a lot of responsibility at home. However, Ms. Jones felt his family had a strong commitment to education. In Ms. Jones' view, Eddie started the year as one of a group of boys with a "tough guy" attitude. Ms. Jones said she worked hard to gain his trust, and to make him and everyone in the class comfortable and ready to learn. Half way through the school year, when she told us this, Ms. Jones said she felt Eddie had become a fully engaged student, which we observed as well. This analysis demonstrates how Eddie took on a new science-oriented identity as a result of several connected experiences he had during the river investigation.

Katy. Katy lived with her mother and her older siblings. Her father was in Mexico at the time of the study. Ms. Jones told us that Katy qualified for services for English language

learners. Ms. Jones said that while Katy enjoyed the support, Ms. Jones thought that she did not need it- that she was highly capable and a competent speaker and writer in English. Ms. Jones described her as a hard worker and an average student. Our observations were that overall Katy was less engaged in group work than some of her peers, but very socially active. This analysis illustrates how the river investigation enabled Katy to engage more fully in some practices than others, in ways that changed her opinion of science but not her view of herself as a science-oriented person.

Learning Settings. The analysis presented here focuses on a subset of events from the year-long study, as described in Table 2.

Setting 5. Classroom: Students consulted a number of sources, including maps, videos, websites, and radio reporting. In addition, three guest speakers (disciplinary experts) came from three stakeholder organizations in the Superfund clean-up process (visits took place on three different days). (February-March 2014)

Setting 6. Fieldtrip: Students conducted water quality field tests of the Superfund river at a local park. (March 2014)

Setting 7. Fieldtrip: Students toured the Superfund river with community-based activist group. (April 2014)

Setting 9. Classroom: Students analyzed the water quality data and compared the data from the watershed education center investigation to their research on the Superfund river. Students compiled what they learned about the Superfund site into a book that argued for increasing awareness of the environmental issues. (April 2014)

Setting 10. Culminating Event #1: Fieldtrip: Students presented their book to the Mayor at his office and asked him to help them increase signage for the river in order to increase awareness of the environmental issues. (May 2014)

Event Cluster 1: Conducting Background Research & Disciplinary Expert Presentations
(Table 2, Learning settings 5 & 7)

Ms. Jones's class began learning about the Superfund site by spending several weeks conducting background research and from class presentations by disciplinary experts involved in the Superfund clean-up process. After introducing the Superfund site investigation by showing students on a map how close the Superfund site was to their school, Ms. Jones pointed out that at least two of the students in the class live in a neighborhood next to the river. She told the class about how she used to teach at an elementary school even closer to the river and that her students used to swim in the river until they learned it was too polluted to do so. Ms. Jones sought to frame the river as a community resource and issue that impacted the community around them.

The students spent several days conducting background research using a variety of resources produced by the stakeholder agencies and other media groups to conduct background research to learn more. They watched videos, listened to radio reports, read webpages, and closely examined community fact sheets, white papers, and a detailed community map that was created to raise awareness and public involvement with the river watershed. Ms. Jones asked students to generate questions of interest to them about the Superfund site and the clean-up process. Ms. Jones categorized the questions and then students prioritized a few questions in each category that would drive the river investigation over the next few months.

Ms. Jones framed the background research students did as an examination of authentic resources available to the public that were created by stakeholder agencies, which is emphasized in the *Framework for K-12 Science Education* (2013) as an important scientific practice. She

described this as different from typical classroom practice in the lower grades where students drew from resources that were specifically scaffolded for classroom activity. Instead, Ms. Jones emphasized that the answers to their questions would not be found in order, or even in one resource, and that as fifth-graders, they would need to learn how to navigate authentic texts. Moreover, she described the complexity of the Superfund issue and the various stakeholder perspectives they would learn about:

Ms. Jones: These groups that you're going to learn about. They don't agree with each other. In fact at some points they've been really angry with each other, because they don't think the other one knows what it's talking about. And so, depending on where you go for information, you're going to get a different answer, which, wow, that makes it even more confusing. But a lot more interesting, isn't that right?

Because of the divergent goals of the agencies involved in the clean-up of the Superfund site, Ms. Jones framed the information students would encounter as possibly contradictory. Ms. Jones told the students: “Ok, so ... that's what we're going to working on. Well, who thinks what here and how do I feel about all this. Where do I stand after learning about everybody's own perspective?” Ms. Jones encouraged the class to take a critical stance on the language each agency used to portray their role, the issues, and the clean-up plan. The class spent a lot of time discussing each agency might have specific interests and their sometimes conflicting priorities for the clean-up plan. In this way, Ms. Jones portrayed the Superfund clean-up issue as a hybrid space in that it was “multiscripted, multivoiced, and polycontextual” (Gutiérrez, Baquedano-López, & Tejeda, 1999, p. 287). The three agencies invited to the classroom contributed their perspectives and ideas, and Ms. Jones conveyed that the students and the community should as well. As a class, students created a final graphic organizer that distilled and presented the most important pieces of evidence that each disciplinary expert used to explain the damage to the

river, the clean-up plan for the river, and the effects of the clean-up (including Why should we care?).

Ms. Jones invited the disciplinary experts to talk to her class to provide information, to demonstrate the complexity of the Superfund issue by focusing on the varied views on the issue, and to present role models of professional scientists. The critical stance of the classroom applied to authentic resources prepared students to generate critical and challenging questions the three disciplinary experts that visited class. Some of the questions students asked included:

“Where will the contamination go (when it is removed)?”

“Do you think it is a river or a waterway?”

“Are you worried about the timeline for the clean-up?”

“What has been most surprising to you about the clean-up process?”

“How do you (personally) feel about the clean-up and the pollution?”

In each of the visits, the experts were surprised by the level of the questions and the confidence of the students in asking them, as evidenced by their responses such as, “Oh wow, that’s a really good question,” or “You all are ready to do my job for me.” The guest speakers all seemed used to being invited into classrooms solely to share their knowledge with students and all three were visibly taken aback when they realized that the students in Ms. Jones class were asking critical and uncomfortable questions. For example, during the presentation from Todd, a disciplinary expert from one of the responsible corporations, the class discussed one of the sources of the pollution from Todd’s company and the sediment contamination of the Superfund river. Todd went to great lengths to describe the many possible sources of the contamination and the difficulties of pinpointing all of them. During this discussion, one student asked Todd, “Do you defend your company?” Todd’s answer was short, “I defend my company because we’re doing good things.” Todd’s presentation focused on framing his employer as doing work important manufacturing work for the whole country, earlier in the 20th century when most of the

pollution occurred, and still today. He extended this narrative to describe the contributions to the Superfund clean-up work they had supported so far.

Several features described here led to the positioning of Ms. Jones' fifth-grade students as knowers, users, and authors of science-related products related to a complex socio-scientific topic. First, Ms. Jones provided authentic scientific and community texts for students to gather information from and to generate their own questions for further research, including for disciplinary experts. Ms. Jones positioned students as developing experts, capable, in fifth-grade, of making sense of complex texts and making up their own minds. Second, she highlighted the different perspectives on the Superfund site held by each stakeholder agency and media sources. She encouraged students to think critically about why each agency took the stance they did and how that served their interests. Finally, in authoring and presenting their critical and challenging questions to the three disciplinary experts in class, the students were empowered to challenge the expectations and discourses of the disciplinary experts in relation to the complex scientific and social issues related to the Superfund site.

Disciplinary Expert Catracho's Presentation—Opening up Spaces for Broader Affiliation. In addition to positioning students to be recognized as authors by themselves and disciplinary experts, the visits from disciplinary experts provided other specific and powerful identification resources for some students. One goal of bringing disciplinary experts into the class was to make students aware of the different kinds of science-related jobs that exist, the different kinds of people that do them, and the paths they take to get into those professions. Catracho's visit was especially powerful for the Spanish-speaking students in the class. Six of twenty-eight students in Ms. Jones' class identified as Spanish speakers. Here I describe how the students' interactions with Catracho, the program manager from the community-based activist

group, provided opportunities for identity work that gave some students a new perspective on their relationship to science.

As soon as students learned about Catracho and that he would be visiting the classroom, several students showed great interest in him and his visit. Eddie, whose family was from Mexico, was particularly interested in the fact that Catracho was a native Spanish speaker and a biologist, and expressed his excitement to his teacher and the researchers several times. Catracho was immediately made aware of the Spanish-speaking students' excitement to speak to him in Spanish when he arrived in class. The first thing he did in his presentation was to address this:

Catracho: I heard some of you speak Spanish. I speak Spanish, and I was actually surprised when your teacher was asking me the question of where I was from.

Catracho seemed surprised that aspects of his cultural identity might be of interest to the students and the teacher. He went on to have the students guess where he was from. He told them he was from Honduras and then began his presentation. He later referenced his identity as an immigrant to the United States as one of the reasons he does his work, to help other people:

Student: What made you want to join the clean-up coalition?

Catracho: Ooh, that's a good question. Wow. I'm a biologist and I've always wanted to save every single animal in the world. I didn't care about people much. But I actually took a job because I knew I needed to learn how to interact with people to make them understand how important the environment is, I took a job with another nonprofit to do that. And I learned that it was great and I was good at it. And I enjoyed myself. And then, when the [clean-up coalition] had an opening, I even liked it more because this issue affects people that are new to the United States. People that look like me, that are like me. So I'm very passionate about that. And I decided that I wanted to make a difference for all the other people that look like me, that are new to the United States, that are affected by the pollution, and might not know how the pollution might be affecting them. So, and, when we protect the river's health and we make the river healthier for people, we're making it healthier for fish and wildlife, so I'm doing what I always wanted to do.

In this segment, Catracho described several different identities that he leveraged in choosing his profession and in continuing to do his work. He made clear to the students how his multiple, overlapping identities, as a person new to the United States, as a Spanish speaker, and a biologist, have influenced him to do the work he does, making a difference in the lives of others who may be disempowered or disproportionately affected by pollution.

Shortly thereafter, Katy and Eddie each engaged with Catracho in Spanish in front of the class. After Catracho's slide presentation on the river and the clean-up plan, Katy asked if she could come up and read the sign in his last slide, a fishing safety sign in multiple languages located at the river. Eddie volunteered to help her and stood next to her as she read.

1 Katy: Can I read the sign in Spanish?

2 Catracho: Yes.

3 Eddie: Oh yeah, can I read it?

4 Catracho: Of course!

5 ...

6 Ms. Jones: Why don't you come up here and read it.

7 Eddie: I'm going to come up and help you because you don't read really good Spanish.

8 Katy: [crosstalk]

9 Katy: El consumo del pescado del mar, cangrejo y mariscos puede ser peligroso
10 [crosstalk] (al la viva/vida?). [The consumption of fish from the sea, crab and
11 mussels can be dangerous [crosstalk] (to living?).]

12 Eddie: [inaudible]

13 Catracho: Good job.

A few minutes later Eddie then asked Catracho if he could ask him a question in Spanish:

14 Eddie: Can I say it in Spanish?

15 Ms. Jones: Sure.

16 Catracho: I'll have to translate though.

17 Eddie: No.

- 18 Catracho: Because I want everybody to understand.
- 19 Eddie: Ok ok. Whatever. Ok, uh, what was it.
- 20 Katy and another student both spoke in Spanish to Eddie [crosstalk].
- 21 Eddie: Trabajan en different partes del “river” o estan [inaudible] (juntados?) en todo el
 22 “river”? [Do you work in different parts of the river or [inaudible] (do you work?)
 23 on all of the river?]
- 24 Catracho: He's asking if we work in different places along the river or we do work
 25 throughout the whole river. Tricky question. The whole river, the Superfund site,
 26 is 5 miles long...

In these segments, Katy and Eddie make bids to demonstrate their expertise in Spanish and show their connection with Catracho. They each engaged their cultural identities in classroom activity in ways that were not typically recognized in class—from what we observed over the school year. While Katy and Eddie often spoke Spanish to each other, and in fact, regularly used it to exclude others (see Wortham, 2008, for a similar social use), it was rare that they found opportunities or reasons to leverage their identities as Spanish speakers, as children of families from Mexico, or as children of recent immigrants in service of classroom work. It is not clear what Eddie's intent was when he said that he did not want Catracho to translate his question. One possibility is that Eddie wanted to connect with Catracho by engaging him in a way that only a few people would understand. In this way, he seemed to attempt to privilege the other Spanish-speakers in the class and to position himself as a central member of the group. Eddie seemed to want to show Catracho that he was “like him.”

Each of the three disciplinary experts who visited class expressed how impressed they were with the students to Ms. Jones. Primarily, they were surprised by the sophistication of the students' questions, demonstrating that their initial expectations for the classroom presentation and class interaction were challenged. The three experts seemed to be typically positioned as experts sharing information in classroom visits, not to be challenged or questioned.

Catracho even decided to make room in the schedule for them to join him on a boat tour of the Superfund site the following month (Table 2, Learning setting 7). As with Catracho's classroom presentation, his talk on the boat focused on the environmental justice issues brought to the forefront by the Superfund designation of the river and the clean-up plan, while also pointing out the important contamination and clean-up sites along the river. At the end the talk, Eddie again leveraged what he viewed as shared cultural and linguistic resources to chat with Catracho in Spanish, talking about a variety of things, including asking Catracho about his favorite foods. The river boat tour reinforced the identity and social affiliation work that began in the classroom during Catracho's visit. All of the students were able to engage in authentic ways with a scientifically-oriented community member who was also a part of Katy and Eddie's Spanish-speaking community. This experience provided an opportunity for students to learn more about the Superfund site and how the practices and conceptual knowledge they were building applied in the real world, while also finding more common ground with Catracho through casual conversation.

Discussion. Several features of the disciplinary experts' visits contributed to powerful science-linked identification work for some students. First, students were positioned as knowers, users, and authors of science, ready to ask critical and challenging questions about the work of disciplinary experts, which was a disruption of typical classroom structures for the students and the disciplinary experts. The production and presentation of critical questions by students from marginalized communities to people with decision-making power marked a strong rearrangement of the roles and expectations that the disciplinary experts were used to. It created new opportunities for students to be recognized as science-oriented people by themselves and by other significant narrators (Sfard & Prusak, 2005). In this case, the three disciplinary experts had

the power to act as co-authors of student identities by recognizing the sophistication of student thinking, in class and to their teacher.

Both the way students were positioned during these presentations and Catracho's presence as a disciplinary expert with a related cultural history for some students allowed the classroom to be reconstructed in a more culturally congruent and agentic way for students like Eddie and Katy (Achinstein & Aguirre, 2008). Catracho provided a 'cultural match' for some students, in that they identified with him, as someone who might share aspects of their cultural experiences, discourses, and values. His presence in the classroom allowed Katy and Eddie to leverage and foreground cultural identities that were not often recognized in the classroom.

Additionally, Catracho made explicit a direct connection between his professional interests, his cultural identity, and his passion for the environmental justice issues associated with the Superfund site. In this way, he demonstrated how cultural and scientific identities, which can often be seen as competing, actually complemented each other in his mind and drove his passion for his work. While surely there were other sociocultural differences between Catracho and the Spanish-speaking students in Ms. Jones' class that were not highlighted here, we know that Catracho shared a similar cultural and linguistic background with some students as a recent immigrant and a Spanish speaker. He provided a connection that may have helped students in crossing cultural and linguistic boundaries in the learning environments. Catracho's presentation, and specifically the way he named his multiple identities, provided an example for students of a successful, science-credentialed adult in ways that presented future possible selves for them (Achinstein & Aguirre, 2008; Polman & Miller, 2010). It may have never occurred to Eddie and Katy that their multiple identities could be leveraged to do scientific work, or to make a difference in their community, as evidenced by their excitement for Catracho's presentation. In

fact, though Catracho was very clear in how his cultural identity shaped his professional path, he too seemed surprised that it mattered to the students or the teacher. This may be because Catracho is typically invited to simply share his professional knowledge and not necessarily his personal background and professional trajectory.

Finally, interacting with Catracho in the authentic setting of the Superfund site itself during the boat tour reinforced Eddie's opportunities to identify and affiliate with Catracho through professional and casual conversation. It also had the potential to broaden students' views of how and where science happens, and how scientific practices and content are relevant in the real-world. In their description of the benefits of place-based education, Smith and Sobel (2010) emphasize the collaborative relationships between community members and their schools. Place-based education helps students to become engaged with the local community in ways that encourage and support them to become active civic contributors. It also theoretically requires that teaching is not limited to what goes on between teachers and students in the classroom, but that community members can also provide resources for youth. This project provided opportunities for both. It was a potentially powerful experience for students to see Catracho doing science-related work both in their classroom and on the boat tour on the Superfund site. The boat tour provided an opportunity for students to see how practices and content they had engaged with related to the real world, which has the potential to broaden their views of science and opened space for them to see the river as a contested scientific and social place, with impacts for people in their community. The identity resources available during Catracho's classroom visit were again prominent, at least for Eddie, on the boat tour fieldtrip he led. It reinforced and situated the scientific concepts students were learning about (stormwater issues, environmental

justice), but also situated Catracho as the kind of person who does science in community settings.

I argue that the repositioning of students as authors and developing experts, in tandem with the identity resources provided by Catracho's visit, created hybridized spaces. The evidence presented here demonstrates how the merging of discourses, expectations, and storylines led to a reorganization of the scopes of possibility for action that were available to students: they became knowers, users, and authors of science. Additionally Catracho provided an opportunity for some students to leverage their other identities as a way to engage in a discussion of science and to see future identities that they might want for themselves. The classroom and the boat trip both became hybridized in that multiple identities were surfaced for some students. In this way, the 'kinds of people' that were thought to be relevant to the scientific practices at hand positioned students in a way where they could more deeply engage in them.

While hybrid spaces are not always generative, and can even be detrimental to students, especially those at the margins, the acknowledgement and active co-construction of third spaces by educators and learners can facilitate access to the production of new knowledge and new identities by producing new understandings of what counts as participation (Gutiérrez et al., 1999). The events here illustrate how learners were able to take on new roles and approaches as they are engaged in ongoing co-participation that both shaped and extended their individual participation and the work the class was able to do in the upcoming events.

Event Cluster 2: Water Quality Tests at Superfund Site and Analysis in the Classroom
(Table 2, Learning settings 6 & 9)

In this cluster of events, the class traveled to the Superfund site, to get collect their own water quality data and to make observations about the state of the site. Ms. Jones was primarily interested in students gaining firsthand experience with the site as part of their community and

with collecting their own data to be analyzed in the classroom and applied to their understanding of 'clean' water.

Data-collection fieldtrip. In March, the class took a fieldtrip to a park on the Superfund river to collect water quality data and make observations about the natural and built environment that would inform their understanding of the Superfund issue. Students were assigned specific procedural roles during the field trip in order to facilitate data collection for each water quality test. Because of bad weather, the students had less than 20 minutes at the park to conduct their tests and document the area through pictures in small groups. In this analysis, I demonstrate how the unique sociomaterial arrangements of the fieldtrip, though short, positioned all students at the center of scientific practices in ways that did not typically occur in the classroom. While the subsequent sense-making did not lead to the specific learning outcomes that were originally intended, it still was a powerful experience for students as evidenced back in class by student's CER statements and by the interviews with Katy and Eddie.

Ms. Jones presented the purpose of the fieldtrip as an opportunity to collect the class's own data related to water quality and to use it to make up their own minds about the Superfund site. Ms. J. talked about how class data was different from the data collected by the stakeholder agencies, and how it meant that students could verify some of what they had heard about and make conclusions from their own tests.

Ms. Jones: So we could rely on Todd's results of how clean the river is. We could rely on Catracho's results on how clean the river is. Do you think those two would be exactly the same? No. They might even use different tests, right? So we need to make sure that we're doing these tests for ourselves.

The class carried out five types of water quality tests in each small group, with each student responsible for a different test. They conducted their tests and used Zydeco to record the

data, which they later sorted, analyzed, and used to write claims, evidence, and reasoning statements about the health of the Superfund site.

Because each student was responsible for a different test within their small group, all students were able to engage in the water quality data collection. The researchers present that day observed all of the students handling materials, collaborating with their peers to keep time, and working together to take photos of each test result and observations of the overall site that they felt informed their understanding of the health of the Superfund site. Both Eddie and Katy were centrally involved in this and a later opportunity to do water quality at another site. They both carried out tests, recorded data for their group, and used the group's tablet computer to take photos. In a later interview, Eddie noted that he realized he was doing the same work that scientists do. He said, "When I was doing the metal test and I was like wow, so this is how they do their work." This is an important part of identification, as Eddie came to see that he was engaging in the same or similar practices to experts.

Katy's involvement in the sanctioned social and materials practices of the water quality fieldtrip especially stood in contrast to what we usually observed in the classroom. On all of the field trips we observed Katy, we saw that her interest, enthusiasm, and engagement was much higher than in class, as evidenced by her talk and action that was centrally focused on the scientific activity instead of focused elsewhere, which was often the case in class. This is an example of the ways in which different settings or contexts can more deeply engage some students (e.g. Bell et al., 2009). The set up on the fieldtrip marked a disruption in the typical structures of classroom small group work, where we regularly observed the same students repeatedly positioned out of the social and material practices of science class. Assigning students specific roles in conducting authentic scientific tests in in the broader community, where science

happens and impacts people's lives, provided a new opportunity for students to engage in practices and identity work that were previously unavailable in the classroom.

For Eddie and Katy, an important feature of the river investigation was going to the actual Superfund site, to collect their own data, and to go on the boat tour. For Eddie, the field trips to the river made him want to learn more about the animals there.

- 1 Researcher: Cool. Did you learn anything new about yourself from the field trip or from the
2 [river] project?
- 3 Eddie: That I can help with the [river] and that I want to help on the [river]. Yeah, that's
4 all.
- 5 Researcher: Yeah, it's not too far from here. Are there things that you are more interested in or
6 excited about since you've been to the [river] park?
- 7 Eddie: I'd say about the boat trip.
- 8 Researcher: Ah, the boat trip to the [river], yeah.
- 9 Eddie: I want to see if any type of animals down there or how they live with all the
10 polluted water in there.
11 ...
- 12 Researcher: Is the science that you did on the [water quality] field trip the same or different
13 than the science you do at school?
- 14 Eddie: Different.
- 15 Researcher: How is it different?
- 16 Eddie: Because we actually get to go to the place where we can test and everything,
17 where the water is so yeah. That's what's different.

Even though we observed a difference in Katy's engagement in scientific practices on fieldtrips versus those in the classroom, Katy did not always see the practices she engaged in on the field trip as novel or different from those she participated in in science class. In other words, in her perception, the field trip did not afford her any opportunities to engage in new practices or identities. In one of her interviews, she likened the practices on the field trip to those in science class, and also at home, cleaning and testing the water of her cousin's aquarium. However, she did note that the place afforded an opportunity that was different than classwork.

Katy: In science we just talk about the [river] and we don't really, well we do, but we don't do like the water or anything.

Katy described how she sees continuity in the science practices across the settings of her life while realizing the affordance of getting data from the river site. This likely represents a more sophisticated view that moves beyond “school science is science,” yielding insights into the parallels and differences Katy recognizes between everyday practices and those of the science classroom (Nasir, Rosebery, Warren, and Lee, 2006).

Student sense-making of water quality data. Students did some initial analysis of their data in the field, comparing the results for the pH and metals tests to the indicator charts to determine their meanings. This set of practices highlights the dynamic and intertwined nature of the scientific practices in the context of actual investigations, including those in the field (Bell, Bricker, Tzou, Lee, & Van Horne, 2012; Latour, 1995). Over several days in class, the students worked with Ms. Jones in a whole class format to explore more deeply the definitions of each tests and how the data students collected contributed to their understanding of the cleanliness of the water. While setting the stage for sense-making, Ms. Jones linked the students’ river investigation work to two current news stories: 1) the contamination of a municipal water supply in West Virginia caused by a leak at a company that produced chemicals for coal production; and 2) a landslide that destroyed a local town and killed several people:

Ms. Jones: The wastewater treatment facility said oh, there's none of [the chemical] in our wastewater, we've gotten rid of it. And they were working with one test, a kind of test, like you did your water quality tests. Well the thing was, the people in [city] were like I don't really believe you because I can still smell it, right? So this independent scientist group came in and they said, yeah, guess what, there's still, and then they gave a number of parts per billion of that chemical, and they said it's in your wastewater treatment facility.

In this segment, Ms. Jones emphasizes the importance of considering who gets to conduct tests, interpret results, and make decisions. Later that day, the class listened to a news report on the

local landslide. Ms. Jones pointed the students' attention to the end of the article, where a scientist reported that his research led him to be unsurprised by the landslide, but that there is no money to support getting the scientific knowledge to the people who make land-use policies.

At the end, Ms. Jones linked this back to the students' investigation:

Ms. Jones: I think that's something else that we need to think about when we think about the [river] and the other areas that we're going to be studying...is what do scientists know and why is it important that the community knows that same stuff? Like it's important that scientists know this stuff, but if only scientists know this stuff, than that's not really going to help anybody.

Ms. Jones' purpose in these two moments was to emphasize the importance of community access to the work of scientists, including citizen scientists, in order to inform important decisions, like whether water is safe to drink or a hillside is safe to build on. I argue that this contributed to a narrative Ms. Jones employed throughout the river investigation to position students as knowers and users of science, as decision-makers, and as people with something to contribute in order to help others. Scalone (2015) describes a parallel instructional design strategy which resulted in increased student agency and science identification, compared to standard inquiry instruction.

Explanation and Argumentation. In this study, claims, evidence, and reasoning (CER) statements were intended to be the primary tool for sense-making. The original investigation question was: How do we determine the health of water in our community? This open-ended, overarching question was intended to help students to think broadly about the complex definition of clean water, how the uses of water across contexts and communities affect that definition, the standards water is held to, and who gets to decide. However, for several reasons, students ended up writing a CER in response to a different question: How do the tests, combined with our background knowledge, teach us more about the [river]?

As we conducted analysis of the CER statements students wrote, it became clear that this question was effective for helping students to start to summarize the complex and sometimes conflicting evidence of the health of the River that they had gathered. However, neither question required the level of synthesis we were hoping for the students to take on: to use CER to come to conclusions about the broader scientific and social phenomena of “clean” water. Students focused on summarizing what they learned and the CERs that resulted are lists of pieces of evidence or facts gathered from a variety of sources. A future redesign could ask students to use their initial arguments as a foundation to engage in the broader issues associated with clean water.

There are three primary features of the design as it was implemented that may have contributed to outcomes we saw in the student responses. First, the question Ms. Jones chose, “How do the tests, combined with our background knowledge, teach us more about the [river]?” did not specifically address what could be learned from the water quality tests. One possibility for this choice is that Ms. Jones thought this question would allow students to more broadly address all of the research they had done, but still allow for concrete discussion of their results. My sense is that the overarching question seemed too broad to Ms. Jones and not focused enough on the specific work the students had done.

The second feature of the design that may have contributed to the resulting CERs is that because we did not have access to the river sediment, the primary location of the most toxic and prolific contaminants. Additionally, we did not have access to the appropriate tests to measure the contaminants and so while the tests students used were relevant, they were not a direct match for the ways in which the involved agencies talked about the clean-up process. This mismatch between the work the students did and the work the agencies were doing complicated the

discussion and may have confused students about the usefulness of their data. Ms. Jones found herself backtracking at several points during the sense-making process to help students prioritize the information they had to answer the question. For example, Ms. Jones suggested they may need to use the word ‘however’ in their claims or reasoning to explain any conflicting results they got in their data.

Finally, the structure of Zydeco sets up students to write their claim before the evidence for the claim is selected and copied into the CER statement. Earlier iterations of the CER process occurred during the Land and Water district science kit, in which students came to consensus and all the students wrote basically the same claim. In these cases, the linear structure of the scaffolded CER in Zydeco worked fine—students wrote the claim that the class agreed on and then went looking for the data to support it. Ms. Jones addressed this issue during the river investigation saying, “Usually all of our evidence, like in Land and Water, all pointed in one direction...but here it’s different because these things (evidence) all point in different directions.” An attempt was made to institute a step by step protocol for examining and selecting data before writing claims, but it was not taken up in classwork. Students struggled to analyze and prioritize data in order to come to a claim that answered the question.

Ms. Jones introduced the work on the last day by saying:

Ms. Jones: You're going to link each piece of evidence and you're going to explain each one. Let's say you're using the bacteria positive test. My bacteria positive test shows that the [river] has bacteria in it. That tells me that the [river] is not clean. That is how I explained one piece of evidence.

Investigation Question: How do the tests, combined with our background knowledge, teach us more about the [river]?		
Student(s)	Claim	Reasoning
Ash + Katy	We learned a lot about the [river].	The part 1 and 2 of map shows what We learned by reading the map. It also told us a lot of pollution from factories. The water quality test results show how dirty the [river] river is and how much we should help care for it!

		<p>The text about [Catracho] tells you what he taught us of the many thing that was happening to the [river].</p> <p>The text about [Todd] talks about what he wanted us to know about the [river] and how all the dirty things. The text about the online research told us that the Duwamish river was once invisible to pretty much everybody a and that only 1 of 4 river that drained into the river still drains in the river. The biggest learning is that the Duwamish is really important but people don't have news about.</p>
Eddie (unfinished)	The [river] is so dirty it's a superfund site	<p>the [community activist] group member [Catracho] came to talk to us of the superfund site and the history of the [river].and also [corporation] member [Todd] came to talk how they are going to clean up the [river]. And [Catracho] and [Todd] both talked about how the [river] is a superfund site and both said that there are over 42 chemicals in the [river] and talked how the [river] was one of the most polluted rivers in the United States of America. and [Catracho] also said that when you go down to the [river] there are signs in different languages to tell you that the river is polluted. [Todd] said that [corporation] made airplanes in world war 2 and they made the world war 2 planes here in [city] and the place where they build the place the roof was a disguise as a...</p>

Table 3.3. Claims and reasoning statements

The CER statements in Table 3 show that students used the reasoning to recount the story of the river. This demonstrates that the prompt was read by students as requiring a historical explanation rather than a scientific one, which may be a more common type of prompt for them. Additionally, students gave primacy to the expert accounts rather than to their own data. In Ms. Jones' preparation of students to write these CERs she emphasized that students should be drawing on a variety of sources, including their tests and the background knowledge they gathered from the disciplinary experts. In the end, neither Ash and Katy or Eddie included any of their water quality data in their claim. It is not clear why these students focused only on their background research (we did not get to ask about this in the post-interviews). Though the tests students used are authentic water quality tests, they did not match the tests being done by the agencies involved in the clean-up of the Superfund site. It may be that the core scientific concept,

what does it mean for water to be clean?, became convoluted and lost, to the students and even the teacher. However, even the question as asked might have been interpreted by the teacher and students as an opportunity to generalize about their data and methods. Students might have been scaffolded to think critically about how the Superfund designation came about, the practices scientists and other stakeholders used to determine contamination levels, and the decision making processes agencies used to plan the clean-up.

Even in light of these issues, I argue that Zydeco facilitated boundary crossing in that it allowed for sense-making based on authentic, personally-relevant, and place-based data. First, all of the case study students we interviewed mentioned that the water quality data collection at the Superfund site was the activity that made them feel most like scientists or doing the work scientists do. Additionally, I observed that students were fully engaged in the collection of their own data at the actual site of the Superfund river and that this created a sense of ownership and interest in engaging with the data back in class. Finally, student data collection drove a number of conversations between table groups as students wanted to understand and use data collected by other tables, requiring students to articulate clarification questions and explanations to each other about the usefulness of data.

As mentioned earlier, Katy was not typically centrally engaged in small group work in class. In an interview, she acknowledged her primary role as an outsider in the sense-making process during classwork:

- 1 Researcher: Can you think of a time when you contributed something to the group, like you
 2 had an idea or you did some of the typing or what was something that you did that
 3 helped the group? What kinds of stuff did you do to help them?
- 4 Katy: Me and Ash would usually take turns typing but sometimes I'd do most of the
 5 typing. Then he'd just tell me what to type.

This comment was in line with what we often observed: Katy was repeatedly positioned out of activity, sometimes by others, sometimes of her own doing. When she was engaged, she often participated in procedural tasks rather than intellectual ones. Here she described how rather than undertake negotiation and argumentation of ideas, she and her partner Ash split the task: Katy took what Cohen (1994) describes as the role of “typist,” while Ash took the role of “thinker,” telling her his ideas for what to type (see also Herrenkohl, 2006). How this happened is an important and complicated story that is beyond the scope of this chapter. Ash was often an inclusive and helpful partner who tried to engage Katy to think with him about the task at hand. Other times he showed frustration with Katy, primarily for engaging in talk and activity not related to the task. It is possible that though Katy’s teacher considered her to be a competent writer and speaker in English, her official status as a language learner somehow impacted her experiences in class. While our observations made clear how Katy often positioned herself out of activity in these ways, we also often saw her other tablemates deny her bids for access to materials and ideas. These positioning systematically reduced the scope of possibility for her learning in important ways, although she did tend to find some specific ways in which to participate in the work and to learn science.

However, both Eddie and Katy showed understanding of important and complicated pieces of the Superfund site issue. For example, in their exit interviews at the end of the year, both Eddie and Katy described how the river might not ‘look’ dirty, which meant that people might not know about the pollution and the associated health issues. This aspect was one of the main challenges being addressed by the community-based activist group.

- 1 Researcher: What do you think about when you think about the environment now, this year?
 2 Eddie: It's not always clean.
 3 Researcher: It's not always clean?
 4 Eddie: It may be polluted without us knowing.

Katy went one step further and described how this might lead people to continue their everyday practices without realizing the implications for their health.

- 5 Researcher: Cool. Okay. What do you think was the most important thing that you learned on
 6 the field trip?
 7 Katy: That, on the outside the [river] doesn't look that dirty...That there were still people
 8 that were standing right next to a sign that says not to fish and they kept fishing.

These exchanges demonstrate that despite the complexities of implementing meaningful sense-making work in the classroom, students in Ms. Jones' class did come to understand some of the important underlying issues as the heart of the Superfund site clean-up.

Discussion. Several features of the water quality investigation positioned students as capable, developing experts at the center of scientific practices. The *Framework for K-12 Science Education* (NRC, 2012) describes how the importance of engaging students centrally in practices “helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world” (p. 42). The authors go on to describe the curiosity, interest and motivation that can develop for students when they engage in science as a creative endeavor. Ms. Jones leveraged the water quality investigation to meet these goals in several ways.

First, Ms. Jones continued a narrative, or messages constructed across the unit, about students' relationship to science that served many purposes. This narrative included the storying of science for different purposes and therefore the need for critical consumption and that science happens in and out and across school boundaries. It situated the work the students were doing in

authentic settings and issues and in the work of professionals, and of importance to the local community. It engaged students in a frame of science as ideally a shared or democratized endeavor that can be used to support community interests and goals. The narrative also served to position students as capable of and responsible for interpreting complex and contested information, making sense of their own data, and becoming critical consumers to work toward their own conclusions about the Superfund sites' social and scientific issues. In this way Ms. Jones connected students a specific storyline about themselves as science learners- that with supportive mechanisms and connection to areas of personal and community consequence, they were all capable of doing science in ways that matter given the interests of community life and of the broader society (NRC, 2012).

In some ways, Ms. Jones performed the roles of a cultural broker for her students, in that she made some aspects of border crossing explicit throughout the river investigation (Aikenhead, 2002). Gutiérrez and Larson (2009) point out that understanding the discourses of a community of practice and how one is positioned enables one to change position, a process in which significant narrators, such as Ms. Jones, can assist or deter. While she did not explicitly help students identify the cultures they are a part of and the ways in which their worldviews may be different from those of science (e.g., engaging students in explicit understandings of how their own experiences and repertoires of practice have been sociohistorically positioned in relation to the environment, their community, and to scientific issues that affect them), she did constantly reinforce the broad ways in which science has a distinct language, beliefs, values, and conventions, and that these are in contrast to what students may hold or have experienced before.

By taking students to the Superfund site to collect samples that they would then analyze and interpret, Ms. Jones made the learning experience into an authentic endeavor, by engaging

students in the practices and concepts they learned about in class in the real world and recognized as the authentic practices of scientists. Assigning each student a role in conducting the water quality tests, the typical sociomaterial arrangements in the small group work were disrupted. All students had access to and worked with materials, conducted tests, and collaborated to report their data and make sense of it. For Eddie, this investigation, along with the boat tour, piqued his curiosity about the animals that live in such a polluted place and helped him to realize that he could use science to consider this related problem. This supports the notion that engaging students in authentic practices about interdisciplinary topics can further student interest and feed ideas for ongoing investigations (Bell et al., 2009).

Back in class, sense-making was either done in the large group with Ms. Jones leading the discussion, or in pairs, writing CER arguments in Zydeco. The simple division of labor that Katy and Ash and other pairs took on is a known challenge of computer tasks in small group work, especially for mixed-sex groups like Katy and Ash's (Cohen, 1994), though we saw this occur in same-sex pairs in Ms. Jones class as well. Without more attention to the complexities of the social and academic interactions at her table, I cannot say with certainty why Katy so often disengaged from scientific practices in class or engaged in procedural tasks like typing instead of discussion. However, Katy's full engagement in data collection on the fieldtrip, where all students had assigned tasks, is evidence that supports the claim that preparation for small group work through careful construction of a variety of roles can be effective for improving the engagement of all students in discussion and sense-making (Cohen, 1994; Herrenkohl, 2006).

Finally, though scaffolding the sense-making process for students brought unexpected challenges, students did engage in authoring explanations that helped them understand the broader social and scientific issues of the Superfund site. The primary findings here is related to

the crucial role of having a well-focused question in relation to a scientific phenomena—something that may have been lost due to the mismatch between the tests students carried out and the central contamination issues of the Superfund site. A well-focused question such as ‘How does the analysis of your data support or contradict the claim that the Superfund river has clean water?’ may have kept the scientific phenomena more central to the student explanations.

Event Cluster 3: Visit to the Mayor’s Office

(Table 2, Learning setting 10)

At the end of the year, the students synthesized what they had learned from their background research, disciplinary expert presentations, and primary data into a book meant to inform and persuade the Mayor to take further action about the river. Led by the student teacher, Ms. Drum, and a fellow teacher candidate, the students engaged in a service learning project: Ms. Drum defined this as an opportunity to use what students are learning to help the community. Early on, the students and Ms. Jones had keyed in on a website’s statement that the statement that the Superfund river was “invisible” to the greater community, partly because general awareness of the river was low.

- 1 Ms. Jones: What do you think it means, that the river is invisible? What do you think that
2 might mean? Using your background knowledge. Using what you’ve learned so
3 far about the river. About how polluted it is. Where it is. What do you think it
4 means that the river is invisible?
- 5 Sherry: I think that some people who have a business there just look at it and are like
6 whatever, that river.
- 7 Eliza: They're not really thinking it's interesting, it's just a river, not a big deal.
- 8 Luke: They don't notice it.
- 9 Ms. Jones: Does it actually mean that the river is literally invisible? No, it doesn't. What it
10 means that a lot of people don't really pay attention to it. That leads to me to start
11 questioning it. And I'm sure that leads you to starting questioning, well why are
12 people dismissing it?
13 ...

- 14 Sherry: It could also be that it's so dirty that people just don't want to think about it.
- 15 Ms. Jones: Sherry just said, that it's so dirty, it's so polluted that people don't even want to
16 think about it. It's easier to just play in Lake Washington...than to think about this
17 dirty river.
- 18 Ms. J: Can you think of anything in their life or their family's life that is just so messy or
19 so complicated that people don't even want to talk about it? Yeah, that happens
20 sometimes.

Building off of Sherry's comment that the river was so dirty that people just didn't want to think about it, Ms. Jones also posited to the students that maybe it was invisible to people because they did not want to deal with the complicated issues of the Superfund site. The two student teachers focused on this idea and facilitated a conversation with the students about what they could do to make the river visible to the greater community. The students brainstormed ideas based on what they had learned issues that had come up throughout the investigation. For example, Ms. Jones had pointed out on several occasions that part of the reason the river might be invisible is because none of the three bridges going over the river announce the river with a sign, the way other bridges over other waterways in other parts of the city do.

The group eventually settled on taking advantage of an upcoming visit to the City Hall, where the class would meet with members of the City Council and the Mayor of the city. Ms. Drum asked students: What could we do at City Hall? What would you need to prepare? How could you inform and persuade the Mayor about what you have learned about the river? Among the many overlapping suggestions made by the class, Eddie and Katy both made contributions that were taken up in the final plan. Eddie said that their water quality data could inform and persuade the Mayor. Katy suggested that they should propose a sign that presented information about the river's history and wildlife. The students broke into groups to create draft signage, finish the river book, and write a script for what a few students would say to present to the

Mayor in their meeting about their project and their request. A week later, the class presented a copy of the book and draft signs to a City Council member and to the Mayor as part of their argument for the need for increased public awareness of the Superfund site in the city. Because the students did not work in their science groups, the video collected during these activities is not focused enough on Katy and Eddie's participation to say how they each engaged specifically in the practices involved in authoring the river book, the signs for the bridges, and the script students used to present to the Mayor, I do know that both found an opportunity for their ideas and opinions to shape this culminating project.

The book students created summarized the work they had done to understand the Superfund site (see Figure 2 for excerpts). The first portion focused on answering the original questions of interest the students generated about the river, including 'What does it mean that the [river] is invisible?' and 'Why were people dumping toxins and other pollutants?' The next section summarized the water quality data they collected and analyzed, followed by summaries of what they learned from each disciplinary expert about the perspectives on the Superfund site of the stakeholder agencies.

be “invisible.” They argued that signs could help remind people not to pollute so that people would not get cancer, one of the known impacts of exposure to the contaminants in the Superfund site. The book was well received, though the Mayor seemed surprised that the students (and Ms. Jones) had an agenda for the meeting in which they wanted to educate him for a goal they thought he should share. The Mayor proposed that he and the class should work together to get an ordinance passed by City Council, complete with a visit from him to their school to publicize the ordinance and the Superfund site. After making these promises, the Mayor quickly asked what other questions the students had for him and the conversation changed to the current hiring process for a new chief of police in the city. After the field trip, Ms. Jones attempted to follow-up with one of his staff members, to no avail. This, in combination with the upcoming end of the school year kept the students from following up with the Mayor on his promise.

Discussion. Several features of the presentation of the river book to the Mayor positioned students as authors of science-related work and provided an opportunity for them to receive public recognition for this. First, Smith and Sobel (2010) describe authentic, or place- and community-based education as requiring “students to deal with complex information, consider alternatives, apply forms of inquiry and communication associated with academic disciplines to real-world settings, write reports and speeches, and convey their findings and ideas to people beyond the school” (p.77). This idea of consequential culminating presentations of conclusions is a central problem-based learning design principle and what Heath (2012) calls a driving influence on learning. As a class the students created graphic organizers distilling and prioritizing the main points of the complex arguments from each stakeholder agency, other background research, and their water quality tests. Through writing CER statements they began

to summarize what they learned about the Superfund site and the ways that they knew it was contaminated. Additionally, through the production of the river book, draft signage, and a script for their presentation to the Mayor, they represented what they had learned and as a class, developed an argument for increased signage and awareness of the issues throughout the city.

In preparing for and carrying out their presentation to the Mayor, the students in Ms. Jones' class focused on how to inform and persuade the Mayor of their points, which are interdisciplinary skills. The student teachers positioned these in the realm of social studies and civic education, but they are also important aspects of what scientists do (NRC, 2012). This separation is a typical issue where interdisciplinary activities get pulled apart into disciplinary pieces that do not actually match the nature of the work in the real world. The emphasis here was only very loosely focused on how science informs policy as a form of civic engagement, which really was at the heart of the work the students did.

Finally, in the face of significant narrators, the city council and the Mayor, Ms. Jones's students were again positioned as knowers, users, and authors in science in ways that disrupted what the audience (especially the Mayor) expected. Though the final plan was not carried through, the opportunity to present their work to the Mayor was an opportunity for voices that are often marginalized to be heard, even briefly, by those in positions of political power, and to bring to the forefront an authentic environmental justice issue to an authentic audience (Bang et al., 2014).

Case Studies

Eddie. The events described here and the connections between them contributed to a change in Eddie's stance on science and his ability to do science over the course of fifth grade. In summary, there are three things evidenced by the above analysis that contributed to a change in

Eddie's stance on science. First, Eddie saw an opportunity for and worked to make a meaningful connection to Catracho, which was reinforced and grown by multiple meetings in different settings. Eddie interacted with Catracho in the classroom and on the river boat trip, both of which became settings with hybrid goals and language use that leveraged and sometimes made explicit Eddie's multiple identities: as a student, as a native Spanish speaker, as the child of parents who had immigrated the U.S., and as a science-oriented person looking to learn more about it. Catracho's interactions with the class provided Eddie with a science-oriented role model that he felt a cultural connection to.

Second, by talking with his mother about the river investigations, Eddie learned that not only did his family cross the Superfund river every Sunday to get to church, but also that his uncle used to swim in the river. Given the contaminant levels, this was not recommended after heavy rains.

- 1 Researcher: Let's see, are there things that you are excited about that you didn't think were
2 exciting before this year.
- 3 Eddie: The [river]. I always cross the bridge and that was just a regular river. I didn't
4 really care about it. Now I care about it.
- 5 Researcher: You're excited?
- 6 Eddie: Because we go to church there every Sunday.
- 7 Researcher: Oh, okay.
- 8 Eddie: We have to cross the bridge.
- 9 Researcher: I remember you saying that, okay, so crossing the [river]. That's exciting because
10 now you know that it's there. Did you talk to your family about that? About the
11 [river]? What do you tell them?
- 12 Eddie: My mom's like, "Oh, I did not know that." It's one of the most polluted rivers in
13 America. I don't know. We never would notice that it was polluted or it was called
14 the [river]. We just knew it was a river. I'm like, "Did you used to go swimming?
15 I think your uncle did once."
- 16 Researcher: In the [river]?

17 Eddie: He took boat trips when he was smaller. I was like, "Oh yeah? So how come he
 18 doesn't know the name of the [river]? Of the river?" My mom was like, "He never
 19 paid attention to the name of it. He just swam there and went in the boat with it."

Eddie's mother went on to position him as doing something exceptional because of what he demonstrated to her that he had learned through the river investigation.

1 Researcher: Do you feel like your feelings about science are different this year than they were
 2 before, or do you think they're the same?

3 Eddie: Yeah.

4 Researcher: How come?

5 Eddie: I wasn't really good at science. This time I've been learning about science, and
 6 then I talk to my mom about science, she's like, "You never talked like this."

7 Researcher: Oh really, she's noticed.

8 Eddie: Yeah.

9 Researcher: That you were excited about it?

10 Eddie: I talked about it. She doesn't even know ... I used these words that she doesn't
 11 really understand. She's like, "Where do you get this from?" I'm like, "The
 12 school."

In this interview with Eddie, we learned that he felt compelled enough by the Superfund issue to take the language of the investigation back to his family—essentially introducing his family to the complex scientific issue in their community of which they were previously unaware. Eddie's discussion of his conversation with his mother highlights that school experiences (in and out of the classroom) can help shift student discourse and identity. Attending both to how students' home discourses and identities shape learning in school and how school experiences influence what happens for them at home makes clear in this case the ways in which Eddie leveraged his school experience to extend his learning pathway in relation to the Superfund site back at home. With the help of his mother as a significant narrator, Eddie reshaped his perspective on himself as a science learner (Sfard & Prusak, 2005).

Finally, Eddie actively appropriated opportunities to engage in scientific practices and authorship made available to him in both the classroom and in the field. Eddie was consistently an active participant in classroom discussion and small group work, especially using Zydeco to organize his group's data and write CERs. He was usually, though not always, positioned by members of his group as socially and academically competent.

I argue that because of Eddie's experiences across the Superfund river investigation—with its relevance to his family life and connection to a possible future with Catracho—Eddie experienced recognition for a new science-linked identity from several significant narrators, including his teacher, the disciplinary experts, and his mother. Based on Eddie's enthusiasm for making a connection to Catracho, who provided cultural congruence for Eddie in the science classroom in a way that was atypical of Eddie's experience, Catracho's presence especially provided important relational resources (Bell et al., 2012; Nasir & Cooks, 2009), creating a new science-related possible future for Eddie—that he could belong to the group of culturally diverse scientists who draw on their own experiences to do work for social justice. These influences on the scopes of possibility for science learning, across settings and time, contributed to Eddie's new identity as a science-oriented person, as well as his motivation to care for the river and to learn more.

Katy. The events described here engaged Katy in science in new ways—primarily in her classroom interactions with Catracho and with the scientific practices associated with water quality testing. While Katy did not experience the same shifts in scientific identity that Eddie did, she did come to new disciplinary understandings and perspectives at the end of the year.

- 1 Researcher: Do you think your feelings about science this year have changed at all or do you
- 2 think they are the same?
- 3 Katy: I think they changed.

- 4 Researcher: How come?
- 5 Katy: When I was little I used to think that science was super duper boring.
- 6 Researcher: Now what do you think?
- 7 Katy: It's kind of fun.
- 8 Researcher: What did you like about it this year?
- 9 Katy: That we did lots of fun things like go to a lot of field trips because of science.
- 10 Researcher: Are there times during science this year when you felt like you were acting like a
11 scientist or doing the work that scientists do?
- 12 Katy: No.
- 13 Researcher: No?
- 14 Katy: No.
- 15 Researcher: So you think what you were doing was pretty different than what scientists do?
- 16 Katy: Not really but I don't feel like I'm a scientist. I feel like a normal person that does
17 science stuff.
- 18 Researcher: What kind of stuff do you think you've done that's the same as what scientists do?
- 19 Katy: Take temperature [inaudible] from rivers and stuff. I don't know.
- 20 Researcher: OK, so doing some of that water quality stuff you think they've done. Is there
21 other stuff that you've done in class this year or on field trips that you think is
22 similar to what scientists do?
- 23 Katy: No.
- 24 Researcher: You don't feel like a scientist, you feel like a normal person who does science?
- 25 Katy: Yeah.
- 26 Researcher: What would it feel like to feel like a scientist?
- 27 Katy: Have a white coat on. (laughs)

As learners move into new communities of practice, participation within the prevailing cultural practices must be reconciled with their personal notions of self (Gutiérrez, Baquedano-López, & Tejada, 1999; Van Horne & Bell, in preparation). Katy showed an important affective shift in her perspective on how fun science was. However, she held onto her very canonical view of scientists, and of herself, one that continued to keep her from thinking of herself as a scientist. Zimmerman (2012) tells a similar story of Penelope's hybridized identities. Penelope, like Katy,

did not seek to be recognized as a scientific person, while still learning scientific content and practices in informal and formal spaces in her life. The evidence here bolsters Zimmerman's point to the importance of recognizing the ways that under-represented youth in science engage in science-related activities, even as they distance themselves from science.

The findings here also support Zimmerman's (2012) claim that studies of science learning and identity must be a holistic account including "youth's intentions and perspectives when participating in science practices" (p. 625). Katy's story is a complicated one and there are several possibilities made explicit in this study that contribute to her outcomes. First, Katy told us that she saw the practices on the fieldtrip as closely related to everyday practices she was already engaged in, which on one hand may have helped her to see her home practices as more science-related. On the other hand, this may have kept her from seeing the practices she engaged in on field trips as novel or interesting in ways that would pique her excitement or interest in science.

Though Katy recognized and leveraged the shared linguistic resources that Catracho brought to the classroom, Catracho's role as a cultural match did not offer Katy the gender congruence that it offered Eddie. This is just one of several possible reasons Katy did not make a strong connection to Catracho and therefore did not see the same possible futures for herself that potentially led Eddie to come to care about the river and want to learn more. It could also be that she was aware that most of science tends to be male-dominated. Additionally, Katy told members of her family about her experiences with the river investigation, these interactions did not carry the same weight that Eddie's did for him. If this is true, Katy's experiences were not reinforced over time as Eddie's were.

Additionally, as mentioned earlier, further analysis of Katy's classroom interactions are needed to fully understand how she was positioned by herself and others in relation to doing science. While Eddie was sometimes positioned out of science activity in the classroom, as Chapter 4 will show, this was a much more prominent feature of Katy's typical experience than Eddie's. Overall, Katy did find ways to engage in authentic scientific practices, especially on field trips, that contributed to a change in her perspective on science class as fun. However, because she did not experience many overlapping and redundant supports that Eddie experienced— significant narration from family members, both cultural and gender congruency in a science-credentialed role model, and consistent, central participation in scientific practices in the classroom— Katy did not recognize that the intervention described in this study contributed to a significant change in her stance on herself as a science-oriented person. However, the findings here provide evidence that Katy was making progress toward a more positive affective perspective on science, as well as more central participation in scientific activities.

Discussion

The purpose of this study was to examine the ways that designing for learning across settings can position young people in relation to science. The findings describe the ways in which non-dominant elementary youth engaged in scientific practices and identity work in and across a range of settings, and the instructional design features that supported these outcomes. Little attention has been paid to the ways that hybrid spaces might be created by coordinating learning across a variety of informal and formal learning environments over time. In what follows, I discuss the features of this study that supported the creation of generative hybrid spaces, where students gained access to new forms of participation and identification. I argue that through the leveraging of authentic resources, opportunities for student authorship (and

coordination) of boundary objects, and specific narratives (or images) of science across time and settings expanded the scopes of possibility available to youth in relation to science learning and identification. Additionally, I discuss the findings described here in relation to youth activism to demonstrate how design research like this can be leveraged for the civic engagement of youth.

Authentic Resources

Previous work highlights in the importance of engaging youth with authentic practices, texts, roles, and places (e.g., Dewey 1902/1990; Kirshner, 2008; Smith & Sobel, 2010). In this study the introduction of and engagement with authentic resources in and out of the classroom over time created several generative hybrid spaces for learning. A key feature of this study that supported youth engagement in scientific practices and identity work was access to authentic resources in relation to a real-world problem (Bell, 2004; Van Haneghan et al., 1992). Students were supported to navigate complex resources intended to be leveraged by mostly adult audiences and stakeholders as the Superfund site clean-up plan was developed, debated, and settled. This activity in itself hybridized the typical learning environment and associated structures of the classroom with the real-world practices, discourses, and narratives of science in the real-world.

Beginning the investigation of the Superfund site with student sense-making of authentic texts set students on an important trajectory that reshaped their involvement in scientific practices and identity work throughout the year. It enabled them to engage in several subsequent learning situations in new ways as knowers, users, and authors of science. Students were prepared to be critical consumers, to engage with disciplinary experts in the classroom as competent developing experts with opinions about the clean-up plan, not just seeking answers, but listening and interacting with a thoughtful and critical lens. The confluence of this

preparation, the new positioning it afforded students, and the resources and discourses brought by the disciplinary experts created a hybrid space in the classroom where students engaged in new forms of participation. While all of the disciplinary experts introduced new scientifically-credentialed role models into the classroom, Catracho's visit especially created new opportunities for recognition of identities not typically leveraged in classroom instruction. In this way, the social space of the classroom was restructured to make new ways of being, knowing, and doing available to youth (Bell et al., 2012; Herrenkohl & Mertl, 2010). This space made explicit for some students the ways in which identities can be hybridized, in that multiple identities can be merged and leveraged to make new connections to disciplinary work.

Both the classroom visits from disciplinary experts and the students' visit to City Hall marked hybrid spaces where students' typical ways of being at school (and on school sanctioned fieldtrips) merged with the new positionings as developing experts and the typical expectations of the people students interacted with. In both spaces, students' positioning as developing experts acted to disrupt the typical societal narratives of youth, especially marginalized youth (see also Ladson-Billings, 2009; Ladson-Billings, 2014). The adults, as public figures and scientifically-credentialed role models had the potential to act as significant narrators, positioning (and publicly describing) youth as competent, informed, and poised. While the findings presented here do not deeply address the meaning that students (or adults) made of these experiences and the subsequent shifts in the societal narrative about what marginalized youth are capable of, it is possible to say that these stories traveled- to the teacher, to the students, and home to some students' families. Future research is needed to fully understand the impacts of these stories on longer-term opportunities for equitable science learning. However, Bang et al. (2014) say that opportunities for marginalized youth voices to be heard by people in positions of power are rare

and crucial, both for engaging youth in the political, environmental, and economic issues that affect them, and for finding solutions to the problems themselves.

Youth Authoring of Boundary Objects

In this study, boundary objects played an important role in the creation of generative hybrid spaces. The investigation questions, student-collected data, and written explanations in response to the investigations, all facilitated by a mobile application, served as boundary crossing objects by inhabiting “several intersecting worlds and satisfy[ing] the informational requirements of each of them” (Star & Griesemer, 1989, p. 393). With the exception of the investigation questions, the boundary objects described in this chapter were all created by students—they represented socially genuine opportunities for youth authorship in relation to the investigation of the Superfund site. The creation of these objects allowed students to engage in scientific practices, such as taking ownership for and analyzing data they collected in authentic places and to leverage what they had gathered from important community spaces back into classroom practices. These objects mediated student engagement with environmental science by providing continuity across settings that allowed for students to engage in practices that would have been otherwise unavailable to them, such as analyzing primary data in service of understanding the Superfund clean-up debate. Finally, I argue that the student generated questions, used to critique and challenge the disciplinary experts, as well as the culminating book about the river, served as boundary objects that facilitated the development of hybrid spaces because students were able to leverage them to gain access to new positionings and participation in practices across a variety of settings. Like engagement with authentic texts and other resources, these objects helped to facilitate the disruptions of expectations of what youths’ capabilities and position them as knowers, users, and authors of science.

Akkerman and Bakker (2011) point out that it is important to note that boundary crossing should not be seen as the dissolution of boundaries between spaces, but “rather as a process of establishing continuity in a situation of sociocultural difference” (p. 152)—across the student investigation of the Superfund site and the policy conversation with the Mayor. In this study I have described examples of the ways that continuities across settings played out for some students. Future work should attend more deeply to ways in which the boundaries between settings exist and are shaped by the sociocultural differences between them in order to better understand how to bridge authentic learning across important spaces in the lives of youth.

Narratives of Science

Tzou et al. (2010) argue that youth must be engaged in the prevailing narratives of the environment in order to make explicit their positioning in relation to environmental issues. This did not happen in the ways that the original design called for, by engaging students in developing narratives of science and the environment in their own lives and examining these in relation to prevailing narratives. However, Ms. Jones used narratives about the culture of science to demonstrate how socio-scientific issues are hybrid spaces themselves. By engaging students in the complexities of the Superfund clean-up plan, encouraging a critical stance, emphasizing the importance of community involvement and access to science, and highlighting students’ abilities to collect their own data and generate their own ideas, Ms. Jones described the co-construction of socio-scientific issues, such as that of the Superfund clean-up plan, as an interdisciplinary and messy endeavor. She specifically outlined the ways in which science should draw on the cultural resources not only of disciplinary experts, but also on the communities impacted by policy decisions that are informed by science. One way to address this further in future studies would be to engage students in an adaptation of a “testimonio” activity (e.g. Gutiérrez, 2008; Perez Huber,

2009) in the classroom, in which youth have an opportunity to reflect on and share in their own voices their experiences in science learning and how their everyday lives and communities have been reflected (or not reflected) in those experiences. This kind of activity provides space to “develop students' new understandings about themselves and their relations to the immediate and the larger social world” that they could then use to navigate other settings (Gutiérrez, 2008, p. 149).

Ms. Jones portrayed the work of using science to understand and solve community-based problems as a contentious arena, where people do not always agree on what constitutes the right answers and the best solutions for all people and the environment. Though these narratives about the environment and the culture of science did not deeply address conflicting ways of knowing and the inequities that perpetuate issues of environmental and social justice, they did make clear to students the ways that socio-scientific issues like the Superfund site are, and should be, co-constructed by a variety of voices, goals, and contexts (Gutiérrez, Baquedano-López, & Tejada, 1999). Future work is needed to further address the ways that already marginalized youth (and other community members) are further positioned out of scientific activity through these narrations.

In summary, the coordination of learning across settings in this study created opportunities for engagement in overlapping and iterative social and scientific practices that reinforced content, relationships, interest, engagement, and ultimately the uptake of identification resources for students in science. The study design created a range of differentiated hybrid spaces, not just in that students drew on cultural resources of one setting in another, but also by introducing and merging new social and scientific meaning-making practices into settings like the classroom, disrupting both student and adult perceptions of what it means for fifth graders to

engage in science through “new understandings, extend[ed] navigational possibilities, and adapt[ing] meaning-making practices to new forms and functions” (Rosebery, Ogonowski, DiSchino, & Warren, 2010, p. 324). Positioning youth as contributors to authentic endeavors using scientific practices supported engagement in important identification work by expanding the resources available for students throughout this study, and hopefully in the future.

Engagement in hybrid spaces and in authentic work in this study were important because they helped students to see themselves as member of their community and as agents of social change. Students were positioned in these hybrid spaces as developing experts with the ability to prioritize and leverage resources they needed to create explanations and arguments based on their experiences with varied institutions (through disciplinary experts) and in other places. The merging of practices and identities in and across spaces provided opportunities for the development of new identities, as it did for Eddie, as a science-oriented person. It created new scopes of possibility by repositioning youth, through new storylines that disrupted preconceived notions and stereotypes, and changed the discourses for both youth and adults about what youth were capable of and the kinds of people they could be.

Youth Activism

While activism was not part of the original design, the events that emerged in this study provide insights into the important learning outcomes that might be facilitated by including youth activism as a goal of designing for learning across settings. Over the course of this enactment and the subsequent analysis, it became clear that to fully examine the importance of designing for learning across settings for positioning youth as developing experts, it is necessary to include some discussion of what it means to support youth activism work.

Kirshner (2008) describes youth activism as more than just engaging in activities of community service, but that which “seeks to influence public policy or change institutional

practices, often with a social justice focus” (p. 63). Youth activism focuses on emergent, open-ended, real-world tasks that often culminate with youth interaction with or presentation to public officials. Youth activism groups exist primarily in out of school organizations, where youth are expected and empowered to drive the work and lead their peers (Kirshner, 2007).

While the design for this study originally included an action project of some kind, I did not know that we would be able to facilitate student access to disciplinary experts or other policymakers such as the Mayor until the middle of the year. Some of these opportunities arose only a few days in advance, as a result of Ms. Jones’ interest and persistent inquiries. Additionally, even when the Mayor’s visit was scheduled, it was originally intended, as in years past, to be part of the domain of social studies. It was only a few weeks before that Ms. Jones made the call to connect the students’ visit with the Mayor to their work on the Superfund site. These are just some of the complex logistics involved in doing authentic, emergent work with youth.

In this study, the work the students did to prepare for and present at the Mayor’s office could be described as a ‘token’ opportunity for youth participation for two reasons. First, the focus of the culminating project on developing a sign that would let people know about the Superfund site was a worthy and important avenue to educating the public. However, in the end, students did not engage fully in the central socio-scientific issue at hand: the final clean-up plan. In hindsight, an authentic culminating task would have been to engage students in the specific scientific, political, and economic details of the clean-up plan itself, especially as the plan had implications for the community and the natural environment, in order to develop their own arguments for selecting a particular clean-up plan. Second, students were not able to see through the Mayor’s promise for an ordinance and a publicity event. While this is probably as authentic

an outcome as any that comes from the political process, students did not get to see any efforts toward making their request a reality.

However, in a time when many elementary school classrooms include virtually no science instruction at all, I argue that the design features described here that supported students in Ms. Jones' class to authentically engage with the scientific and social practices associated with a complex community-based issue can still provide a model for considering how to engage students in local, problem-based issues in some of the meaningful ways that youth activism work happens. In addition, the opportunities for youth in this study represent an incredible commitment by Ms. Jones and the administration at Granite Elementary to science education. Ms. Jones, who engaged in the Superfund site investigation with her students in addition to thoroughly covering three district science kits that year, particularly demonstrated a commitment to empowering youth and disrupting societal expectations, especially for marginalized youth. By supporting students to engage in scientific practices and interact with disciplinary experts in meaningful ways, her work, even in what might be considered a pilot year, contributed to positive student outcomes, but also served to disrupt typical adult views of youth, positioning youth not in a deficit model of education, or worse, as "vulnerable or dangerous," but as competent, critical thinkers with important contributions to make to their communities (Kirshner, 2008, p.63; see also Rosebery et al., 2010).

Design Implications

The findings from this study have several implications for future designs of learning across settings. First, youth should be engaged in community-based problems that position them as developing experts who can contribute to solutions and to a better understanding of the problem. The most powerful experiences for youth in this study in terms of engagement in

scientific practices and access to science-related identification work came from iterative and overlapping opportunities in which youth began to develop relationships with disciplinary experts, and with place. These developing relationships were crucial to how youth saw themselves as members of multiple and overlapping social and geographic communities, which ultimately helped Eddie develop a sense of responsibility and agency in relation to helping with the Superfund site.

In terms of the sense-making processes that teachers and students engage in both in the classroom and in community locations, there are two main implications of this study. First, designing cross-setting interventions of this kind is complex and challenging, especially in coordination of the learning of disciplinary core ideas across settings and activities. In this study, scientific practices were relatively easy to keep track of and facilitate—in the design we and the teacher often focused on what students would actually do in and out of the classroom. The focus on writing CERs, in itself a major change in classroom practice for Ms. Jones and her students, in coordination with other practices in and out of the classroom, obscured the central scientific concept, what makes water clean. Foregrounding and revisiting the core scientific question, and possible explanations, should be the major focus of preplanning and the enactment.

The second implication for sense-making processes has to do with the intellectual roles that students take on in relation to social positioning and curriculum design. The benefits of assigning students different roles at several steps along the way (e.g., large group discussion, small group work, data-collection, writing explanations) are well-documented elsewhere (Cohen, 1994; Herrenkohl, 2006) and evident in the water quality field trip described here. Engaging students in specific intellectual roles, as well as in reflection on the contributions they and their classmates make, would likely have provided more equitable outcomes for students in our study

like Katy, who would have benefitted from more central positioning in relation to scientific practices in the classroom.

Partnerships with different organizations are essential for carrying out this kind of cross-setting intervention in schools. The partner organizations in this study facilitated access to people, places, and ideas that would otherwise not have been available in the classroom. There are many community-based educational organizations that are designed specifically to serve teachers and students, but coordinating learning between schools and these programs can still be complicated and challenging. Field trips and guest speakers are not often well connected to the classroom curriculum and a great deal of preparation and collaboration is required to leverage these opportunities to deepen student learning and not just add more commitments to the schedule for teachers. While the details of these challenges to design for coherent learning experiences and their implications warrant their own chapter, it is worth noting that informal organizations that partner with classrooms should strive to leverage their unique resources to meet the specific learning goals of classrooms (NRC, 2015). Particularly, community-based, informal educational organizations can provide unique and hybridized opportunities for students to engage in scientific practices in authentic places and with a variety of community members who can support youths' scientific identities. Informal educators and community-based organizations could be more centrally included in professional development focused on the vision associated with the *Framework for K-12 Science Education* (2012). School administrations and teachers need to develop capacity to support and facilitate relationships between schools and community-based organizations to leverage the rich resources available outside of schools.

Conclusion

Storksdieck (2011) draws on literature in environmental and sustainability education to argue that the interdisciplinary nature of these subjects requires that learners are not isolated from the larger world, but that “formal and informal elements of education are supported alongside each other in a coherent framework” (Palmer & Birch, 2003, p. 459). Further, Storksdieck (2011) argues successful learning happens when learners are engaged in real-life experiences that cross typical subject boundaries. This chapter makes evident the ways in which designing for learning across boundaries—both of discipline and setting—can engage youth in authentic, community-based, scientific issues. The analyses show some of the complexities that arise during the implementation of an enactment across settings and time, but how powerful the outcomes for youth can also be. A close examination of the case studies for other students in Ms. Jones’ class would likely tell different stories than those showcased in the analysis. However, the stories of Katy and Eddie point to the importance of engagement in scientific practices and with disciplinary experts, opportunities for public contributions to change in the community, significant opportunities to narrate science, and bridges between the classroom and everyday and family practices and interests.

Young people must be engaged in the communities where they live to address solutions to real-world problems—both to create new forms of meaningful learning, but also to better inform solutions by engaging the perspectives of all community members. This chapter describes a very small part of what was a complicated and rewarding enactment designed toward this end. The findings point to several possible features of future models for engaging youth in science and activism to make change in their communities.

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Chapter 4: Images of Engineering and Learning: Social Positioning Dynamics in a Fifth-Grade Engineering Design Project

Engineering education is an integral part of science, technology, engineering and mathematics (STEM) education, but did not exist in K-12 science standards until the creation of the *Next Generation Science Standards* (NGSS, 2013). The standards, in conjunction with the *Framework for K-12 Science Education* (NRC, 2012), call for a shift in focus to practices, concepts and ideas of science *and* engineering with dual goals of preparing learners for further education and careers in STEM and preparing all learners to be critical, well-informed citizens. These consensus documents argue for this shift in order to provide a foundation for all students to “better engage in and aspire to solve the major societal and environmental challenges they will face in the decades ahead” (NGSS, Appendix I, p. 103) by engaging learners in the ways in which STEM fields are integrated, and by emphasizing an understanding of the human-built world (NRC, 2012, p. 2).

Engineering education, defined as “any engagement in a systematic practice of design to achieve solutions to particular human problems” (Appendix I, p. 103), can serve as a useful pedagogical strategy because it provides a context for learning science, math, and technology concepts, is highly iterative, includes problems which may have multiple solutions, and focuses on models, systems, and analysis (NRC, 2009, p. 4). Additionally, the shift to include engineering education standards in K-12 science education has the potential to provide access for historically marginalized learners who may see science as irrelevant to their daily lives. Engineering education is especially positioned to attending to educational equity because it provides opportunities for addressing meaningful problems that are both personally- and community-relevant (NGSS, Appendix I, p. 104).

However, a more integrated model of STEM education that includes both science and engineering practices has implications for changes in classroom practice. These changes represent a major shift from traditional approaches which ignore engineering education and reduce science education to that in which students “observe what they have already been taught” (Reiser, 2013, p.7). Implications include developing pedagogical approaches to engage learners in engineering practices to define problems and design solutions. To understand how to successfully engage teachers and learners in what may be novel classroom practice requires understanding the contexts in which learning happens. In this chapter, I describe how one teacher adopted these new engineering practices as learning goals, and how the subsequent availability of identity resources allowed learners to engage in science and engineering to varying degrees. I analyze the instructional design features that made images and practices of engineering available to fifth-grade students as their veteran teacher engaged in co-design and enactment of engineering design in the classroom. Further, I examine the implications of “images of engineering” available in the curriculum and in teacher practice for the social positions available to students related to disciplinary learning.

Theoretical Framework

Sociocultural accounts of science education recognize science as a particularly contested area as the specific practices, discourses, texts, and values of academic science often stand in stark contrast to learners’ everyday lives—especially those of marginalized learners (e.g. Aikenhead, 1996; Calabrese Barton, Tan, & Rivet, 2008; Moje, Collazo, Carillo, & Marx, 2004; Phelan, Davidson, & Cao, 1991; Tzou, Scalone & Bell, 2010). For example, Calabrese Barton et al. (2008) describe the science classroom as “its own subculture, with particular ways of knowing, talking, and doing that do not always clearly align with the social worlds that youth

bring to learning science” (p. 72). Participation requires navigational knowledge of the assumptions and values in play that may not be apparent to all learners. The *Framework for K-12 Education* (NRC, 2012) and the *Next Generation Science Standards* (NGSS, 2013) explicitly set out to increase equity in STEM education, describing how science education reform must merge the everyday cultural worlds of learners and the culture of science to better understand the broader outcomes for learners. Sociocultural studies of science learning consider aspects of learning environments such as the shifting of roles in relation to each other over time, the development of certain ways of being in relation to science, and broadening views of who can do science and what science is (e.g. Bell et al., 2009; Bell et al., 2012; Bricker & Bell, in review; Brickhouse & Potter, 2001; Calabrese Barton & Tan, 2009; Carlone & Johnson, 2007; Herrenkohl & Mertl, 2010). For example, Herrenkohl and Mertl (2010) emphasize a broad recognition of the ways of knowing, being, and doing that students contribute to and that emerge in a science classroom. They describe evidence of how students gained knowledge and skills, but also came “to understand themselves as science learners in new ways,” which have the potential to open up new science learning pathways (Herrenkohl & Mertl, 2010, p. 193).

The *Framework* (NRC, 2012) states that engineering design is a valuable context for learning scientific practices and the integrated nature of the varied fields of STEM, but also that it is a useful venue for addressing educational equity in science and engineering education. From a sociocultural point of view, the problem-based nature of engineering design makes it uniquely suited to engage students in personally- and community-relevant issues. Additionally, design work as a problem-solving strategy can specifically support efforts in classrooms to engage students in making sense of scientific phenomena. However, because engineering design represents a new pedagogical strategy in most classrooms, it is important to consider in more

detail how implementation can support these learning goals. In this theoretical framework, I first characterize design work and then describe how design work can drive the restructuring of traditional classroom dynamics to provide a supportive learning environment for all learners.

Engineering Design Work

Design activities span a variety of disciplines and can provide authentic, interdisciplinary, and problem-based contexts for learning (Roth, 2001). In order to characterize the nature of engineering design work in the classroom, it is useful to consider not only theories of engineering design, but also of design processes used more broadly across disciplines.

Design work can be considered a strategy for problem-solving. Studies of design work have found that while there is no specific formula for engaging in the design process, there are features present in the process that all designers undertake (Braha & Reich, 2003; Razzouk & Shute, 2012). It starts with the identification of a specific problem and is shaped both by what the design is intended to accomplish (the criteria or specifications) and the limitations that must be addressed (constraints) (NGSS, 2013). For example, the building of a university student dorm must meet the criteria of housing a certain number of people while contending with constraints of space, building codes, and cost. Designers research the identified problem, generate ideas for solutions, create conceptual or built models, evaluate solutions through systematic testing and analysis of data, identify and evaluate failure points and trade-offs, and iterate on their designs in order to come up with the best solution with respect to both the criteria and the constraints (Braha & Reich, 2003; Razzouk & Shute, 2012). Criteria and constraints can be technical, based on scientific theory or practice, or human-centered, and can therefore be negotiated (Bucciarelli, 1988). In the example above, designers have to contend with technical considerations such as the

construction of load-bearing walls, as well as human-centered constructs such as aesthetics of layout and interior design.

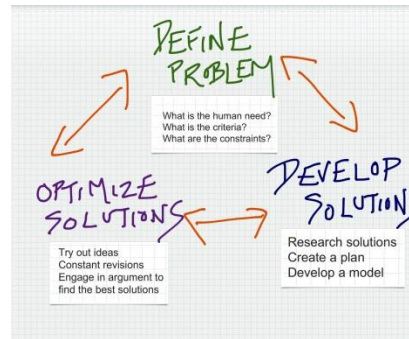
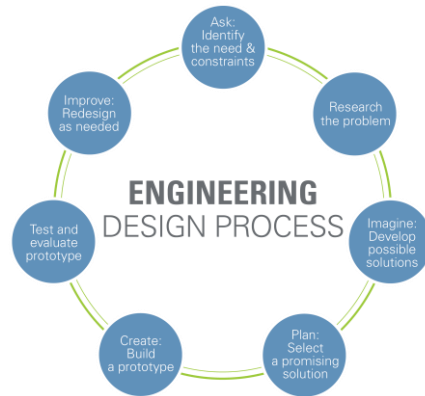


Figure 4.1. Engineering design process (from teachengineering.org) *Figure 4.2.* Engineering design triangle (drawn by Ms. Jones, adapted from NGSS)

Design work is often dynamic and in flux, meaning that the problem, criteria, and constraints can undergo constant adjustment as ideas or additional problems are discovered or identified (Hatchuel and Weil, 2009). Braha and Reich (2003) describe it as an “iterative, exploratory, and sometimes a chaotic process” (as cited in Razzouk & Shute, 2012, p. 182). While engineering design is a creative and iterative process, it sits apart from other kinds of design (such as fashion or landscape) in that it is also governed by systematic and principled rules that are not absolute, but summarize years of accumulated experience (NRC, 2009, p. 38) (see Figures 1 and 2 for examples of instructional depictions of the engineering design process).

Finally, design work is a social process (Bucciarelli, 1988). Design work requires the collaboration of people across disciplines, such as engineering, marketing, and operations, to fully understand complex problems, and design and implement a solution. Optimization of designs happens as designers work together to identify and evaluate failure points and trade-offs in relation to criteria and constraints, while interdisciplinary interaction ensures that designs fully account for all aspects of a particular problem, both technical and non-technical. Disagreement

and the challenging of ideas in design teams can be very productive because it often leads to re-examination of design proposals and consequently, better strategies (Stempfle & Bradke-Schaub, 2002, p. 492).

In some previous studies, the social nature of design is accounted for by documenting the importance of interpersonal skills within and across disciplines (e.g. Razzouk & Shute, 2012). Roth (2001) goes further to describe design as complex work situated at the intersection of social, historical, political, psychological, and economic influences. For example, Bucciarelli (1994) calls out the variety of activities and contexts that engineers engage in, some solitary and some collaborative, as “potentially important design acts; all may influence the way the design proceeds and the ultimate form of the artifact” (p. 160). The process of design and the final artifact reflect the divergent or shared norms, perspectives, goals, beliefs, and interests of the design participants (Bucciarelli, 1994). In this view, because design is socially-constructed, design activity must be considered to be situated – it cannot be separated from the context in which it occurs. Thus, the social, historical, and institutional environments in which design work occurs shapes design activity (Lave & Wenger, 1991; Liem & Brangier, 2012; Suwa, Gero, & Purcell, 2000).

In summary, designers act as authors of solutions in complex and sometimes ambiguous territory to solve ill-defined or open-ended problems—those that do not have a predefined outcome or expected solution. Some prior research has described design-thinkers as those who are recognized by others as technically knowledgeable, systematic but flexible, proficient at selecting and prioritizing pertinent information and making evidence-based decisions, tolerant of ambiguity, and effective communicators (Razzouk & Shute, 2012, p. 336). While this previous work describes some of the important traits and skills for individual and collective success in

design work, it does not thoroughly take into account the situated view of engineering design. Sociocultural perspectives on engineering, such as Bucciarelli (1994) or Hall and Stevens (1994), highlight the ways in which engineering design happens in communities of practice (Wenger, 1998), focusing on the particular behaviors, identities, and discourses that are privileged and resourced (or not) in design settings (Lave & Wenger, 1991). Making explicit the features of design contexts and social interactions that support recognition of people as design-thinkers is important in order to support broadening participation in design fields (Bell et al., 2012).

Design Work in the Classroom

Researchers and practitioners who have successfully engaged students in design work recognize that to engage students in the authentic features of design, attention must be paid to the structures of design enactments in classrooms. The open-ended and collaborative nature of design work requires “a reworking of traditional approaches” in education, shifting towards “student-centered pedagogies that allow students to participate in design communities in a way that positions them as producers of knowledge and active designers of their own social futures” (Mathews, 2010, p. 1). Previous research has documented the positive outcomes that occur for youth in learning environments that afford opportunities for agency, choice, and other resources for trying on new possible identities (Ito et al., 2013; Mathews, 2010; Scalone, 2015). However, the features of these environments mark a potentially new and uncomfortable learning ecology and positionings for some youth, especially in relation to their typical school experiences. For example, Mathews (2010) describes a studio-based curriculum intervention where students initially struggled in the semi-autonomous context to conceptualize, organize, and carry out their own projects. Engaging students in dialog about the differences between design work and traditional structures of classroom learning environments allowed students to recognize and take

on new, more autonomous roles as authors and producers of knowledge in the project.

Familiarizing youth by making explicit the privileged practices, identities, and discourses of design work is important in order to make clear how design activities can build on youths' assets, such as previous experiences and interests.

To position youth as authors and producers of knowledge through engineering design, classroom communities must support students in new practices associated with design-thinking and productive disciplinary engagement. The focus on the practices of science and engineering in the NGSS highlight a shift from traditional models of science education where students *learn about* scientific ideas to one in which students *figure out* scientific ideas that explain how and why phenomena occur (Reiser, 2013, p. 4). The NGSS presents engineering design as a potential avenue for students to uncover and explain scientific phenomena—to become producers of knowledge in the classroom.

Roth (2001) describes classroom engineering design enactments not as dependent on “acquisition of all principles of science, engineering, and design before actually engaging in design” (p. 212), but as a venue for acquiring just in time knowledge. While traditional models of design learning might focus on learning as the application of knowledge to design, Roth argues that innovative design uses knowledge as just one of several resources “secondary in importance to the norms and practices in the particular community” (p 212). Engineering design in classrooms is a productive process for sense-making practices, rather than just a product of those practices. Sense-making can take a variety of forms in and out of school (e.g. Zimmerman et al., 2010). The NGSS put forth several sense-making practices in science and engineering education, with a particular focus on explanation and argumentation, in which students develop and argue their ideas in order to make sense of natural phenomena. As one example of how

sense-making has been supported in the classroom through explanation and argumentation, Engle and Conant (2002) put forth four instructional supports for student debate in the classroom:

1. Making the subject matter problematic.
2. Giving students authority to address such problems.
3. Holding students accountable to disciplinary norms.
4. Providing relevant research resources.

These tenants are intended to provide a framework for supporting productive disciplinary engagement, and are well-aligned with the engineering design process in classrooms in which students work to understand a problem space in order to find solutions by engaging with problematic subject matter and debating their ideas. Engle and Conant (2002) found that this framework enabled students in their study to adopt such practices as using evidence to support their claims and holding themselves accountable to the contributions of others.

Reworking traditional approaches in the classroom to support sense-making through design work has important implications for classroom communities in general, but particularly for collaborative small group work. In this chapter, I put particular focus on small group work for two reasons. First, collaborative work is a common, authentic practice both in professional design work and in classrooms that has implications for what work is prioritized, how work gets done, and how one is identified as a contributor. Though many students spend a lot of time in classrooms doing group work, the open-ended and iterative nature of collaboration in design work means that students may need to modify the steps they typically go through to solve a problem and complete a group design task. Second, attending to how design work supports students in productive disciplinary engagement in small group work is important because the identities, practices, behaviors, and discourses in play in small groups are much different than those in the whole classroom setting (Barron, 2003; Cohen, 1994). Specifically, Barron (2003)

points out that while school values specific kinds of identities, often focused on individual achievement, group work values other kinds of identities and prosocial behaviors.

Much work has been done on the successes and potential inequities of cooperative groups in classrooms that can inform how engineering design work can be successfully implemented in classrooms. Systematic inequalities based on factors such as academic and socioeconomic status, ethnicity, attractiveness, popularity, gender, and race can lead to both inequitable interactions and unequal learning outcomes (Cohen, 1994). Cohen describes the ways in which status, defined as “an agreed-on rank order where it is generally felt to be better to be high than low rank” (p.23), affords some students opportunities to engage in the social and material resources of a learning environment and constrains these resources for others.

Barron (2003) argues that cooperative group work requires that students engage in both the *content space* (the problem to be solved) and the *relational space* (the interactional challenges and opportunities) (p .310). These two spaces must be negotiated simultaneously, as students monitor their own progress in relation to that of others, in terms of epistemic and social processes. This negotiation therefore requires understanding of how one is positioned in relation to the complexities of the problem and the group, as well as how to position oneself in relation to these in order to meet ones’ goals and those of the group. In other words, a student needs to monitor and evaluate how their thinking about the problem aligns or misaligns with others in the group, and needs to be able to communicate and negotiate effectively in order to complete the task. Barron points out that identification work is in play in these negotiations, as students consider whether they can take the social risks involved in disagreement or admitting confusion or uncertainty.

Engineering design provides a potentially productive learning environment for students to engage in scientific and engineering practices, for meaningful sense-making (productive disciplinary engagement), and for engaging students in personally- and community-relevant issues. However, if we want to authentically position youth as designers and authors, we need to consider how the sociomaterial arrangements of the classroom, especially in small group work, support students to engage in the chaotic but productive spaces of engineering design.

I argue that to restructure the classroom to focus on an intentionally ill-defined task such as engineering design in collaborative small group work, we must understand the social positionings that are available or unavailable to learners as they navigate both the content space and relational space, and determine how these positionings afford or constrain their engagement in engineering practices and their scopes of possibility in relation to engineering. In this work, I describe the enactment of engineering design in one fifth-grade classroom as students designed solutions for a classroom-based problem. I use the Cultural Learning Pathways framework (Bell et al., 2012) to examine the discourses, positionings, and identities privileged by the enactment design, the images of engineering portrayed by the teacher, the dynamics of small group work, and how these factors impacted the availability of identities related to science and design for students.

To this end, this chapter addresses the following research questions:

1. How do engineering design practices get appropriated by a fifth-grade teacher and enacted with students in her classroom?
2. Specifically, how do the “images of engineering” embedded in the curriculum and implementation shape the social positions available to students as they engage in engineering design tasks?

Teacher and Researcher Curriculum Co-design Collaborations

This study took place in the context of instructional design work which emerged from two intersecting research practice partnerships. The primary partnership, from which this engineering design enactment took place, took a design-based implementation research (DBIR) approach. This approach seeks to address the challenges of developing programs and policies that can be broadly used in a variety of settings, while attending to the specific constraints and affordances of each setting. To this end, DBIR projects range in scale from individual classrooms to multiple school districts, and have four common elements (Penuel & Fishman, 2012):

1. A commitment to iterative, collaborative design,
2. A focus on persistent problems of practice from multiple stakeholders' perspectives,
3. A concern with developing theory related to both classroom learning and implementation through systematic inquiry, and
4. A concern with developing capacity for sustaining change in systems.

The intent of these principles is to build partnerships which develop, test, and refine models of educational engagement through iterative design and implementation over time in ways that allow products and programs to travel across contexts.

The Collaborative Projects Context

The Science Education Improvement Project (SEIP). The teacher at the center of this study participated in two separate but intersecting research practice partnerships during the year of this study. The first was a three-year DBIR project designed to launch implementation of the NGSS by creating a network of practitioners from two neighboring districts and researchers to form a university/school district partnership called SEIP. The focal problem of practice for the SEIP design research partnership was to develop a strategy to support teachers to adapt existing curriculum in order to take up the NGSS scientific practices, with a focus on explanation, argumentation, and engineering design solutions. The SEIP project included 70 teachers from

two schools in two districts. The partnership started with a five-day summer institute, with the intent to: 1) build content knowledge about the practices in NGSS, specifically explanation, argumentation, and engineering design; 2) identify teaching tools to support student engagement in those specific practices; and 3) adapt existing curricular materials to include the highlighted practices. Specifically, teachers and researchers partnered to develop *lesson enhancements* in existing curriculum that accompanies district science kits with a focus on a claims, evidence, and reasoning (CER) (McNeill & Kajcik, 2012) structure and engineering design challenges. After the initial summer institute, practitioners and university partners met three times over the course of the school year to analyze student work and reflect on emergent problems of practice.

This partnership project was built with several design features that have implications for the study presented in this chapter. The first feature was a shift away from the top-down approach typically employed in district professional development toward a focus on teacher agency and planning. This shift served to validate the informal sharing strategies of teachers within their networks and marked a change in the culture of science education from the districts' perspective. The teacher in this study took a central role in the design of lesson enhancements and co-facilitated a professional development at her school to engage other teachers in focal practices. Another feature was the introduction of teachers to engineering design in student-accessible ways, which was a new focus for almost all of the teachers participating in the partnership. In order to help teachers find their way into new forms of instruction, the district partners focused on providing a low bar that could be exceeded, rather than a high bar that felt inaccessible. The intent was to facilitate shifts in instruction over the course of the school year as practitioners analyzed and reflected on student work across their classrooms during that time period. Additionally, a decision was made in the initial summer institute not to focus on the

sociocultural aspects of instruction, such as specific facets of facilitating social interaction. However, partners helped facilitate the development of tools such as a social construction learning sequence designed to help teachers consider how to engage students in the social practices associated with explanation, argumentation, and engineering design.

Environmental science learning across settings. The teacher in this study was also part of a year-long design-based research study focused on connecting environmental science and engineering practices across settings for fifth-grade students, as described in Chapter 3. Over the course of a school year, the teacher and I co-designed a year-long set of coordinated environmental science and engineering activities in three settings: the classroom, a residential environmental field program, and several local ecosystem exploration field trips. I collected data during the Land and Water district kit curriculum enactment because of the potential emergent connections to the environmental science unit as we developed it throughout the year. This cross-setting project introduced the teacher and students to Zydeco, a mobile platform designed for student investigations in and out of the classroom. The platform engages students in a scaffolded version of the CER process, which we used several times during the Land and Water curriculum enactment, though not during the Rainmakers lesson presented later in this chapter. I include this information to highlight the intersections of the two studies and to show my involvement in facilitating goals from both projects.

Methods

Settings and Participants

The data for this chapter were drawn from a fifth-grade class at a culturally and linguistically diverse elementary school in a large urban area in the Pacific Northwest. Ms. Jones had been (and continues to be as of this writing) a long-time research partner with the Learning

in Informal and Formal Environments (LIFE) Center and the UW Institute for Science and Math Education (ISME). During the year of this study, she was in her 14th year of teaching, with seven years in her current position at Granite Elementary School. The students in Ms. Jones's class were a very linguistically and culturally diverse group. During the 2013-2014 school year, there were 25 languages in addition to English spoken throughout the school.

After several days of classroom observations early in the school year, nine students were chosen as case study students. The nine students were selected to represent the wide range of ethnic and racial diversity in the classroom, as well as a variety of observed positionings and identities conferred upon or asserted by students. I hoped to capture a variety of theoretically illustrative stories of case study students as they participated in varied and complicated ways in the classroom. During science instruction, the nine case study students were seated together at two of the six group tables in the classroom.

Data Collection

This chapter focuses on data collected during a five-day engineering design challenge called Rainmakers, which took place during a three-month-long unit on erosion and deposition grounded in the fifth-grade district science kit curriculum, Land and Water.

Classroom Observations. The data corpus used in this study of the classroom interactions during a year-long study included audio and video recordings of five days of instruction (10 hours), fieldnotes, email exchanges between the teacher and researchers, and planning documents. During classroom observations, two video cameras were set up, one focused on each table of case study students. One of the two cameras was also positioned to easily capture large group discussions at the front of the classroom. Additionally, I reviewed documents associated with the ongoing SEIP teacher professional development that took place

starting in August 2013, including powerpoint slides, lesson plans, worksheets, and fieldnotes. Data analysis included initial coding of the five days of the Rainmakers enactment to identify images of engineering put forth by the teacher. This process involved developing content logs of the videos of both small group work and large group discussion for all five days of instruction, repeated viewings of the videos, and the creation of analytical narratives. By reviewing the narratives and the literature, I determined themes that I used to develop the analytical structure I describe below.

Interviews. Each case study student was formally interviewed at five points over the school year, using a semi-structured protocol. The aim of the interviews varied across the year, but generally sought to capture students' interpretations of science in their lives as they engaged in science practices across settings. The interview data collected informed my understanding of students' participation in the engineering design work presented here, but it is not analyzed or included in this chapter. The focal teacher was formally interviewed three times either by me or by other members of our research team. Interviews with the teacher focused on her teaching background, her perceptions of science and engineering in her classroom, the impacts of the professional development and her participation as co-designer, and the backgrounds and classroom experiences of the case study students. Additionally, I and other researchers had many informal conversations with the teacher over the school year; those conversations became part of our fieldnotes.

Student Work. The student work analyzed in this chapter included their science notebooks, which provided some information on their participation in science and engineering practices. Unfortunately, the central student work for this chapter—the engineering design pitch artifacts (mostly conceptual and physical models)—was lost before it could be collected. The

physical models that can be seen on camera were included in the analysis of the video-recordings.

Data Analysis

Sociomaterial Arrangements for Engineering Design Practices. The first research question, which focused on the nature of engineering design practices as they were appropriated and enacted in the classroom, required an analysis of the social and material constraints and affordances of the classroom enactment. This included understanding the intent of both the professional development and the engineering design lesson plan as co-designed by the teacher and others. I also attended to the instructional design features of how the lesson was enacted, and the engineering design practices made available to students. I asked the following analysis questions: How do instructional design features prioritize specific engineering design practices and what form do these practices take in the classroom? This allowed me to describe the purposes of the lesson and contextualize the classroom enactment.

Defining Images of Engineering. The second research question focused in part on the nature of the images of engineering embedded in the curriculum and in teacher practice. Answering this question first required examining how the professional development and the co-designed lesson signaled particular definitions, principles, purposes, and norms of engineering. Next, I examined how the teacher took up these (or other) stances on engineering in classroom enactment. To do this, I asked the following analysis questions: What stories about engineers and the work of engineering are conveyed in the professional development and curricular materials? What stories about engineers and the work of engineering are conveyed in the classroom? What norms define and guide the work of engineers? Asking these questions enabled me to define the scopes of possibility available to students during the enactment.

Scopes of Possibility in Relation to Disciplinary Learning. Finally, to understand how positions as producers of knowledge were made available to and taken up by students, I examined the expectations, discourses, and social positions associated with each image of engineering enacted in the classroom and the meaning of these made by students and the teacher. I specifically attended to the tensions that arose as students attempted to navigate both the content and relational spaces of collaborative small group work. Throughout the data analysis, I asked: What sociomaterial arrangements facilitated (or did not facilitate) student engagement in engineering design practices? How do students take up the discourses and practices associated with the images of engineering available in the classroom? How do students' bids for participation in engineering practices get recognized by their peers, the teacher, and other adults in small groups and in the classroom in general? What are the tensions between the students' desired rights and responsibilities, viewed in this analysis as bids, and those conferred on them? In this way I looked for patterns in how students took up, resisted, and/or reappropriated the sanctioned classroom practices during the engineering design task and how these actions reified existing or led to new social positions.

Findings

Mathews (2010) describes the affordances and challenges of studio-based pedagogy such as that provided by the Rainmakers Engineering Design Challenge. While the open-ended nature of design work has the potential to engage young people as “producers of knowledge and active designers of their own futures” (Mathews, 2010, p.1), it is also a potentially complicated and chaotic space for students to navigate. While Ms. Jones' class often worked on classroom projects in small groups, introducing engineering design into the classroom meant creating a space that Ms. Jones described as “a really uncomfortable place for your students to

be...[Students think:] ‘I’m not sure what I’m doing, I guess I’m going to go back and make it better...I thought that I was at the end [of the design process], but now you’re telling me to do it again’” [140603]. Ms. Jones described the difficulties students’ experienced as instruction shifted from the familiar and linear steps of the scientific method in the district science kit curriculum to the Framework /NGSS focus on the iterative and cascading cycles of scientific and engineering practices. Ms. Jones felt that her participation in the SEIP summer institute and the co-design of the Rainmakers lesson helped her to facilitate a comfortable space for her students and much of the work she did in the classroom reflected this focus.

In the findings presented here, I describe how the Rainmakers Engineering Design Challenge provided an entry point for a teacher new to the practices of engineering to successfully engage in the design and implementation of a classroom engineering task. In the Rainmakers lesson, Ms. Jones set out to engage students in the social and material practices of design work by focusing the engineering design triangle, optimization, the design pitch, and public testing of the designs, all in relation to an existing science curriculum. In two sequences, I demonstrate how Ms. Jones organized the engineering design task through specific ‘images of engineering’ and the related outcomes for students. By examining the small group work of two table groups and the large group discussions over the five day enactment, I demonstrate how the enactment opened up possibilities for some students to engage effectively in the content space, creating workable rainmaker models and meeting the NGSS engineering standards for 3-5th grade, while also attending to the challenges students encountered in small group work. These challenges served to reify existing social categories which created a barrier to participation for several students. The challenges identified here, as well as the implications for future instructional design, fall into two categories: the complexities of intertwining science and

engineering practices in the classroom through the systematic testing of designs and collection of data that can be used for argumentation around scientific explanations; and effectively scaffolding collaborative small group work in an open-ended design task.

Rainmakers Engineering Design Challenge

The Rainmakers Engineering Design Challenge was co-designed by Ms. Jones and a small team of teachers and researchers during the summer institute. Ms. Jones pitched the original idea for the unit—and the group quickly settled on it as the focus of collaborative curriculum development. The team was interested in developing a design task to address the NGSS performance expectations for 3-5th grades in relation to engineering practices and core ideas (Table 1).

Students who demonstrate understanding can:

3-5-ETS1-1.	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5-ETS1-2.	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3.	Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Table 4.1. NGSS Engineering Performance Expectations for 3-5th grades.

Ms. Jones came up with the idea to replace a somewhat functional, but not very realistic, sprinkler head that was part of the Land and Water kit. The educational goal was to engage students in engineering design with the goal of developing a better test apparatus for the science experiment than was otherwise available. This focus on engaging in engineering to develop testable conditions for a science investigation is an authentic practice in scientific work (e.g. Litzinger, Lattuca, Hadgraft, Newstetter, 2011). The overall learning sequence for the lesson is illustrated in Table 2.

Day One	<ol style="list-style-type: none"> 1. Engineering process design outline (triangle) 2. Define problem- Introduce the investigation question 3. Relate to everyday, authentic examples—discussion of simulator, reasons to model rain, examples that serve as background research 4. Review constraints and criteria 5. Design, build, test, refine 6. Review engineering triangle, revisit problem, constraints and criteria 7. Discussion of failure, iteration (iPhones) 8. Draw a conceptual model
Day Two	<ol style="list-style-type: none"> 1. Revisit the problem, criteria, materials, replication 2. Discussion of grants, making pitch (examples, Boeing, KOF3 radio) 3. Plan pitch (drawing and writing) 4. Gallery walk 5. (some redesign)
Day Three	<ol style="list-style-type: none"> 1. Revisit making pitches, models asking questions, giving feedback, criteria 2. Give pitches 3. Work on models while pitch results are decided 4. Results announced, one group has to re-pitch
Day Four	<ol style="list-style-type: none"> 1. Pass out project rubric, revisit triangle, collaboration strategies 2. Introduction of fishbowl testing process 3. Build (model redesign) 4. Fishbowl testing 5. Revisit redesign, design optimization and real-world engineering examples
Day Five	<ol style="list-style-type: none"> 1. Discussion of states of water (for assessment) and the upcoming experiment 2. Experiment 3. Debrief and discussion of states of water, runoff, groundwater

Table 4.2. Rainmakers engineering challenge learning sequence by day.

In an effort to foreground the engineering design practices while also setting the bar at an attainable height for the implementation of new practices in the classroom, the lesson was intended to engage students in an authentic classroom problem (creating a device to “make rain,” described below- for an upcoming experiment), but the lesson was not intended to engage them in using engineering design to better understand scientific phenomena. The lesson plan describes the intent of the engineering task in Rainmakers:

...students in this lesson need a good rainfall simulator to engage in their science experiment about where rain goes. At the start of Lesson 3, students groups will design and create different rainfall simulators using materials provided to them and some reasonable items they request to use. They will test their rainfall simulators, iterate on their designs as needed, and use their simulators to perform experiment 3.

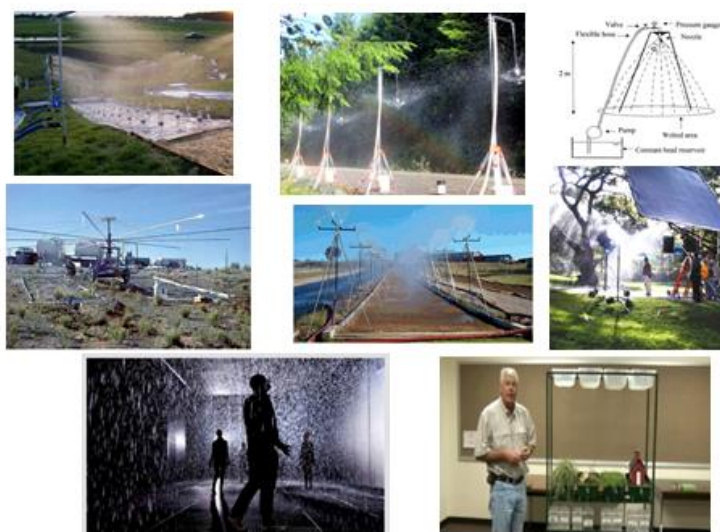
The lesson describes the design criteria as what the simulators should do, and the constraints as the materials students will have available to them, which I will describe further in the analysis below. Ms. Jones' group also developed a rubric (Table 3) for assessing student engagement in engineering practices with the following categories:

Engineering a Rainfall Simulator Rubric	Yes!	Almost there . . .	Not yet
Restate the design problem Students understand the criteria and constraints and can explain what they need to design	Students fully describe the design problem	Students partially describe the criteria and constraints	Students don't show an understanding of the design task
Present an Initial Design Plan Students explain/list/draw their first ideas, why they rejected them, and their design plan	Plan includes a clear design for the simulator using only the approved materials	The plan is somewhat clear or somewhat complete	The plan is not clear or complete
Build and Test the Initial Design Students build and try out their design	Students develop their rainfall simulator and successfully test and analyze its operation. They work through failure.	Students complete the development of their simulator but fail to test it appropriately	Students are not able to complete their simulator
Refine and Optimize Students adapt or change their design based on the design criteria or other sources	Students take in feedback from the gallery walk and initial trial and revise their simulator	Students take in feedback from the gallery walk or their initial trial but fail to revise their	Students do not take up feedback from the gallery walk or their trial

	successfully	simulator	
Justify Final Design Students explain why their design meets the criteria	Students communicate the elements of their designs and how it fits with the design criteria	Students partially communicate the elements of their designs and how it fits with the design criteria	Students are not able to communicate their design and how it has been developed to fit with the criteria
Participation and Collaboration Students will work together and contribute throughout all phases of the engineering task	Students collaborated as a team throughout the entire process	Students were collaborating on specific portions of the process	Students did not collaborate successfully throughout the process

Table 4.3. Rainmakers engineering challenge lesson rubric.

In addition, the lesson plan included a slide that showcased examples of rainfall simulators, meant to spark a discussion of who might use a rainfall simulator, where one might be needed, and for what purpose.



Rainfall Simulator Design Ideas for Lesson 3

Figure 4.3. Examples of rainfall simulators, which served as background research in the classroom.

Finally, a list of “sentence stems for collaboration” was included in the lesson plan, but this was not introduced in Ms. Jones’ classroom. The document focused on developing social

norms for collaboration by providing examples such as how students might express agreement, disagreement, make a suggestion, and include all team members.

To agree:	<ul style="list-style-type: none"> • That’s a great idea. • I agree because... • I think that will work because...
To disagree	<ul style="list-style-type: none"> • That’s an interesting idea, but it might not work because... • I disagree because... • I don’t think that will work because
To keep things moving:	<ul style="list-style-type: none"> • It sounds like we agree to... • How should we...?
To include all team members:	<ul style="list-style-type: none"> • What do <i>you</i> think? • Do you have any ideas? • Let’s let [name] share.

Table 4.4. Sample sentence starters from the “Sentence stems for collaboration” document included in Rainmakers Lesson Plan.

The sequences presented here were drawn from the five-day enactment of the Rainmakers Engineering Design Challenge lesson, as it was embedded in the Land and Water curriculum. There were four days of instruction with the kit curriculum before the design task began, in which students drew on their prior knowledge to consider the water cycle and the purpose of models for learning about the real world. Their first experiment, just before the design task was assigned, used ice packs and saran wrap on the stream tables to model the water cycle. Engineering design had been presented in the classroom earlier in the year as part of the Models and Design district science kit curriculum.

Sequence 1: Engaging in Design Work through the Engineering Design Triangle

Disciplinary practices and images of engineering. A fundamental focus of engineering education is the principled, iterative process that engineers use to engage in design work in order to solve a problem or meet a human need—as represented in the engineering triangle (NGSS, 2013; NRC, 2009). Ms. Jones enthusiastically embraced the engineering design triangle during the summer institute. She spent a fair amount of time drawing her own version of it on her tablet during the Institute. She then readily implemented it as an instructional tool in the Rainmakers

lesson to engage students in engineering images and practices in specific ways. In this analysis, I argue that the engineering design triangle, and specifically the instructional design of the criteria and constraints, helped to operationalize the process for achieving a successful design, but lacked some instructional supports needed for collaborative small group work in an open-ended task.

Engineers follow a principled process of the engineering triangle to solve a variety of authentic problems. Ms. Jones began the Rainmakers lesson by defining the problem the class was facing. She asked the class: “Why would you need to model rain and how do you do that when you water plants outside?” After discussing sprinklers and a few other ideas, Ms. Jones presented the slide of examples of designs people have built to simulate rain for a variety of purposes, “in real life.” The class discussion of rain simulator examples served as the background research on the various ways that engineers have designed rain simulators to meet a variety of needs in everyday situations. In this way she laid the ground work for the problem as she then presented it to students:

Ms. Jones: Our next experiment, that’s coming up? We can’t do the next experiment yet. We need to engineer a way to do the experiment...so right now, we have a little bit of a problem. So we have to turn to our engineering triangle. And the problem is, that we have this question we need to answer. The question is: What happens...to the land as it rains? So that’s my investigative question right now, but I can’t answer that question because I don’t know how to make it rain. So you guys need to engineer a design where we can have, we can actually do our experiment and make it rain, however you do that, so we can see what happens to the land. . .We can’t model this because we don’t have anything to model rain with, so you guys are going to design a rain model for your stream tables.

Ms. Jones framed this design challenge as an example of scientists using engineering to do their work. Students were tasked with building something that could simulate rain on their stream tables so they could then measure and understand the effects of rain on land in terms of erosion and deposition. Ms. Jones then revisited the engineering design triangle to set students up for the Rainmakers Design Challenge, with an emphasis on the *design problem* the class faced. Though

the problem was teacher-defined, the authenticity of the task was increased in that it was embedded the design challenge in the upcoming scientific investigation and presenting engineering design as the authentic work scientists need to engage in to do their experiments.

Ms. Jones took this conversation further on several occasions, reinforcing the narrative of engineering by focusing on how engineers have worked on problems that were relevant to students' everyday lives, such as iPhones and Boeing planes. By telling stories, Ms. Jones situated the class assignment in the authentic contexts of students' lives outside of the classroom. First, she set out to help students recognize *when* engineering exists in their everyday lives (Calabrese Barton, 1998; McDermott & Weber, 1998, NRC, 2013). Second, she articulated the classroom design task as similar to the work that professional engineers do. In doing this, Ms. Jones seeded scopes of possibility for identities in relation to engineering, by highlighting the kinds of persons and sociomaterial practices associated with engineering (Bell et al., 2012). One could argue that these strategies made explicit what Markus and Nurius (1986) described as possible selves –ideas of what students might or might not want to become—associated with design work, thus making these available for students to take up. The stories then hold the potential for students to act and be recognized as designers, engineers, scientists, decision-makers, and authors of their own work through the design challenge. Ms. Jones intended to set the stage for the class as whole to contribute to an engineering endeavor, working in small groups toward a design that met the problem's criteria and constraints.

Assessing designs according to criteria and constraints: There is no one “right” design.

After describing the design task, Ms. Jones asked the students: As engineers, what should your first question be? Because the students had worked with the engineering triangle before, they quickly identified the need to define the project's constraints. As is typical of classroom

enactments of engineering constraints (NRC, 2009), the constraints of the Rainmakers design task centered on the initial materials allotted to students to build their models, and implicitly, the time they would have to complete the task. To complete the steps associated with defining the engineering problem, Ms. Jones presented three criteria—the model should: (1) rain evenly over the land; (2) use all 500mL of water; and (3) be easy to replicate. While Ms. Jones did not explicitly tell her students during Rainmakers that there was no one correct way to design and build their rain simulators, she told students: “You need to engineer a design so that we can make it rain, however you do that.” In this way, she set students off to start the task with the assumption that there were many ways to engineer a design that would solve the problem. However, Ms. Jones also added that their model should be the best model of the class: it should not just meet the criteria for rain, it should be the best model for rain. This was a vague framing of quality that did not give students enough to debate about.

Scopes of possibility in relation to disciplinary learning. In this first sequence, Ms. Jones introduced students to the first step of the engineering design process, defining the problem. Students showed engagement through interest, excitement, and productivity in terms of making progress toward conceptualizing, building, and testing successful designs.

Because of the teacher-defined nature of the problem, the criteria and constraints were pre-defined and did not require students to engage in the problem space “expressed through requirements and specifications” (Razzouk & Shute, 2012, p. 335) in order to author these. However, in large group discussions, Ms. Jones and the students regularly revisited and framed their progress towards developing solutions using the engineering design triangle. In one instance at the end of the first day, the students reviewed the problem, the criteria and constraints, and considered what other parts of the design triangle they have worked on. Ms.

Jones called on Skylar to describe how her group engaged in developing solutions, which was where students spent most of their time in the engineering triangle throughout the enactment. Skylar responded: “We made a plan and tried to make it rain all over our platform... and we tried an experiment with our model.” A cursory examination of the classroom as students were engaged in the task and of the large group discussion after would show that as in Skylar described, students generally were successful in generating initial design ideas, and building and testing models during their work the first day. Students were so visibly excited about getting to the design work that Ms. Jones even commented on their enthusiasm to go back to their science tables. Additionally, students showed their interest for the project by taking ownership over their ideas and designs. Their frequent use of the word “our” indicated that they saw themselves as responsible for their design and invested in its success (see Cornelius & Herrenkohl, 2004).



Figure 4.4. Table One tests their initial design.

However, a closer look at how students negotiated the content and relational spaces in the small group work brought into question what made a successful design (Barron, 2003). The following segment represents a typical exchange at Table One, as they negotiated the design proposals they would take up and build. In this segment, which occurred about 10 minutes into

small group work on the project, Polly, Lucy, Ash, Katy, and Jordan discussed design ideas for their rainmaker. In Ms. Jones' classroom, Polly, Lucy, and Ash were socially recognized as academically successful students. Polly was also seen as a leader in the class, as she often answered questions or made other bids to interact with adults in the classroom. We often observed Polly referring to doing whatever it took to get a good grade. Katy was less academically successful, but was socially well-positioned by her peers. Jordan struggled academically and socially, and his interactions in the group reflected his positioning in this way. During their group work Polly took and maintained control of both the materials and the design ideas.

- 1 Polly: The spoon, I want to use a spoon [crosstalk 00:12:25].
- 2 Katy: Why don't you do it the opposite way?
- 3 Polly: Wait, can I see something? What if we poked holes in this spoon. Then put the
4 spoon here.
- 5 Katy: Oh, yeah [crosstalk 00:12:36]. Maybe under here.
- 6 Ash: Can't we just do this?
- 7 Katy: That's exactly what I just said, dude.
- 8 Polly: What if we put some of this stuff on here? Then we poked holes in it. Then put
9 like [crosstalk 00:13:00].
- 10 Lucy: Then it would only come out one drop at a time.
- 11 Katy: If only we could make it bigger.
- 12 Polly: Let's just test it out. No, you guys. I mean put paper stuff on here. Poke the holes
13 on there and we then somehow attached it to the bottle and made it like wheeee
14 [crosstalk 00:13:18].
- 15 Polly: Wait.
- 16 Ash: That didn't work.
- 17 Polly: Wait, wait, wait, wait. Can you pass me the top?
- 18 Jordan: What are you doing?

- 19 Polly: I'm doing what I'm doing. Hey, what if we did this? Water would go in through
 20 here and then it would come out the bottom. Then we would have this on it with
 21 holes. Then we could just lalalalala (shakes the model) [00:13:47].
- 22 Katy: This group has some weird ideas.
- 23 Polly: Wait, will one of you go get the paper towel, I want to test this out [crosstalk
 24 00:14:00].

While several of the students in this group made design proposals, Polly maintained almost complete control of the materials and “held the floor” (Goffman, 1981), ignoring the bids made by her group members to engage in the design process (lines 2, 8, 19). She asserted her role as the sole producer of design proposals for most of rainmakers project (line 19). In this moment, Polly monopolized the materials and engaged with her tablemates only to try to persuade them to agree with her ideas, creating a barrier to mutual engagement in the task. She was the only one who used the word “our” throughout the building and brainstorming of the group’s model. In this way, she appropriated the design task to meet their own personal goals—to maintain her status in the group and to work the situation in order to get a good grade. This positioned others in the group in adverse ways and created a set of relational affordances and constraints for others in the group. It thus had implications for the differential success of the individual members of the group insofar as they could engage in the design practices. The other students were unable to engage in the content space at all except as an audience and supporter for Polly’s ideas. Indeed, their questions to Polly about the work did not even warrant responses in her mind (line 19).

One interpretation of the interaction described above, is that it is possible that Polly was able to use her social capital to direct the design activities in her group at least partly because of the instructional design choices that determined the criteria and constraints employed in the task and the purposes they served. The criteria and constraints of engineering design are used to

assess the success of a design, but often, as in this enactment, the criteria and constraints are instructional and not engineering-related (NRC, 2009). That is, they served to confine the task to fit in the context of the school classroom—to use the materials readily available and a reasonable amount of water, and to be easy for another small group to use to answer their investigative question. In the field of engineering, criteria and constraints include both negotiable, human constructed criteria, such as aesthetics or government regulations, but also those based in scientific concepts, such as the load-bearing nature of different materials (Bucciarelli, 1988; NRC, 2009).

For Table One, the negotiation of a design solution based on the provided criteria proved difficult because the criteria were not specific or quantifiable, and so the definition of a successful iteration became more openly debatable. Because the criteria and constraints in this lesson were entirely instructional, as opposed to actual engineering constraints, and the criteria for quality rain on the stream table surface were so vague, success was ambiguous and the ways in which designs met the criteria and constraints were up for debate in the students' small groups. Student arguments for design proposals were not driven by data as evidence, but on brainstormed ideas (Stevens, 1999). In the case of Table One, students then had better access to social categories than to evidence, leaving them to leverage social status, not scientific ideas. The two small groups I observed in the solution development phase spent most of their time negotiating design proposals and trying designs out. However, their ideas were almost entirely speculation, not based on scientific evidence collected from systematic testing. This means that they spent the bulk of their time negotiating the relational space of the design work through a navigation of the positioning dynamics, rather than collaborating on the content space. This

served to reify the existing social participation structures in the class, engaging students with high social capital in design practices, and excluding others.

Sequence 2: The Design Pitch

Disciplinary practices and images of engineering. A core activity of design-based disciplines like engineering is the *pitch*, in which designers share a conceptual or physical model of their design and argue for why it best meets the criteria and constraints of the problem and should thus be implemented and/or funded. This activity was a major focus of the Rainmakers lesson. A professional engineer suggested it to the Rainmaker design team during the summer institute as an authentic practice that happens in industry all the time. In this analysis, I show how Ms. Jones used the pitch as a way to rearrange the sociomaterial practices of the classroom to engage students in practices of engineering design. I compare two small groups' pitches to demonstrate how success in this process was defined. I argue that while the rearrangement of the sociomaterial structures in the classroom supported groups to engage in engineering practices, small group work was not restructured in the same ways, resulting in one group to not succeed in making their pitch.

To get the resources they need to do their work, engineers use evidence to argue that their ideas best meet the criteria and constraints. Ms. Jones introduced the design pitch briefly on the first day of the Rainmakers enactment as how engineers work to convince others that their design is the best one and to specify the outcomes. She told students what they would need to do to give their pitch:

Ms. Jones: A pitch is...what engineers use in the real world...What you'll get to do, you'll get, if you work on this today, and I want you to be thinking, man, if I, if we only had this one other thing, what would it be. Now you need to think of what that would be and then...Wednesday, you'll get to pitch that idea to me and a couple other people and we will either say ok, sure you can have that, or no, sorry. So we'll get the pitches from every table and some will be accepted and some won't

be accepted. They'll be accepted based on how well you've thought about how it's going to be used and how well you guys are working together.

Ms. Jones defined the criteria for a successful pitch. Students would need to convey their process and their expected outcomes, as well as show that they worked together well throughout the process. The rubric in Table 2 outlines more specifically how the students would be assessed on these aspects of the pitch and several other features of the design process: students would need to show they understood the design problem by explaining how their design would meet the criteria and constraints; explain why they rejected any initial plans and explain how their new design meets the criteria; and work together to contribute throughout all phases of the work.

Finally, Ms. Jones provided sentence stems to scaffold what she expected students to include in their presentations: "Currently our plan is... If we had _____, it would be awesome.

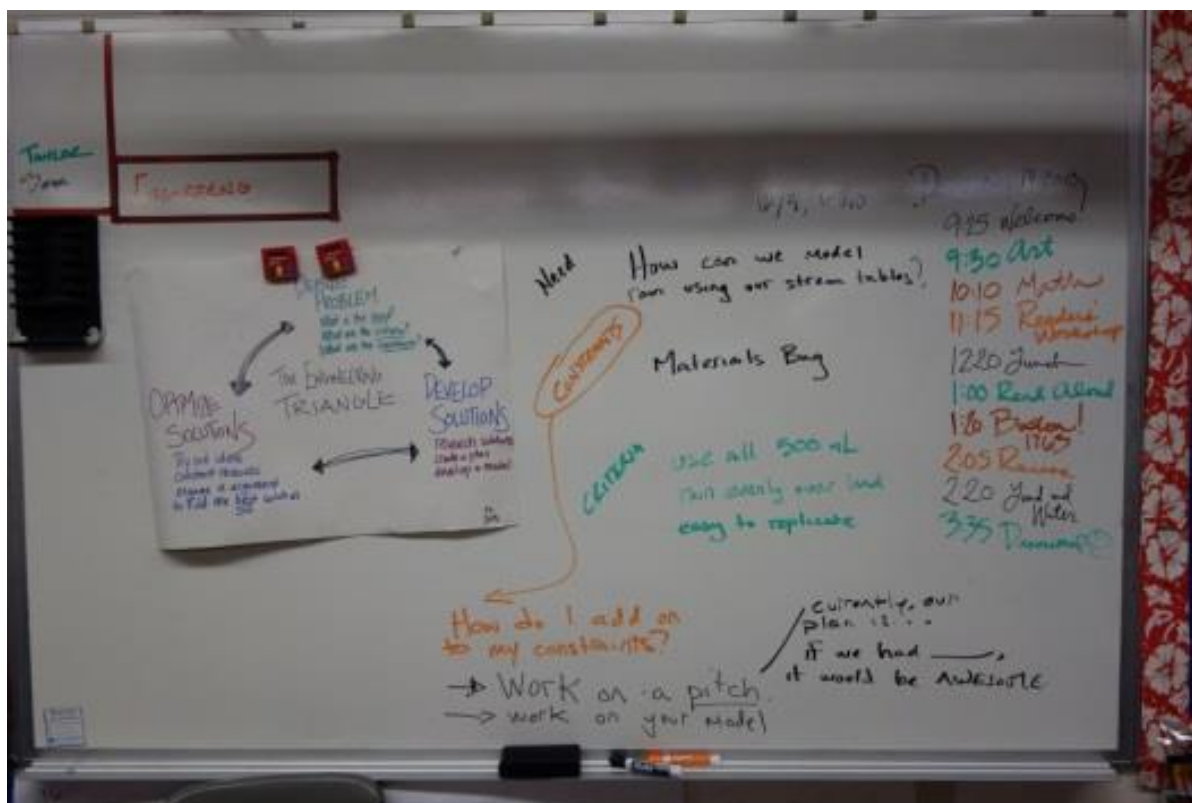


Figure 4.5. Ms. Jones' classroom whiteboard on the day of the design pitch.

Leading up to the pitch, Ms. Jones again positioned students as doing authentic work of engineering by describing how giving a pitch is just like writing a grant—proposing an idea to be funded by describing the outcomes. This was particularly relevant to the classroom as Ms. Jones had written and been awarded a grant earlier in the year for the resources that supported a classroom project in which students wrote, recorded, and produced a weekly radio show. In the class discussion of this, students reflected on the positive outcomes they felt justified the grant Ms. Jones received for recording equipment and Ms. Jones made this an explicit example of what they would need to do in their pitch—describing how they would meet the goals of the project.

Ms. Jones framed students' roles during the design pitch in specific ways. First, she positioned the groups in competition with each other. Ms. Jones told students that they needed to ask each other questions during the pitches because ultimately students wanted theirs to be the best design. By asking other student groups' critical questions about their design, students could challenge the integrity of other designs and increase the chances of getting their design pitch granted. In reality, while this is an authentic part of a pitch in the real world, there was no limitation on how many pitches Ms. Jones would grant—something that was never explicitly stated but became apparent as all groups were (eventually) granted their requests. Instead, this prompt served as an instructional tool to engage students in thoroughly considering their designs, and those of their peers, in relation to the criteria and constraints and communicating effectively with others about why the additional materials they requested would make theirs the best model for making rain. Finally, Ms. Jones made it clear that she did not expect everyone in each group to talk during the presentations, but that everyone in each group should be able to answer

questions. This classroom practice could help ensure a level of shared understanding within and across groups.

Scopes of possibility in relation to disciplinary learning. In this second sequence, Ms. Jones presented the design pitch, related to its real world practices, and set up students up to participate in a structure of atypical classroom interaction—positioning each group as being designers and by asking students to directly question each other. This arrangement of classroom practices is at odds with the standard approach to inquiry kits where students follow proscribed procedures, in that in this model they have significantly more agency for their learning.

Gaining and holding the floor. In the group at Table One, Polly maintained the floor during the design process, all the way through the design pitch.

- 1 Polly: What happens is when we shake to make the water come out, it keeps sloshing all
2 over. And then we tried to put a lid on and we didn't have a way to pour the water in,
3 so we were thinking then if we had a funnel, we could attach it to the top of it so that
4 we could pour the water into that. And it would have a lid, but it would also still have
5 the water going into it.
- 6 Ms. Jones: Can you hold it up so that everyone can see it?
- 7 Polly: And then the funnel, if that plan fails, it can still have lots of other uses. It can use
8 itself to try and use different materials. We can cover it and try it and do something
9 with it or we could use it to keep the water going straight. Any questions?
- 10 Skylar: Wait so the funnel has an opening to it. Right?
- 11 Polly: It has an opening at the top and an opening at the bottom so that-
- 12 Skylar: I know, but when you shake it, wouldn't the top tilt because your top—
- 13 Polly: No because it drains down into this little cup.
- 14 Ms. Jones: Katie? Oh, hold on, Katie. Go ahead.
- 15 Katie: So, in the funnel it has a big hole in the bottom. How would it only look like rain if
16 it's not gonna just pour down?

- 17 Polly: Well, no. We're going to attach it to our—to our little thing. Right now, [our
18 conceptual model shows] it's floating above because we wanted to show you what it
19 completely looked like, and then later on we would tape it down to the top so that
20 would be a lid and it would let the water go in smoothly. Hopefully.
- 21 Ms. Jones: OK, Winnie?
- 22 Winnie: Are you letting the water get out like the rain?
- 23 Polly: As you see here, there is little holes. The foil is would be right here—
- 24 Winnie: [inaudible] –just rain, yeah.
- 25 Polly: Yeah. We tape it like this and we poke holes in-
- 26 Ms. Jones: Wait. Wouldn't that mean that someone has to hold the bottle of water? Someone
27 would have to hold the funnel, and somebody else would have to hold the cup over
28 the whole thing?
- 29 Polly: You tape. We're taping the funnel to it so somebody would pour the water in—
- 30 Ms. Jones: Got it.
- 31 Polly: –then you would do it, and then somebody would pour more water in.

This segment demonstrates the ways in which Polly and other students successfully engaged in argumentation around the design ideas of the Rainmakers models. Polly used the instructional language Ms. Jones provided to explain the Rainmakers model her group designed and the failure they encountered up to that point in relation to the criteria and constraints (lines 1-2). She made a design proposal and claimed that a funnel would allow them to pour water into the model with a lid on it to solve the problem of water sloshing out (lines 3-5). She described the possibility of failure and iteration without specifically describing what the failure was or what would happen (lines 7-9). Finally, Polly made another design proposal that addressed other problems the funnel could solve and the iterations she expected her team may need to go through to test the design. She defended the design proposal not with scientific evidence, or data, but by

speculating on what she thought would happen based on what they tried with the first model (lines 17-20). Part of this is the nature of the pitch in that students were asked to make requests for new materials that they believed would make their design “the best” with only a vague notion of what that meant.

Skylar, Katie, and Winnie clarified details of the design proposal and evaluated Polly’s claim about the funnel’s purpose in the design (lines 10, 12, 15-16, 22). Skylar provided critique about the proposed design by making a claim (speculating about what might happen to the water) and posing a specific question. Katie confirmed a detail of the design and provided critique about the proposal by referencing one of the criteria—that the water must “rain” evenly over the land.

Though Ms. Jones did facilitate questions from other students during the presentations, she more or less let students interact with each other directly—much more so than was typical of classroom instruction during our observations (lines 14, 21). In this way, the typical social practices of the class were restructured. Ms. Jones limited her usual initiate, respond, evaluate (IRE) interaction style and students took on the role of evaluating each other’s design ideas. They were positioned to be publicly knowledgeable about and argue for their design and challenge each other through questioning and giving feedback in relation to the criteria and constraints. In some ways, Ms. Jones used the pitch activity to confer new rights and responsibilities on students, even for a short time. Ms. Jones implemented several of Engle and Conant’s (2002) conditions that made debate possible. The subject matter was problematic in that it was open-ended and had no one right answer. The students had unusual authority to address each other directly in asking critical questions about issues they saw in others designs. Ms. Jones held them accountable to disciplinary norms by providing sentence stems and

reminding them of the social norms for classroom talk in large group discussion (I agree because/I disagree because____).

Table One's pitch was granted because it met the requirements for assessment. Polly represented her group to make a design proposal using the scaffolded language provided by Ms. Jones. She defended her claims about the design and had a cohesive plan that implied the group had come to consensus. From our observations, we know that the design Polly presented was in actuality almost completely her work, with little input from her tablemates. In this way, what defined success for Table One was Polly's ability to take control of the group work and maintain coherent control through the design process and the pitch, without contestation from the other students in her group. The assessment of success based on how well one person represented the group's work at the front of the room, and the lack of monitoring small group interactions allowed this non-democratic process to unfold undetected by the teacher (or any of the adults in the room).

Contested participation and ownership of ideas. At Table Two, Ahu, Luke, Eddie, and ReyMaya initially failed their pitch and were asked by Ms. Jones to prepare for a re-pitch. In the interactions leading up to the initial pitch, Luke acted as he often did, as the gatekeeper for the other students, directing and sanctioning modes of participation for the other students. On the day before the pitches, Table Two built and tested a design that they deemed a failure. During the brainstorming session ReyMaya was absent, and Eddie, Luke, and Ahu agreed almost immediately on a design in the first five minutes—to ask for a bucket in which they planned to drill holes.

On the next day, on Ms. Jones' prompting, Eddie gave ReyMaya a one sentence summary of what they had done so far. When it came time to draw the model, Ahu, who was

usually the least engaged in small group activities, grabbed the paper and he and Eddie argued about who should draw the design. They argued about if it needed to be perfect or not. Ahu drew for about two minutes and Luke made some contributions. Ahu said, “We’re finished.” ReyMaya looked at it and said, “That’s the pitch?” Luke said “It’s done,” and told ReyMaya that their pitch was for a bucket. While ReyMaya was talking to Ahu, Eddie seemed to make a case to Luke for why he should take a turn drawing the design, but their conversation was inaudible. It ended with Luke saying to Eddie, “Ok, you draw on the back of it,” and then telling Ahu that Eddie was going to do that. Ahu argued with them saying it was done, but Eddie sat down and started drawing.

While Eddie drew the next design the group talked about other things, including other ideas for pitches. One of the ideas discussed was to set up the stream table the way they did for the first investigation in Land and Water, using an ice pack to create condensation on plastic wrap that is stretched over the top of the bin, and shaking the bin to let the water droplets fall on the land. Luke dismissed the idea, saying something about it being too hard to replicate—which was one of the criteria for the challenge.

After a classroom gallery walk, in which groups rotated to look at each other’s designs, Eddie continued working on the drawing. At this point, he had spent most of the class time working on the drawing for the pitch. Ms. Jones came by and asked him to take a break, walked him back to his desk and gave him a flyer to put in his backpack. During the two minutes Eddie was gone Ahu and Luke jumped in and started coloring the drawing. After Luke accused ReyMaya of not doing anything, she said, “I don’t even know what’s going on right now, we’re just supposed to make something that rains?” The boys dismissed her (Luke said: “You’ll have to make a time machine and teach yourself.”) and continued coloring as Eddie came back and

watched. ReyMaya made several bids to get the group to build their model, pointing out that they were the only group without a model. Ms. Jones said it's time to clean up. As Luke walked away from the table, ReyMaya yelled to Luke across the room, "We didn't make anything, all we did was work on the drawing." Ms. Jones ended class by telling the students that one person from each group could continue working on the pitch at home if needed.

So far, it is clear that the small group work at Table Two was regularly a place of contention for all of the participants. The three boys agreed on their design relatively quickly while ReyMaya was gone, but each of the four students spent the remaining time negotiating access to the design task, with little success. Prior research shows that friendship and gender both play a part in understanding group dynamics (Détienne et al., 2012). ReyMaya was positioned out of the activity entirely, most likely because she had a more distal social connection to the boys in her group. Not only had she missed the initial planning of the pitch due to being absent was she the only girl in the group, she was the only African-American in the class. From what we typically observed of ReyMaya and her tablemates, it was likely that she would have been left out of the group activity entirely if Ms. Jones had not reminded her teammates to at least fill her in on their work so far.

The next day Luke left early for a dentist appointment and Eddie, Ahu, and ReyMaya found that he had drawn three more pitches the night before. Ms. Jones pointed out to them, "Ok, so you need to be familiar with what the pitch is." Just as ReyMaya, Ahu and Eddie started to wade through the designs and prepare their presentation, ReyMaya was pulled out of class by the school counselor. The counselor's act of pulling ReyMaya out of class likely negatively impacted her participation in the group work, in that she did not have a chance to negotiate for a role in the design pitch. This is similar to what happened to Eddie when Ms. Jones pulled him

out of group work to give him a flier and Luke and Ahu took over the drawing on which he had been so focused. While ReyMaya was gone, Eddie and Ahu argued about which design to use for their pitch.

1 Eddie: I don't think this one, because too much water will come, so I think—

2 Ahu: What?

3 Ahu: [crosstalk]...holes. We're going to take like tinfoil and put like holes and then the
4 water will come out.

5 Eddie: My idea...

6 Ahu: What, these are not your ideas.

7 Eddie: Then heck, man.

8 Ahu: None of these are your ideas.

9 Ahu: That was my idea. And the bucket, but these two were his (Luke's).

10 Eddie: Yeah, not that one [inaudible].

11 (Eddie looked carefully at each page. Ahu tried to take the pages away from Eddie.)

12 Ahu: Do that one. We're—got it.

13 Ahu: Here. [gestures for Eddie to give him the pages].

14 Eddie: Nononono not yet.

15 Ahu: I want to start. Let's draw it. Let's draw it first.

16 Eddie: I'm still thinking what to say. Ok fine.

17 Ahu: Let's draw the picture first.

18 Eddie: What?

19 Ahu: Let's just draw the picture first.

20 Eddie: Wait, bro,

21 Ahu: Oh you're going to take your time [inaudible].

22 Eddie: You're smart at math, but I'm so [inaudible] at science.

23 Ahu: you?

24 Eddie: Yeah, um, so—

25 (Eddie resumed studying the plans.)

26 Ms. Jones: OK, you've got another minute.

- 27 Ahu: See, we have to draw it first. Hurry up.
- 28 Eddie: What do we have to write?
- 29 Ahu: Just tell her that we're going to do it.
- 30 (Ahu took a page away from Eddie.)
- 31 Eddie: Not yet.
- 32 Eddie: Not—
- 33 (Eddie put his head down on the desk, then lifted it up again.)
- 34 Eddie: Oh my god, I'll let you do whatever you want.

In this segment, there are several notable features that contributed to the failure of Table Two's subsequent pitch. The contestation of ideas in the group came to a head as Eddie and Ahu struggled to assign responsibility for deciding which conceptual model to use in the design pitch—for whose work should be recognized.

In this interaction at Table Two, and shown earlier in Table One, the students found their identities as competent contributors under constant threat during small group work. To understand the nature of these threats and the implications for student participation in engineering design practices, attention must be paid to “what is at stake in the situation, and for whom” (Détienne et al., 2012). Ahu asserted ownership for what he considered his ideas and positioned Eddie as having not contributed, ignoring the immense amount of time Eddie spent actually creating the conceptual model. Eddie found himself working hard to be recognized for his contribution, even assigning generalized disciplinary identities to both him and Ahu to position himself as competent and knowledgeable in science. Both Ahu and Eddie worked to resist being positioned in “disenfranchising social positions” in the small group (Bell, Tzou et al., 2012, p. 277). This segment demonstrates the ways in which the general valued behaviors and identities in school, in which students identities “are based on being smarter than others”

(Barron, 2003, p. 350), become liabilities in small group work. During the preparation for a performance in which they might be publicly recognized for their contributions, the consequences were heightened and the contested space of ownership of ideas became explicit and overshadowed their ability to work productively together.

Just before it was time to start the pitch presentations, Ms. Jones walked by and overheard some of Ahu and Eddie's conversation. Ms. Jones suggested they give both pitches. Later, Eddie, Ahu, and ReyMaya, who had returned to class, were called up to give their pitch for their design and ask for more materials. Eddie started giving the pitch but handed the paper to Ahu before finishing the first sentence. Ahu and Eddie went back and forth giving parts of the pitch and responding to questions from Ms. Jones and the other students. As it became clear to Ms. Jones that the group was not prepared for the first pitch—they could not sufficiently demonstrate their understanding of their plan and how it would meet the criteria—she asked about the second pitch.

- 1 Ms. Jones: What kind of bottles?
- 2 Eddie: The Sprite bottles.
- 3 Ms. Jones: -and four of those?
- 4 Eddie: Yeah. Ask Luke [00:24:11].
- 5 Ms. Jones: Well, you guys don't even know?
- 6 Eddie: No. We do know, but Luke came up with this weird thing.
- 7 Ms. Jones: OK. So you, I understand that you have a second pitch.
- 8 Eddie: Yeah.
- 9 Ms. Jones: OK. What is your second pitch? When you ask questions, boys and girls, you'll
10 ask questions about either their first pitch or their second pitch. [00:24:42]
- 11 Eddie: We're asking for another cap so we can poke holes in it. We weren't ready for the
12 second one.
- 13 Ms. Jones: Wait, another what?

- 14 Eddie: We're not ready for this one.
- 15 Ms. Jones: Well, it looks like you want a whole 'nother container.
- 16 Eddie: Yeah.
- 17 Ms. Jones: OK. Well, Eddie, you just spent a lot of time drawing that. Can you tell us about
18 that one?
- 19 Ahu: We're [inaudible] bucket and poke holes on the bottom and then put water in and
20 [inaudible 00:25:30].
- 21 Ms. Jones: OK. Alright, any questions? Lots of questions. OK. Go ahead.
- 22
- 23 Ash: If you were to get another bucket, would you need to move the bucket?
- 24 Eddie: No.
- 25 Ms. Jones: If you were to get another bucket, would you need to move the bucket or would
26 you be able to just have it standing still?
- 27 Eddie: We'd probably hold it.
- 28 Ms. Jones: Probably hold it. OK.

After the pitches were given, the adults in the room conferred and Table Two was the only group that was not granted their requested materials and was asked to re-pitch the next day—which they did so successfully. It was clear that the group had done a considerable amount of design work, but the failure point was in their collaboration. As examined earlier, Polly's group did not collaborate at all either, and the root of Table Two's failure does not seem to be simply that they did not work together well. Two events seem to have had implications for Eddie's participation and the group's failed pitch. First, Ahu discredited Eddie's claims of ownership for the idea he spent a great deal of time creating. Second, Ahu made the decision to not pitch the Eddie's work, but chose another design proposal that Luke had worked on by himself at home. In this segment, Eddie resisted public identification as the source of the ideas or even knowledgeable about his group's plan by deferring to Luke's ideas in his responses to

questions. Based on his interaction with Ahu just before they presented, one possibility is that Eddie felt disenfranchised by his tablemates' disregard for his contributions. Just as Polly did at Table One, both Eddie and Ahu focused not so much on the content of the designs, but on protecting perceptions of their own individual competence (Ames, 1981; Barron, 2003). To some extent, Eddie acted in order to try to save 'face' (Brown & Levinson, 1987) during the consequential moment of the pitch, by disassociating himself from the work. He seemed to try to protect himself from being negatively positioned in relation to the design work he was unprepared to describe by distancing himself from responsibility for it.

It is important to emphasize that Table Two had a legitimate design proposal that would have met the assessment criteria and been granted, had they successfully negotiated collaboration on their ideas. In this instance, the failure wasn't because of a failed design, it was in the social processes needed to carry out the pitch. This sequence also makes clear the socially constructed nature of the conceptual model and the design pitch. Neither Eddie nor Ahu held fully congruent internal representations of the conceptual model (Bucciarelli, 1988). The design itself was a contested object. ReyMaya saw the design as incomplete because the group did not build anything like they were supposed to in the brainstorming process. Luke took responsibility for the designs by working on them alone at home the night before. The lack of collaboration during class, given the interruptions and personal dynamics, tied to the structural pressure to come up with something to present during the design pitches, led to a situation in which Table Two did not have a consensus approach to present.

One of the challenges during the engineering design enactment was creating opportunities for leveraging distributed expertise in collaborative design processes. Ms. Jones often talked about collaborative work and the importance of listening to each other, but publicly

consequential moments like the design pitch or the gallery walks tended to privilege high-status students—who would attempt to control small group processes. The structure of these moments provided an opportunity really for only one student in each group to demonstrate their contributions to the group, rather than drawing on and demonstrating the different expertise of each student. Thus, students resisted the stated requirements to collaborate and instead high-status students sought to maintain recognition for all of the work at hand and to control the public presentation of the group's work.

Though the ways that this activity played out for individual students were complex, the instructional intent of the engineering design pitch was to engage students in a consequential, authentic (to the classroom) endeavor. Students used the design triangle to situate their work, engaged in a design problem in relation to criteria and constraints, revised design plans after trying out their models, and justified their requests for additional materials. The opportunities to participate in engineering design practices were not equitable, but this activity served as a first step toward restructuring typical classroom practices to focus on student agency, creativity, and argumentation.

Coda. This chapter focuses on two learning sequences that occurred during a five-day engineering enactment, but several other events during that time contributed to the findings described here. Though a full analysis of these are beyond the purview of this chapter, it is relevant to briefly acknowledge the way that images of iteration and optimization in the engineering design triangle contributed to the social positionings of youth and their engagement in engineering practices.

The practice of optimization in engineering education is described as “the pursuit of the best possible solution to a technical problem in which *trade-offs* are necessary to balance

competing or conflicting constraints” (NRC, 2009, p. 89). As part of the engineering design triangle, Ms. Jones focused heavily on optimization as a set of core practices that included: a) try out ideas; b) constant revisions and; c) engage in argument to find the best solutions. Ms. Jones focused on two images of engineering in relation to optimization.

In addition to testing their designs, engineers and scientists share their ideas with each other, then use what they have learned to optimize their design to be the best. The co-designers of the Rainmakers lesson plan included a gallery walk, a pedagogical tool designed to engage students in discussion by moving through stations. The intent in Rainmakers was to give students an opportunity to learn from each other by explaining their own and observing each other’s designs and asking questions. Gallery walks were a common practice in Ms. Jones class. Ideally, gallery walks give all students an opportunity to act as authors in sharing their work, or as researchers, gathering ideas and thinking critically about other designs. In Ms. Jones’s class, gallery walks were very lightly structured, so that one student at each table ‘hosted’ their design and explained their groups’ work to others. Other students who were not hosting were expected to learn about other groups’ work and bring ideas back that could be incorporated to optimize their design. Students often argued about who would stay to explain the design to others and Ms. Jones mediated these conversations by asking, “Who is most prepared?” She told the class, “The person who is staying at the table should be someone who is confident in their knowledge of the design.” While this was a worthwhile point, this instruction by itself did not provide enough structure for other students to make real contributions to the process. It implied that not everyone was responsible for the design and allowed some students to be excluded from the process.

Failure is necessary and a good thing. Ms. Jones addressed one of her initial concerns about the ‘messy’ nature of engineering design in the classroom by discussing the importance of

failure and iteration with the class. Ms. Jones tried to make the messy space more comfortable for students by acknowledging and unpacking failure, what it means, and why it's useful. In this sense, she changed the typical narrative of failure in school, which as she described is often thought of as a bad thing. Additionally, Ms. Jones made a direct connection between failure and improvement through iteration and described how this happens with iPhones. I observed students discussing the merits of failure in the large group discussion, but in small groups they were still primarily concerned with the time remaining to get the work done and getting a good grade.

Scopes of Possibility in Relation to Disciplinary Learning. Instructional practice around optimization was explicit and iterative in large group discussions in Ms. Jones' classroom, but as is commonly found in engineering curriculum materials, design improvements were based on brainstorming rather than analysis (NRC, 2009). Students were able to take up and reflect on the focal components of optimization, feedback and failure, as ideas in the design processes, but did not take up trade-offs of competing constraints in their work and therefore did not demonstrate the optimization process as an "evolution of thinking," as Ms. Jones described it. From observations, it is clear that neither Table One nor Table two used what they gathered from gallery walks to make revisions in their designs. Most groups showed what is called design fixation, in which they do not take up new information to create new designs, retained a specific focus (Razzouk & Shute, 2012). For example, Table One maintained the funnel idea to the end design.

Importantly, gallery walks were another venue that served to reinforce existing positionings of students in relation to engineering practices in the classroom. Those who had higher academic status, and thus were already situated in the core of activity as authors, were positioned as knowledgeable and others found there was little room for them to participate. As

described further in the discussion of this chapter, Cohen (1994) describes the challenges of excessively structuring the protocols for open-ended work in classrooms, but the scaffolding of social norms and intellectual roles, or even just attention to the existing “sentence stems for collaboration,” may have supported the participation of all students. For example, specific attention to the rotation of group members as presenters in the gallery walks would have enabled more students to act as authors, repositioning youth with opportunities to take on new identities as contributors to the engineering design task. Structures for reporting what students learned from other designs, such as using a jigsaw strategy to make individual students solely responsible for learning and sharing about another groups’ work may have enabled more students to contribute ideas.

Discussion and Design Implications

Through an analysis of the instructional design features that engaged students in engineering design work, I have shown the ways in which the images of engineering embedded in the curriculum and implementation shaped the social positions available to students as they engaged in design tasks. In essence, I have tried to show how Polly, Eddie, and their small groups navigated the novel practices of engineering design through the content space and the relational space of large and small group work. In this discussion, I address issues that arose in this enactment that have specific implications for introducing engineering design work into K-12 classrooms.

First, in the sequence presented here, the engineering design triangle worked as an instructional tool to provide scaffolding to the general design task in the classroom. The teacher, new to engineering education, sought to position her students as engineers and provide a framework for engaging in what she recognized as the potentially chaotic, authentic task—

generating and comparing multiple solutions in light of the criteria and constraints to enable their next scientific investigation with the stream table. The students eagerly took up the tasks of developing models, negotiating participation in the related practices (manipulating materials, asking questions, etc), and trying out their designs—to varying degrees of success for individual students. The stage was set for students to see themselves as doing the work of professional engineers in an authentic classroom problem.

Second, the design pitch publicly problematized each groups' design and thus the social construction of those designs. Students were positioned to engage in public argumentation about design proposals, which was a marked shift in typical classroom practice in which Ms. Jones usually used an IRE structure. They acted as developing experts in engineering design practices both by presenting and defending their own designs and critiquing the work of others.

In this discussion I suggest that two key aspects of the engineering design work had significant implications for student outcomes in relation to equitable engagement in engineering practices: 1) the importance of conveying the integrated nature engineering and scientific concepts and practices, specifically, the NGSS Disciplinary Core Idea focused on including fair tests as part of the improvement process for model development; and 2) the relational goals and intellectual roles of small group collaboration in open-ended activities.

The Integrated Nature of Science and Engineering in Practice

One of the primary tensions of including both engineering and science practices and concepts in the NGSS is accurately framing the integrated nature of engineering and scientific practices and concepts, while also demonstrating the ways in which they differ. An additional issue is making the engineering practices and disciplinary core ideas accessible to the large number of K-12 teachers who may have little experience with engineering education. Making the

similarities and distinctions between science and engineering explicit is important to understanding the interdisciplinary nature of the work that scientists and engineers do. However, this potentially leads to an instructional tension, especially as new teachers are newly inducted into the practices of engineering and science. In this chapter, students wrestled with and demonstrated their understanding of the first two Disciplinary Core Ideas of engineering, primarily in the large group discussions and the design pitch. They also participated in argumentation around design ideas in a form of public debate. However, Reiser (2013) argues that “in meaningful scientific argumentation, the claims are steps towards developing explanatory models, and are constructed by interpreting evidence from investigations” (p. 8). Engineering design based on a core scientific phenomenon then serves as a useful context for meaningful argumentation practices.

Design implication. The *Framework* (2013) emphasizes the importance of quantifiable criteria “so that one can tell if a given design meets them” (p. 204). Quantifiable constraints might include limits to cost, weight, size or performance and data can be analyzed in relation to the constraints to make design decisions. Though the *Framework* (2013) does not specify the importance of considering scientific principles that might limit solutions or systematic processes for evaluating solutions until the end of eighth grade, I argue as the *Framework* (2013) does, that successful designs hinge on the specificity of the criteria and constraints. I contend these should be attended to in earlier grades, as it might allow for argumentation based on student-collected data rather than the unsystematic brainstorming observed in this study, allowing for students to work toward understanding the underlying scientific concepts. The integrated nature of science and engineering can be drawn on in class to provide authentic design experiences and avoid the known problem of design projects that are overwhelmed by “student excitement about hands-on

activities” (NRC, 2009, p. 57). Design work that focuses on building knowledge of scientific phenomena can be one way to address the limited amount of time teachers have for science and engineering instruction.

Finally, in this study, I observed how in the absence of quantifiable criteria, students resorted to leveraging social status in brainstorming design solutions. I argue that the inclusion of quantifiable criteria in relation to a scientific concept is critical to equitable engagement of all students in science and engineering practices through engineering design. In addition to explicit social norms for small group work, outlined in the next section, systematic testing and student-collection of data may provide students of all status levels in the classroom access to the resources needed for engaging in argumentation.

Professional development for teachers who are new to the engineering practices, or even to NGSS, should be structured so that engineering design lessons start with a core scientific phenomena that serves as the focus of systematic testing and student-collected data. Reiser (2013) argues that teacher professional development must connect practices to subject matter contexts. This study makes clear the importance of situating argumentation in engineering design as a way to support the participation of all students by problematizing designs in relation to quantifiable criteria.

Scaffolds for Collaboration in Open-ended Design Work

As is typical of classroom practice, students in this study were used to working in an environment that privileged individual achievement. Without social scaffolds, they resisted their teachers’ general prompts for collaboration. Some students were highly self-focused, while others attempted to negotiate the relational space more equitably, such as when Eddie positioned Ahu and himself with equal but different competencies in science and math class.

Of particular significance is that what defined a successful collaboration in the Rainmakers Engineering Design Challenge—creating and presenting a successful design pitch—did not hinge on how well students collaborated, but on the tensions that resulted from the disenfranchising positions students found themselves in and their resistance to those positions. Polly used her academic and social status at Table One to direct activity with some resistance from her peers. However, because Ahu and Eddie found their statuses to be more contentious in how these were recognized by themselves and each other, their inability to collaborate led to a situation in which there was no consensus on the group's design pitch.

Design implication. Détienne et al. (2012) claim that “in sum, collaboration, in design in particular, is inseparable from the interplay of persons, personalities, images of self and other, with all the tensions and affects that are involved” (p.258). Students can struggle with collaboration in any discipline. However, I argue that it is especially important to attend to in engineering design work because of the ways in which successful, authentic design work requires a restructuring of classroom practices that empowers students to each be positioned and recognized as contributors to a creative endeavor through disciplinary practices and provides opportunities for domain identification. The sequences in this chapter show that teachers and students who are new to design work would benefit from explicit structures that shape the steps in a design task like Rainmakers, with divergent possible solutions and a ‘messy’ design space. One way to address this is to, as Mathews (2010) does, cultivate islands of expertise (Crowley & Jacobs, 2002) in which students are responsible for the core concepts in the design, but take on differentiated roles in the process—making each individual student indispensable to the collaborative work. This would allow students to maintain their individual identities as contributors while also helping each other in explicitly defined roles. Additionally, making these

changes and new structures in the learning ecology explicit, with opportunities for reflection on the contributions of each member of the group, may help students to recognize and build new identities as contributors and designers (Mathews, 2010).

To create opportunities for equitable engagement with scientific and engineering content and practices, attention to the relational goals and the intellectual roles that facilitate these is imperative (Cohen, 1994; Herrenkohl, 2006). Cohen (1994) points out that open-ended, or “ill-structured” problems require training for social interactions in small groups, with an eye toward the problems of over-structuring group dynamics, which can lead to micromanaging thinking and talking (p. 28). While Ms. Jones was explicit about the open-ended and messy nature of engineering, in professional development moments, more focus needs to be put on definitions of individual and group competency in ways that support participation by all students.

In terms of teacher professional development, Barron (2003) recommends engaging teachers in reviewing video case studies of small group work in relation to student outcomes and teacher practices. This practice would be especially useful for making explicit the ways that teachers convey images of engineering to students and understanding how students do or do not take up those images in small and large group work (e.g. Reiser, 2013). As enactments of engineering design in classrooms become more common and video data is collected, teachers may benefit from examining the discipline-specific small group work in the ill-structured contexts of engineering design, in order to understand the unique potential and challenges.

Conclusion

This chapter highlights the social challenges associated with scaffolding small group work that enables all students to participate in science and engineering practices. I have argued that equitable engagement in engineering practices requires quantifiable criteria with which to

argue for design proposals, and scaffolded social norms that help students negotiate the relational space of small group work for their own goals. In this study, I showed that the images of engineering and the engineering design task as it was implemented reified existing social roles in the classroom in ways that prevented some students from full participation in all of the intended engineering design practices.

This study aimed to provide insight into how teachers and students successfully engage in what may be novel classroom practice by understanding the contexts in which learning happens. The findings here provide clarity on the aspects of engineering design that may be challenging for teachers and students to take up, especially in relation to focusing on engineering design as an authentic venue for developing explanations and models of scientific phenomena. This study makes clear the complexity of shifting typical classroom practice, from those in which students work together to find a pre-determined, single answer, to instead leverage student agency in the creative and open-ended endeavor of design work.

The findings here point to several areas of future research and implications for both teachers and students. Integrating science and engineering education requires foregrounding both the content space and the relational space in order to examine and make explicit for teachers and students the ways in which engineering design is essentially a socially constructed endeavor, mediated by social positionings, images of engineering, scientific concepts, and available material resources. This study is limited in that it does not attend to the ways in which material objects played a role in the design process, the ways in which students used these material objects to position themselves and others in particular ways, to take on new positions, or to resist positions they found disenfranchising. Additionally, students in this enactment were never formally assessed on the process or the outcomes of their design work. Data collection that

captures how students reflect on their process and learning outcomes, as well as assessments of student work will triangulate the findings on social interactions reported here.

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Chapter 5: Designing for Expansive Science and Engineering Learning and Identification across Settings: Conclusions, Implications, and Future Research

The three analytical chapters of this dissertation examined how youth engage in scientific and engineering practices across settings in and out of school: in the classrooms, in their daily lives, and on field trips. The core goal of this work was to consider expansive learning strategies for designing ‘interventions across settings,’ seeking to create opportunities for the production of science and engineering within the social practices of diverse communities, in order to reorganize contexts of practice and the ways that people imagine themselves and their futures. This work is done in relation to a recent research and policy focus on ‘learning through practice’ to create more relevant and agentic learning experiences for youth from non-dominant communities by attending to learning in and across spaces of intentionally designed hybridity (Moje, Collazo, Carillo, & Marx, 2004) and the coordination of cultural learning pathways (Bell et al., 2012).

In Chapter 2, I revised an existing tool to develop the Science Activity Survey (SAS), an ecologically grounded analytic tool and protocol, to examine the different meanings that young people have for science in relation to the social practices in which they might engage. The analysis found that young people conceptualize science in several stable, discipline-specific ways. Young people saw activities as science-related primarily if the activities include participation in scientific practices, such as making observations or talking about science. These practices were most evident to youth in their school-based activities, but their responses also revealed the potential for engagement in related practices in several other activities in their lives outside of school. The implications of this study point to opportunities for broadening young people’s recognition of science in their lives by focusing youth learning experiences on

authorship and production of science-related investigations. The SAS protocol provides an emic approach for understanding young people's perspectives on science, identifying points of leverage for increasing young people's recognition of and participation in science-related activities, and provides a basis for promoting more equitable science learning environments.

In the design-based research of Chapter 3, I examined the development and outcomes of a cross-setting approach for supporting and investigating student learning of environmental science in a fifth-grade classroom. This chapter made evident the ways in which designing for learning across boundaries—both of discipline and setting—can engage youth in authentic, community-based, scientific issues. The analyses highlighted both the potential and the challenges of working in a research-practice partnership to coordinate learning across settings by describing the powerful outcomes for youth in light of some of the complexities that arise.

Finally, Chapter 4 analyzed an enactment of an engineering design curriculum unit in a fifth-grade classroom—as part of a larger, three-year design-based implementation research study. The project was designed to support implementation of the vision of the NRC *Framework for K-12 Science Education* (NRC, 2012) and *Next Generation Science Standards* (NGSS, 2013) by supporting teachers to adapt existing curriculum in order to take up the NGSS scientific practices, with a focus on explanation, argumentation, and engineering design solutions. Chapter 4 highlighted the images of engineering portrayed by an engineering design curriculum unit and the teacher, and the affordances and challenges of these portrayals as they supported students to engage in engineering design work as the unit was enacted. Findings point to the ways in which students use social capital to leverage their design ideas in the absence of a central scientific concept and specific, quantifiable evidence to support their proposals.

Across the three studies, several high-level conclusions can be drawn as described below.

Conclusion 1: Young people understand science as being primarily associated with school classrooms, especially in terms of when and where scientific practices happen. However, young people also recognize the ways in which a variety of activities across their lives have the potential to be science-related. Media-related activities may have the most potential for youth to take part in authentic and personally-meaningful work in order to engage with science concepts and in key scientific practices. Because young people report doing math in school to be one of the top activities they spend time on, it may be another important venue for the integration of STEM activities.

A canonical view of science as occurring solely in school classrooms is problematic in that it provides a narrow view of when and where science is, the central practices, and who can do science. By leveraging youths' everyday definitions of and practices in science (Bell et al., 2013; Zimmerman & Bell, 2012) and making the disciplinary discourses, tools, and practices explicit, designed learning environments can help youth navigate the field in ways that are meaningful to them and expand their views of when science is (Delpit, 1988). While science is not always the central focus of activities across youths' lives (nor should it be), educators and parents can act as brokers for young people's involvement in science in everyday settings by facilitating the bridging of youth practices of one setting in another. This facilitation can help to broaden conceptions of what counts as science from the perspectives of both youth and adults in their lives and support more meaningful science learning across venues.

The findings in this dissertation also support previous research that documents the prevalence of media-based activities in the lives of youth. Future research should build on this previous work (e.g., Ito et al., 2013) to design and examine opportunities for youth to act as contributors to authentic scientific and engineering endeavors in order to develop disciplinary

identification for youth. Finally, as also indicated in the *Framework for K-12 Science Education* (NRC, 2012), this work supports the purposeful integration of STEM. Specifically, because youth indicated doing math as an activity they do most frequently, it is sensible to consider opportunities to make subject areas interdisciplinary, such as including science and engineering concepts and practices in existing math learning environments in ways that deepen and broaden disciplinary definitions and understandings in each subject area.

Conclusion 2: Designing for learning across settings can support the development of hybrid learning spaces in which youth gain access to new forms of participation and identification in relation to science in their community. Key design features of these environments include: (a) the explicit recognition of science as multi-voiced and an important tool for communities; (b) youth authoring of boundary objects to serve community interests; and (c) youth access to authentic resources—such as people, places, texts, and roles—related to the cultural histories of youth and the unfolding science investigations.

The authentic resources youth might access as they engage in personally- and community-relevant investigations will vary from context to context. In this dissertation, iterative and overlapping opportunities in which youth began to develop relationships with disciplinary experts and with place were among the most powerful experiences for youth in terms of engagement in scientific practices and access to science-related identification work. Particularly, disciplinary experts who share similar cultural or ethnic backgrounds with youth may provide a ‘cultural match,’ as someone who might share aspects of their cultural experiences, discourses, and values and make new possible futures in relation to STEM explicit for youth (Achinstein & Aguirre, 2008).

Additionally, partnerships with community-based organizations can facilitate access to authentic resources that would not otherwise be available to teachers and youth. However, because field trip curriculum is not often well connected to youths' other experiences (including classroom instruction), opportunities are available to more deeply engage youth in scientific and engineering practices in the places where field trips take place (Storksdieck, 2011).

Conclusion 3: Generative hybrid spaces have the potential to facilitate: (a) critical moments of positioning and identification in relation to science of youth participants; (b) the disruption of societal, racial stereotypes of the capabilities of marginalized youth; and (c) contributions to how youth see themselves as members of their community and agents of social change through engagement in science.

Engaging youth with authentic, contemporary, and complex socio-scientific issues in and out of the classroom creates generative hybrid spaces that can provide opportunities for youth to be positioned as critical consumers and contributors to science. The activities in this dissertation allowed for the development of youth-authored boundary objects, such as critical questions and public presentations of student work, which afforded youth access to other resources such as new audiences and ideas. These resources in turn influenced new available identities for youth in relation to science.

A key resource of the hybrid spaces in this study was access to disciplinary experts. Their presence in the classroom enabled new forms of participation, recognition, and opportunities for youth from marginalized communities to be heard by people with decision-making power in their communities. This recognition, of youth as competent and interested members of their communities, is imperative in efforts to make well-informed and equitable decisions in issues of

environmental and social justice. However, the underlying assumption, that youth from marginalized communities are not capable of this work, is problematic and must be unpacked with both youth and disciplinary experts.

Designing for learning across settings can foster classrooms as sites of youth activism, in which youth deeply and authentically engage in socio-scientific, social or environmental justice issues in their communities, positioning them as developing experts in order to seek youth-driven institutional change. These kinds of opportunities can lead to important identification work as youth are recognized as competent and critical voices by themselves and others, including public figures and others who make decisions that affect youth and their communities (Kirshner, 2007).

Conclusion 4: Engineering design work in classrooms and across settings has the potential to be an agentic context for engaging youth in scientific and engineering practices that position them as producers of knowledge and useful designs. Equitable engagement in engineering practices requires specific criteria that can be socially agreed upon with which to argue for design proposals, and scaffolded social norms that help students negotiate the relational space of small group work for their own goals.

It is imperative that classroom participation structures be reorganized to address the open-ended nature of design work, which may an uncomfortable space for youth who are used to the well-defined, convergent activities typical of classroom work. Explicit structures that shape the engineering design process, but which still allow divergent possible solutions and a ‘messy’ design space may benefit educators and youth. Engineering design work that includes systematic testing and student-collection of data may provide equitable access to scientific and engineering practices such as argumentation, as students leverage data to make claims about the worthiness

of design ideas. To this end, the development of engineering activities or curriculum, as well as professional development for teachers, should begin with a focus on core scientific concepts that facilitate systematic testing and the development of arguments for how design proposals meet criteria and constraints.

This dissertation supports previous research that shows that specific procedural and intellectual roles contribute to more equitable outcomes for students who are often positioned out of scientific practices in the classroom (e.g. Cohen, 2004; Herrenkohl, 2006). Assigning youth rotating, differentiated roles in design work gives each individual student an opportunity for central participation in collaborative work (e.g. Crowley & Jacobs, 2002). Additionally, opportunities for youth to reflect on what maybe atypical classroom structures such as these may help them to recognize and build specific identities as contributors and designers (Mathews, 2010). Finally, care must be taken not to over-structure open-ended tasks in ways that may shut down creativity, iteration, and productive failure (Barron, 2003; Cohen, 1994).

Future Research

Each of the chapters in this dissertation point to rich opportunities for future research.

Young people's definitions of science across their lives. The SAS survey and protocol provide a scalable tool that can be refined in future iterations to better understand young people's definitions of science and their identification of and with science within various pursuits across their lives. Educators in classrooms or in community-based programs might develop local activity lists to be used to describe a classroom or community of youth that can in turn be used to inform designed environments that work to bridge youth practices from one environment to another in ways that support engagement in STEM practices and identity development. Detailed ethnographies of individual youth, as well as follow-up interviews that explore the social

relationships that support and influence young people's conceptualizations of science and engineering are needed to better understand the nuances in the varied lives of youth.

Environmental science learning across settings. Future research on connecting environmental science learning across settings should focus on engaging youth in the same socio-scientific dilemmas that community members are dealing with in the real world, while keeping the core scientific phenomena central. In this study, the investigation questions and thus the students' claims, evidence, and reasoning statements were not as cohesive or rigorous as we had hoped. Investigation questions that allow for divergent answers and engagement in argumentation must be carefully and thoughtfully planned. Other models of explanation and argumentation should be explored and implemented in order to meet the needs of all students and to keep youth interest. Equitable engagement in these practices may also include a rigorous documentation protocol with which to track the progression of youth thinking, both individually and in group work. One example of this is to investigate the use of a theory chart, which publicly displays theories offered by youth (Herrenkohl & Guerra, 1998), as a boundary object to connect learning across settings.

Engineering design work in classrooms and across settings. Further studies of engineering design work in classrooms must attend not only to the images of engineering conveyed to youth and the available social positionings in relation to disciplinary practices, but also the ways in which engagement in engineering provides youth opportunities to address interests and issues of personal and community relevance. Engineering design interventions should also highlight for educators and youth the affordances and challenges of engineering as a process not just for using science, but for developing understandings of scientific phenomena.

The conclusions presented in this dissertation are based primarily on the analysis of fieldnotes of observations, content logs of audio and video data, and student work. Future research that examines young people's experiences as they participate in coordinated learning across settings should also include protocols, such as interviews and exit tickets, that capture youth perspectives of their experience in the moment, as well as longitudinally, in order to more fully understand how youth make meaning of these experiences and support other data sources and findings.

Youth routinely encounter science and engineering topics in and across the settings of their lives. However, the coordination of learning across settings and over time is often unsupported. This dissertation considered approaches for the strategic coordination of environmental science and engineering learning across settings for fifth-grade students by creating hybrid spaces that provided opportunities for youth to take on new forms of authorship, authority, and identity in relation to science. The conclusions and design implications presented here address inequities in science and engineering education and inform educational design efforts seeking to develop and support learning across time, places, and communities.

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Vita

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