# Developing Mentors: Adult participation, practices, and learning in an out-of-school time STEM program

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**Abstract**

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This dissertation examines learning within an out-of-school time (OST) Science, Technology, Engineering, and Mathematics (STEM) broadening participation program. The dissertation includes an introduction, three empirical chapters (written as individual articles), and a conclusion. The dissertation context is a chemical oceanography OST program for middle school students called Project COOL—Chemical Oceanography Outside the Lab. The program was a collaboration between middle school OST programming, a learning sciences research laboratory, and a chemical oceanography laboratory. Both labs were located at a research-based university in the Pacific Northwest of the United States. Participants include 34 youth, 12 undergraduates, and five professional scientists. The dissertation data corpus includes six years of ethnographic field notes across three field sites, 400 hours of video and audio recordings, 40 hours of semi-structured interviews, and more than 100 participant generated artifacts. Analysis methods include comparative case analysis, cognitive mapping, semiotic cluster analysis, video interaction analysis, and discourse analysis. The first empirical article focuses on synthesizing productive programmatic features from four years of design-based research.. The second article is a comparative case study of three STEM mentors from non-dominant communities in the 2011 COOL OST Program. The third article is a comparative case study of undergraduates learning to be mentors in the 2014 COOL OST Program. Findings introduce Deep Hanging as a theory of learning in practice. Deep Hanging entails authentic tasks in rich contexts, providing access, capitalizing on opportunity, and building interpersonal relationships. Taken together, these three chapters illuminate the process of designing a rich OST learning environment and the kinds of learning in practice that occurred for adult learners learning to be mentors through their participation in the COOL OST program. In the conclusion, I offer a set of design principles for mentor learning gleaned from empirical findings from the last two empirical chapters on how mentors can productively support the science learning of youth. The findings from this dissertation offer implications for designers of learning environments seeking to leverage experts for mentoring while engaging youth in contemporary science practices in order to broaden participation for youth and adult participants from non-dominant communities in STEM disciplines.

*Keywords:* Deep Hanging, mentors, OST, STEM, broadening participation

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# DEDICATION

This dissertation is dedicated to my participants. I hope this dissertation shares your truths with the world in ways that make you all proud.

# Chapter 1. INTRODUCTION

Afterschool and Out-of-School (OST) programs have been major tools in the repertoires of science, technology, engineering, and math (STEM) educators seeking to broaden participation for youth from non-dominant groups historically underrepresented in these disciplines (NRC, 2009). There are a number of accounts of youth learning in these types of programs but few accounts of adult learning for the participants who are working with youth. These types of programs can help youth develop science identities (Bell, Bricker, Tzou, & Baines, 2012a; Polman & Miller, 2010) engage in contemporary science (Barab & Hay, 2001; Hsu, Roth, & Mazmunder, 2009; Warren, Ogonowski, & Pothier, 2003), see the relevance of science in their own lives (Bricker & Bell, 2014; Calabrese Barton & Tan, 2009), and come to make scientifically literate decisions (Feinstein, 2010; Polman et al., 2010a). Given that adults are partners with youth in these programs, we need to understand the experiences of adult program participants who are essential to the success of these programs focused on broadening participation in STEM domains.

Adult participants can take on a variety of roles in broadening participation programs. They can serve as facilitators, teachers, mentors, friends, and colleagues. Adult learning partners bring their goals and objectives into their work with youth. Heath (2012) calls these caring non-parental adults "intimate strangers." Heath explains that intimate strangers are in a special position with respect to youth because while they build relationships with them as people, their work with youth is typically centered in helping to accomplish an authentic task that youth have chosen to work on. Heath has documented that there are a few key components of the intimate stranger/ youth relationship that are particularly relevant to my work: (a) youth and adults collaborate around consequential tasks; (b) they are engaged in contemporary practice; and (c) they are working towards a final product that will matter to a disciplinary practice community. These dimensions of their collaborative work allow intimate strangers to support but also push youth to attain a standard of performance connected to the rigors of contemporary professional practice. Adult participants in the Chemical Oceanography Outside the Laboratory (COOL) program are mentors to youth participants. Mentorship in the Chemical Oceanography Outside the Laboratory (COOL) program is a hybrid of socio-emotional and academic mentorship. A mentor in the COOL program is defined as an adult with relevant disciplinary content or process knowledge who chooses to work with middle school students to complete a personally, community, and scientifically relevant project. Thus mentors in the COOL program would be considered intimate strangers within a science context. Mentors in the COOL program are professional scientists (2011) and undergraduate students (2012-2014).

Mentorship programs in STEM education contexts sometimes seek to leverage the expertise of professional scientists to help youth learn that they can be and become scientists. Youth from non-dominant communities need bridges, guides, and translators to help establish links between their everyday expertise and STEM practices (Bricker & Bell, 2014; Calabrese-Barton, Tan & Rivet, 2010; Lee, C, 2007; Nasir & Hand, 2008; Zimmerman, 2012). As experts in scientific practices, we often think scientists are well positioned to do this work. Since we would like youth from non-dominant groups to engage in scientific practices, it seems perfectly logical to have youth apprentice into the work with experts as guides. The hope is that when experts and youth work together it will lead to deepening and broadening participation for youth. Sometimes wonderful things happen youth develop identities related to STEM, they take up scientific practices, and begin to participate in new ways. Sometimes problematic things happen, these experiences can concretize stereotypes about the discipline, scientists, or the forms of intelligence necessary to participate, or they can confirm a sense of alienation. For adult mentors experiences in OST programs may reinforce adverse stereotypes about youth, communities, and the education system, or even drive qualified mentors away. The problem is that we currently do not know enough about what mentors bring to and learn from these experiences to help program staff and members to cultivate powerful experiences and avoid problematic ones.

In this dissertation, I am studying mentor learning in the context of their participation in an out-of-school time program. It is composed of three research articles related to this topic. These three papers together explore the Chemical Oceanography Outside the Laboratory (COOL) Program as the context for studying and theorizing about mentor and youth learning. The second and third papers introduce and leverage a theoretical construct called Deep Hanging that mentors in the program used to describe their experiences learning in practice.

Each paper focuses on answering one of the following research questions:

1. How do we collaboratively design an out-of-school broadening participation program that works to create opportunities for youth to agentively act, author, and authenticate as they engage in contemporary scientific practices?
2. What is Deep Hanging and how does it manifest in the ways that STEM disciplinary experts reconstruct narratives of how they came to be and become scientists and the ways that mentors position themselves and youth with respect to STEM?
3. What and how do mentors learn through their participation in an out-of-school time STEM program focused on broadening participation?

The first paper focuses on program content and design, while the second and third papers focus on mentor learning in the out-of-school time, broadening participation program.

The following overview is divided into six sections. The first section lays out the conceptual territory for this dissertation including a description of the Deep Hanging model of disciplinary learning and development. The second section describes the COOL afterschool science program, the research contexts, participants, data collection methods, and my positionality with respect to the project. The next three sections each deal with a single paper. These sections frame the paper, present research questions, describe data leveraged to answer these questions, and explore the intended analysis methods. I conclude with a section on the proposed impact of the dissertation and potential audiences who may be interested in the outcomes of this study.

## Conceptual Territory

In the following section I discuss the literature that forms the conceptual territory covered in this dissertation. The literature overlaps to inform the different aspects of mentor learning and program development that I'm pulling into focus in this dissertation. Learning in practice foreground the sociocultural and historical nature of human development and allows me to explore mentors learning. Including literatures on learning as participation in social practices continues this argument by positioning mentor learning as a collaborative accomplishment of persons and artifacts in designed contexts. A review of some of the perspectives on broadening participation in the literature helps to contextualize the study of design and mentor learning in STEM broadening participation programs. Finally, describing Deep Hanging as theoretical and analytical construct allows me to consider the role that it played in helping mentors understand that they could be and become scientists. Deep Hanging also plays a role in understanding the experiences of mentors in the 2014 cohort learning in practice during the broadening participation program.

**Learning in Practice**

"Practice is a way of talking about the shared historical and social resources, frameworks, and perspectives that sustain mutual engagement in action"(Wenger, 1998, p. 5). Mutual engagement in action is a major component of the conceptual framework I have been developing for this study and in this case. Wenger's statement highlights the mutually constitutive nature of people, contexts, and practices. Learning in practice contrasts with knowledge-based learning frameworks and foregrounds learners as participants in multiple "structures of social practice" (Bell et al., 2012a; Dreier, 2009). This is a fundamentally sociocultural stance and it aligns with learning in practice (Penuel, 2014), communities of practice (Lave & Wenger, 1991), hybrid worlds (Calabrese Barton, Tan, & Rivet, 2008; Warren, Ogonowski,& Pothier, 2003), authentic tasks (Bouilion & Gomez, 2001), and lines of preference (Azevedo, 2011), and practices associated with life-long, life-wide, and life-deep learning (Banks et al., 2007; Bell et al., 2012b).

Penuel (2014) calls for "research on three types of learning in practice, developing expanded abilities for participating in relatively stable practices, adjusting to changes to practices or the need to adjust ones repertoire of tools for participation to a new context, and taking part in the development of new practices" (p. 29). His contribution foregrounded the ways that other researchers have used a focus on social practices in order to describe learning outcomes. Penuel argues that research on learning in practice must actively seek to disambiguate these stances. Learners engaged in communities of practice (Lave & Wenger, 1991) learned through legitimate peripheral participation—increasingly complex participation in the practices of the community their were joining. Communities of practice are an example of a structure of social practice with specific parameters: access to experts, learning with peers, legitimate participation in authentic work, and a focus on learning while doing. In order to relate this perspective to specific educational goals, Calabrese Barton, Tan, and Rivet (2008) add the construct of youth agency to the frame of learning in practice in order to highlight the role of youth agency and personal relevance in motivating STEM learning

Calabrese Barton, Tan, and Rivet (2008) offered an empirical study of young women who leveraged both "sanctioned and unsanctioned resources and identities" into their learning environment to construct the structures of their shared social practice. These young women took control of their learning by leveraging the resources, knowledge and activities of their personal backgrounds into their classroom science learning. This concept of constructing learning environments through hybridization hinged on the presuppositions that people learn in practice and in relation to environments in which they participate. Learning was also viewed as inherently social as the young people "actively negotiated" spaces where they could "engage deeply in science on their own terms while maintaining social status and relational authority among their peers" (p. 81). Calabrese Barton, Tan, and Rivet's contribution to learning in practice placed even more agency in the hands of the participants to hybridize the context in ways that best structured the learning environments for their own learning. Agency in their frame relied upon including past experience which Warren, Ogonowski and Pothier (2003) explored in "structures of social practice."

Warren, Ogonowski, and Pothier (2003) argued against the stance that everyday and science understandings were discontinuous and that everyday experiences were deficits to be overcome through science education. Rather, they suggested that everyday experiences were a source of repertoires of practice that could be leveraged into creating science understandings.

They described the ways that "children both inhabited and analyzed the hybrid worlds they created, opening up new paths to meaning and new ways of seeing in the process" (p. 143). Their contribution was pulling in past experiences as part of the co-constructed contexts, tools, and activities of persons living in social structures. Bouillion and Gomez (2001) pulled in the notion of authentic tasks for learning in practice. Just at Lave & Wenger (1991) explained in their description of novice butchers, not every learning experience allows for learning in community, and Dewey (1963) discussed educative and non-educative learning, there are certain parameters for tasks that allow learning in practice.

Bouillion and Gomez (2001) described science learning in two fifth grade classroom organized around learning in systems. In their study youth learned in practice in mutually beneficial partnerships with external science experts and community organizations. For the purposes of this synthesis, their contribution focused on learning in practice through engagement with "real-world problems." The students studied a polluted river system close to their school. The researchers described this as real world problem because "a) there was no clear answer, the problem was interdisciplinary in nature, it was relevant and of interest to the curriculum and the students' lives, and was highly visible and accessible to the students" (p. 891). This study contributed to the concept of learning in practice by focusing in on the parameters of tasks that allowed for students to learn while doing. Azevedo (2011) on the other hand focused on one learner and his preferences and long-term choices to engage in practices.

Azevedo (2011) offered "a practice-centered theory of interest relationships" and focused on the role of individual interests, participation, and persistence for learning in practice. For Azevedo, "participation and persistence cannot be understood separate from the organic ways that the practice extends into and depends on other practices in their lives" (p. 162). He focused on preferences in “lines of practice” and his contribution foregrounds the central role of learner agency. In his conceptualization, persons chose to participate in practices over the long haul, but learners were also grounded in the co-construction of people, places, and actions. However, participation can be constrained by places, and resources, or access to activity that permits learning in practice.

**Learning as participation in social practices**

A sociocultural view of learning as participation opens up the opportunity to consider the roles of learners, environments, material and cognitive supports, peers, and adult learning partners (Barron et al., 2009; Engström, 2000, Dreier, 2009). Defining learning as participation in social practices allows me to consider how agency, identity development, and identification with the domain impact different forms and timescales of participation for learners. Viewing learning as participation builds upon the rich body of research on the affordances of culture in learning (Lee, C., 2007; Nasir et al., 2006; Rogoff, 2003). Using this construct of learning in STEM contexts shows how science learning is deeply cultural (Basu & Calabrese Barton, 2007; Calabrese Barton, 2001; NRC, 2009, 2012).

Youth from non-dominant groups face substantial barriers to STEM learning based upon the ways that the education and participation dimensions of the domains of science are shaped by race, Socio-Economic Status (SES), gender, English language learning, epistemological commitments, family expectations, and cultural repertoires of practice (Banks et al., 2007; Basu & Calabrese Barton, 2007; Bell et al., 2009; Calabrese Barton, Tan, & Rivet, 2008; Czujko, Ivie & Stith, 2008; Hanson, 2007; Lee, C., 2007; 2008; Nasir et al., 2006). Bang and Medin (2010) suggested that non-dominant communities traditionally underrepresented in STEM also face “lack of degreed expertise” which forms another barrier to youth participation. Beyond the actual barriers, misconceptions abound among important actors in educational systems about youth from underrepresented groups and science learning. Low participation in STEM disciplines has been attributed to deficits inherent in members from non-dominant groups. Critical scholars are working to debunk stereotypical perceptions and deficit-based explanations for lack of non-dominant community member participation. Specifically, scholars continue to argue against perceived lack of preparation to participate in STEM majors (Cjuko, Ivie & Stith, 2008), or imagined lack of family support (Hanson, 2007), and insidious questions about individual engagement (Basu & Calabrese Barton, 2007, Calabrese Barton, 2001).

Youth centered learning environments that leverage mentors can offer youth opportunities to think like scientists, engage in authentic practices, negotiate identities, answer personally relevant questions, and learn about disciplinary specific cultural tools (Calabrese Barton, Tan, & Rivet, 2008; Cornelius & Herrenkohl, 2004; Polman & Miller, 2010; Tabak & Baumgartner, 2010). Harré et al. (2009) defined positioning as a triangle of speech acts, storylines, and stances taken together these constructs shape the ways individuals develop within structures of social practice (Dreier, 2009). Positioning theory frames the ways that constellations of interpersonal interactions and social learning facilitate shifts in sociomaterial practices over time (Bell, et al., 2012a). The cultural learning pathways framework (Bell, et al., 2012a) serves as the conceptual framework for articles two, three, and four. As youth and mentors in the COOL program interact in a learning environment designed to allow for co-constructed moments of coordinated participation in chemical oceanography practices, I was able to observe the ways that mentors and youth's access to places, positions, and discourse shaped their scopes of possibility. Specifically we can observe ways that mentors' moves granted youth access or constrained opportunities for youth to participate in chemical oceanography practices.

Theoretically speaking learning as participation allows me to leverage asset-based frameworks that rely upon deepening participation in disciplinary practices overtime such as lines of practice (Azevedo, 2011), cultural learning pathways (Bell et al., 2012a), professional vision (Goodwin, 1994), legitimate peripheral participation (Lave and Wenger, 1991), and apprenticeship (Rogoff, 1990). A focus on the processes by which mentors and youth experience broadening participation programing can help to shape new conceptual spaces for learning and development.

**Broadening Participation as a Programmatic and Scientific Focus**

Broadening participation efforts have been aimed at increasing recruitment and retention in Science, Technology, Engineering, and Mathematics (STEM) for young women, youth of color, English Language Learners (ELLs), people with disabilities, as well as youth from rural and urban communities of poverty. Youth from these groups have been referred to by various names in the scholarship- non-mainstream, marginalized, disengaged, minority, or underrepresented. I choose the term non-dominant (Nasir et al., 2006) because it links to my definition of learning and helps place the focus on the larger societal forces that confer power or dominance to some groups. Learning is a process characterized by deepening participation in sociocultural activities embedded in overlapping communities of practice (Banks et al, 2009; Bell et al., 2012; Lave & Wenger, 1991; Lee, C., 2007; Rogoff, 2003; Wenger, 1998). Wenger (1998) described learning as deepening participation in a community of practice as both an action (engaging in practices) and a sense of belonging (identity and identification). Communities of practice can include hobby groups, church groups, afterschool activities, drama clubs, sports teams, and other voluntary learning communities. Let us think about practice as “a way of talking about the shared historical and social resources, frameworks and perspectives that sustain mutual engagement in action" (Wenger, 1998, p. 5).

Within the COOL program there were multiple levels of broadening participation. In the undergraduate context, we were working with students with a variety of backgrounds who were being apprenticed into working in informal environments. Within the OST contexts, we were working with youth from groups traditionally underrepresented in the sciences and apprenticing them into authentic STEM practice and the ongoing work of a chemical oceanography laboratory. In the midst of all this work it was essential that we consider the implications of broadening participation programming built within the underrepresentation frame especially as the potential existed for this framing to lead to developing programming with assimilationist leanings.

Bell et al. (2009) argued that broadening participation initiatives based largely on research conducted with White youth, families, and communities would be unlikely to provide solutions for youth from underrepresented groups. Assimilationist perspectives on science equity propose that youth from underrepresented groups lack participation due to lack of access, or interest, or capacity to take up the dominant form of STEM work. Proponents of this stance offer solutions based on giving youth from underrepresented groups access to the same kinds of learning opportunities aimed at increasing participation for youth from dominant groups (Harackiewicz et al., 2012). However, research on African American and Indigenous communities has demonstrated deep cultural expertise and repertories of practice that are well suited to STEM participation—although often under-acknowledged by dominant groups (Bang & Medin, 2010; Basu & Calabrese Barton, 2007; Calabrse Barton, 2001; Hanson, 2007). Everyday science literature builds upon the premise that youth's everyday practices—including argumentation, modeling, asking questions, gathering data—map onto scientific practices in ways that may not be recognized as scientific by teachers or other gatekeepers (Bricker & Bell, 2014; Warren, Ogonowski & Pothier, 2003; Zimmerman, 2012).

Understanding some of the theoretical approaches to broadening participation as a programmatic and scientific focus pushes me to hold the potentially conflicting stances of seeking to bring more participants from non-dominant communities into STEM and pushing on STEM fields to change expectations and definitions of participation. COOL was built on the stance that mentors have a major role to play in broadening participation work.

**Using Mentors to Extended Learning**

Barron et al. (2014) describe the rich and rigorous learning environment that mentors can nurture in collaborative work with youth. Mentors in the digital-youth network (DYN) were expert artists and musicians who worked collaboratively with youth to accomplish personally relevant projects. Barron et al. (2014) defined a mentor as “positive role models and guides to help youth access digital tools and build technological fluency” (p. 61). This approach to thinking about the role of mentors in shaping youths’ development and fluency helped to build an instructional theory of action. The DYN instructional theory of action linked mentor’s practices and pedagogical moves to learning outcomes for youth.

They described an active mentor preparation program that developed overtime to ensure that mentors were prepared to meet the unique needs of youth as DYN transitioned into the more formal learning space of a k-12 context. Mentors in the DYN space were creators in their own right. This kind of relationship to the discipline is also typical for mentors in arts-based learning environments (Heath & Smyth, 1999). Learning environments designed to leverage everyday science practices have the potential to make use of mentors in order to incorporate diverse ways of knowing and thus provide space for youth from non-dominant groups to participate in STEM. Yet questions remain about the best ways to help youth establish a link between their everyday science expertise and formal STEM domains. Involving mentors as brokers in these learning environments is one way to address this problem.

The Society for the Advancement of Chicano and Native American Scientists (SACNAS) is an organization built upon the premise that mentors can build educational and professional bridges for young scientists from non-dominant groups. While organizations like Big Brothers/Big Sisters of America focus on youth development and the socio emotional impacts of long term mentoring, SACNAS goes beyond socio-emotional mentoring to leverage the hybrid space between personal and professional relationships. SACNAS focuses on building networks to catalyze processes that lead to identification with STEM domains, persistence in achieving degrees, and careers for scientists from traditionally underrepresented groups (SACNAS, 2015). SACNAS frames the work they do through the lenses of equity, broadening participation, contemporary work in STEM-related fields, and global competitiveness.

They maintain that a strong domestic STEM workforce must draw on the strengths of all Americans. SACNAS approaches this work by "providing resources, mentoring, motivation and perhaps, most importantly, community" for undergraduates, graduate students, and professionals all along the career pipeline (SACNAS, 2015). SACNAS is an example of an organization that sees the value of sense of community or relationship on creating spaces for professional development, building identities, and identification with STEM domains. SACNAS mentors are also skilled at passing on navigation stories and helping novices learn about the unspoken expectations in STEM learning environments. In the COOL program we called adult participants mentors because we wanted them to see themselves in the role of bringing about these changes in the lives of young people. Mentoring in the COOL OST contexts sought to leverage the expertise of the adult participants as navigators and scientists to help youth learn that they could be and become scientists.

Heath (2012) described intimate strangers as leaders and facilitators in youth and community organizations. These intimate strangers “guided the young people under their charge into understanding concepts related to time, respect for the property and privacy of others, and appreciation for rules and their sources and enforcers (p. 47). Intimate strangers in Heath’s study passed on opportunities for new experiences by connecting youth to internships or apprenticeship opportunities in this way, they introduced new lines of practice (Azevedo, 2011) or shared new interests with youth.

**Deep Hanging**

“Deep Hanging” (DH) is a term introduced by one of mentors in the 2011 COOL Cohort. She used it to describe her learning experiences and the ways that she was brought into science and recognized that she could be and become a scientist. Mentors in the 2011 Cohort were graduate students or recent graduates of masters in science programs. The question of where they fit into the culture of science was a recurring theme in interviews with these mentors and related directly to the ways they positioned themselves with respect to science. The following quote was Eva’s response to a question about how people learn complex science practices. I want to focus your attention on the ways that she describes a process of learning in practice:

> “I think part of it is the ‘Deep Hanging’ that you do. Ideally, it should be through the mentorship of your advisor…Your peers are going through the process, you’re discussing things…So being able to understand where you fit within that cycle, I think comes from just being part of it. I think a lot of it is the socialization that happens” (Eva, 2011).

Eva described a socialization process that did not happen through direct instruction from a more competent other—"through the mentorship of your advisor" but it actually came from "just being a part of [the work]." For Eva, learning to be and become a scientist happened in practice through Deep Hanging. Eva explained that while this learning should happen in direct instruction there were many other involved in her learning and development. In chapter two I will contextualize Deep Hanging in the plethora of other theories of learning in practice. Deep Hanging is more agentive and less teleological than other theories and emerged from a grounded theory analysis of mentor reconstructive history interviews.

During interviews Eva described Deep Hanging as four interconnected characteristics: (a) authentic tasks in rich contexts; (b) direct access and engagement with novel practices; (c) leveraging interpersonal relationships that facilitate participation; and (d) interpersonal relationships that encourage shifts in identity and deepening identification with the discipline. I will use Deep Hanging going forward as an analytical construct to explore the experiences of mentors in the 2011 and 2014 COOL mentor Cohorts.

Exploring the role of Deep Hanging in shaping mentors' motivations can help us better understand what mentors are trying to do when they work with youth. By engaging mentors in reconstructive history interviews about their STEM induction experiences we can gain insight into the ways that they will work with young people. During the COOL preparatory course in the third iteration of the program, we turned mentors into reflective practitioners and focused on developing their ability to think about their own experiences learning from their participation in the OST program. With programs like COOL, our design goal might be to get youth into STEM careers but we offer a more nuanced perspective, we'd like to get youth to a vantage point to

STEM careers and practices long enough to make informed decisions about their continued STEM participation.

The mentors in the 2011 program spoke about wanting youth to know that they could be scientists if that was what they wanted. Eva explained this later in the interview where she described Deep Hanging,

> "what I think is so important for the girls and identity building is to see that they can do science, that there is an option, that the practices that they engage in are like science in this way because when we say science it has the western academy picture behind it…but that's not the only way of knowing or doing practices that help us make sense of the world" (Eva, 2011).

Eva was struggling with the idea of ushering youth into the science in ways that privileged the western definition of science in ways that overshadowed or ignored other ways of knowing. She wanted youth to enter into science in agentive ways that allowed them to make choices about which ways of knowing were relevant to their lives and experiences (Bang & Medin, 2010).

To achieve these ends, we want mentors with expansive attitudes to broadening participation and what it means to participate in STEM. Within the world of teacher education the apprenticeship of observation (Grossman, 1990) is the term used to describe the link between an individual's histories of learning which in turn prepare them to work with learners in particular ways. Findings from the 2011 COOL cohort intimate that this holds true for disciplinary mentors. They learned they could be and become scientists through Deep Hanging and used this construct to position and work with youth in the afterschool program.

# Methods

## Design-based Research

In terms of methodology, Project COOL was a design-based research study (Bell, 2004; Brown, 1992; Cobb, Confey, diSessa, Lehrer, & Schauble, 2003; DBRC, 2003). It entailed both "engineering" a particular form of learning and systematically studying it (Cobb et al., 2003). The goal of Project COOL was to build a science-learning environment based upon the educational goals deemed to be of value for developing extended learning pathways for youth and experts. My ultimate goal was to build theory about adult participant learning as they engage in learning environments focused on broadening participation in STEM (Brown, 1992; Bell, 2004; Cobb et al., 2003). In this dissertation, I use designed-based research (DBR) in order to develop design principles for informal STEM learning environments, to build theory about participant learning, and hence to contribute to the science of broadening participation (Bell, 2004; Brown, 1992; Cobb et al., 2003).

Over the three iterations and four enactment years of the COOL program we had experiences that allowed us to speak to nature of different stakeholders, variable design configurations, and team-based curricular design approaches that may lead to successful implementations in other informal STEM learning contexts. In iteration three the research moved from working with mentors who were graduate students in STEM disciplines to working with undergraduates from a variety of majors. This move prompted the team to develop a concurrent undergraduate class both as a way to prepare undergraduate mentors to facilitate the COOL program and to offer them college credit in return for the number of hours they put into their work in the middle school contexts. Studying the mentor's participation in the undergraduate class led to the creation of a teacher preparation space for informal educators. We have borrowed curriculum and theoretical framing from the work of teacher education researchers to build this space in the 2012-2014 academic years (Cole et al., 2006; Grossman et al., 2009; Guiterrez & Vossoughi, 2009; Windschitl, et al., 2009).

**Participants**

Mentors were the focal participants for this study. I followed them as they travelled across learning contexts from the undergraduate preparatory class into the OST learning environments. In this dissertation I take the stance that mentors developed within the context of multiple, intersecting structures of social practice (Bell et al., 2012a; Dreier, 2009). Mentors in the COOL program were members of a site team, located within a local middle school (Agate, Marble, or Topaz) and they were also part of an undergraduate preparatory and support class (Pyrite). I focused on mentor's learning experiences from three years of COOL data collection: 2011, 2013, and 2014. There were three mentors who were graduate students or recent graduates of masters in science programs in the 2011 cohort. There were six mentors in the 2013 cohort, five undergraduates and one post baccalaureate Biology major. There were four mentors in the 2014 cohort, three seniors and one PhD in forestry management resources. The mentors in the program came from a variety of academic and ethnic backgrounds, had a variety of experiences working with youth, and represented a spectrum of comfort levels working in informal environments.

**Contexts and Participants**

**Project COOL.** There were two levels of participants in the COOL program: (a) undergraduates who were taking a class (Winter & Spring 2014) with COOL research and design team and served as mentors and program facilitators; and (b) youth—middle school students who joined the COOL OST program.  Leveraging the instructional framework for "Developing

Meaningful Expertise" (Bell, et al., 2012c), COOL designers positioned youth as developing experts and sought to build bridges from youth's everyday knowledge of science and technology to discipline specific modes of inquiry and participation. Designed learning spaces brought youth and experts into collaboration to accomplish projects that had personal, community, and disciplinary relevance. Building upon a history of related work (Bell, et al., 2012b), we believed an afterschool learning ecology built around these commitments would place youth and adults into a robust and productive learning environment likely to enable shifts in youth identification with the domains and practices of science.

**Middle Schools**. During the first iteration of the program, we served eight youth who came to the university once a week as apprentices in the SoundCitizen laboratory. During the second and third iterations, we served youth at two local middle schools: Marble, Topaz, and Agate. These middle schools were chosen for their high populations of youth from groups traditionally underrepresented in the sciences. We worked with Marble since the beginning of the middle school based program in 2011. We worked with Agate and Topaz for one year each. As the demographic table below demonstrates, all three schools had high populations of students from non-dominant groups. All three schools had rich traditions of youth programming in the OST space. Our program collaborated with the existing the OST schedule at the schools so as to leverage the existing infrastructure for recruitment, snack, venue, and afterschool transportation.

Table 1. COOL Partner School's Number of Students and Population Demographics

| School | Student Totals | Free & Reduced Lunch | American Indian | Black | Hispanic | Asian/Pacific Islander | White | Multi-racial | ELL (%) | APP (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Marble | 983 | 71% | 1% | 24% | 15% | 51% | 6% | 3% | 17 | 6 |
| Agate | 743 | 82% | 2% | 38% | 12% | 42% | 3% | 3% | 22 | 3 |
| Topaz | 1,160 | 49% | 1% | 31% | 10% | 21% | 32% | 6% | 12 | 42 |

This collaboration allowed us to reach students who might not have been able to participate in an offsite program where they or their families would have been responsible for transportation to and from the program site. Topaz and Marble have dedicated staff who administered OST and ran additional enrichment programming through the school's community learning centers (CLCs). In the Spring OST time ran from 2:30- 4:30 daily. COOL OST took place at Marble and Topaz from April through June 2014. It also allowed us to better understand the trade-offs in learning and identification for youth associated with engaging youth in science in a university lab versus a traditional K-12 classroom space.

There were three foci in the fall undergraduate class- (a) reflective practice through ethnographic methods; (b) NGSS and STEM teaching practices; and (c) experiencing the COOL OST curriculum as participants. During the spring course, undergraduate participants worked in teams to facilitate the COOL OST program at Topaz and Marble. They spent an hour and twenty minutes each week in a class we called Pyrite with researchers and program staff debriefing their experiences and examining their work as reflective practitioners. The rest of the course time was dedicated to planning for the next OST sessions.

**Data**

Data for this analysis come from five years of data collection and multiple sources. Each of the empirical chapters also includes a methods section that describes the data collection and analysis process in greater detail. The following data collection strategies were leveraged across the entire dissertation: video-recording of social interactions, field notes, collection of participant generated work, semi-structured interviews, cognitive maps, and surveys.

**Video-recording of social interactions.** The primary data collection activity of the study consisted of video recording of the undergraduate courses and the OST program sites. We were interested in how participation in particular scientific activities relates to understanding the scientific enterprise and identity in science, I conducted systematic discourse and video interaction analysis on this video data which informed the empirical chapters of this dissertation.

**Field Notes.** In addition to collecting video and audio recordings of program sessions, researchers took field notes during the sessions or wrote reflective field notes after time spent in the field if simultaneous field. Field notes added an additional layer of records. Field notes allowed the team to record events and interactions in places where video and audio equipment would be inappropriate or disruptive. They facilitated analysis by allowing me to more easily locate specific moments, activities, or events within the corpus of video and audio records for further analysis.

**Collection of participant generated work.** The research team collected all participant generated work. This included written work, representations, drawings, and posts to online forums. Undergraduate participants generated responses to readings in the undergraduate class, reflections of their teaching experience, and essays in response to prompts about teaching and learning. Middle school student participants generated worksheets, reflections about their learning, notes about their final projects, and entries in their science notebooks.

**Semi-structured interviews.** The COOL research team conducted face-to-face semi-structured interviews with the mentors at the beginning, middle, and after their participation in Project COOL. The team asked participants a set of questions covering the following topics: their backgrounds and interest in science, their perceptions of themselves and others as scientists and science learners, their role and activities as part of the discipline of science.

**Cognitive maps.** In addition to collecting participant generated artifacts, mentors in iteration 3 were asked to complete three conceptual content cognitive maps (Kearney & Kaplan,

1997) at three different points of their participation in the COOL program. The mindmaps were a snapshot of how mentors conceptions of the term mentor evolved during their participation in the program. During their participation in the program mentors completed three maps. The first at the very beginning of the program prior to working with youth, the second just before they started working with youth, and the third at the very end during the exit interview. At subsequent points, I asked them to look at and comment upon previously completed maps. The mind maps were analyzed using semiotic cluster analysis (Feldman, 1995).

**Surveys.** All participants completed surveys before and after their participation in Project COOL related activities. Mentor surveys covered topics related to their prior experiences with youth, definitions of science, sense of themselves as scientists, ideas about mentoring, and community engagement. Mentor's responses to the survey informed the semi-structured interviews.

## Positionality and Personal Significance

As an Afro-Caribbean woman broadening participation work is very important to me. I want to see the picture of what it means to be and do science expanded to include the experiences of youth from non-dominant communities historically underrepresented in STEM fields. This desire drove me to create and implement programming that connected youth from non-dominant communities with contemporary science even while we reframed what it meant to do science, what counted as science participation, and challenged the picture of who engaged in scientific work.

Within the COOL program, I was a full participant observer. I co-taught and co-designed the middle school and undergraduate curriculum. During COOL undergraduate sessions, I often took on the role of lead instructor. Within the out of school time sessions, I maintained the role of project coordinator. However, as a design team, our focus was always on running a successful program for youth. At times this meant being more of a participant than an observer and jumping in to co-teach and help mentors when the asked for it. With the mentors in the program my role was that of pedagogical mentor and guide into the world of science education. My research team and I spent many hours planning and debriefing the undergraduate and middle school program sessions. When we worked with mentors we talked about individual youth's developmental learning trajectories, flow of lessons, youth development, curriculum development, and pedagogical moves. This largely entailed fielding questions about problems of teaching practice, approaches to teaching STEM content, and youth development work.

Outside of COOL sessions, I coordinated the program, liaised with mentors, school administrators, teachers, parents, and family members. I organized field trips, managed supplies, made calls to collaborators, and facilitated the successful completion of the COOL program from end-to-end. Holding these positions gave me a unique perspective on the program activities and an intimate relationship with youth and mentors that had a positive impact on the interviews, my perspective on COOL sessions, and my analysis of program data.

My approach as a researcher is built upon the belief that all people share the fundamental experience of constantly striving to make meaning of the world and the contexts they encounter in their lives. I believe that persons develop in multiple structures of social practice and that we, as educational researchers, can come to understand these structures by explicitly examining participants' cultural learning pathways (Bell et al., 2012a; Dreier, 2009).

As my scholarship developed, I chose ethnographic methodology as the primary approach in my research because it privileges the experiences of participants and it uses narratives to make sense of the world. I come from a community of storytellers and people who make sense of the world through stories. When I began my PhD program and started work studying informal environments I made sense of my experiences by telling stories. Given this stance to learning and development, I approach my work by combining ethnographic methods with the larger context of design-based research, two kinds of findings emerge from my work: (a) theoretical findings about learning, deepening participation, and identity development for participants from non-dominant communities, and (b) practical findings about program design and implementation within communities of practice.

As a learning sciences researcher with a sociocultural perspective on learning and development, I believe that our work is inextricably linked to questions of social justice and power in relation to cultural repertoires of practice (Gutiérrez & Rogoff, 2003). As a result, I strive always to work in collaboration with communities and participants. I am a deeply relational educator and in my design and research work, this has taken the form of build mutually beneficial partnerships. Thus a major focus of my work is to bring something of value to the table to share with my collaborators. For example, in this the last year of funding for the COOL program my team and I are developing a set of curriculum resources, background information, and lessons that we can share with our collaborators so that they can continue to implement the program after the funding ends. This approach to design-based research (Bell, 2004) honors my commitment to working within community and building sustainable programming. With my participants, it has meant sharing my findings every step of the way and remaining completely transparent throughout the data collection, analysis, and writing process. In the next section, I will describe the three interconnected articles that make up the empirical chapters of this dissertation.

## Article 1

## Designing for Broadening Participation: Four years of design-based research in a chemical oceanography out-of-school time program

The first article focuses on the program writ large as design-based research (DBR) in response to the following research questions: How do we collaboratively design an afterschool broadening participation program that works to support the vision from the NRC Framework for K-12 Science Education and Next Generation Science Standards (NGSS), identity development, mentors, and contemporary science? What lessons can designers of learning environments learn from COOL OST as an example of a collaboration between multiple stakeholders to create an environment where youth can engage in contemporary disciplinary practices? This paper explored COOL as a context for learning about design and collaborative design involving multiple stakeholders. The article details designed elements that created opportunities for youth to experience acting, authoring, and authenticating—which are framed as central features of the desired learning and identification process.

The Chemical Oceanography Outside the Lab (COOL) program was a collaboration between a learning sciences research lab, a chemical oceanography lab, local middle school OST programming, and undergraduate mentors. This article focuses on the development and growth of the collaboration between these stakeholders over the course of the five-year design-based (DBR) research project. Data from COOL allowed me to explore implications for design of this kind of learning environment. One of the goals of this paper was to present a case for building these kinds of collaborations between learning scientists, bench scientists, mentors, and school stakeholders.

The article charts the decisions and changes made to the COOL program over time as a design-based research initiative. Project COOL had multiple purposes but at its core sought to broaden participation in STEM for youth and mentors from non-dominant groups. To this end, COOL partnered with middle schools with large populations of youth from non-dominant groups historically underrepresented in STEM to offer afterschool programming. The program served multiple goals by training undergraduates interested in STEM education to facilitate an afterschool academically-orientated STEM education program.

Data for this analysis come from transcripts of design meetings amongst the COOL team, artifacts created in collaboration with program partners, reflections on curriculum design elements, field notes, video-interaction analysis of the OST program sessions, and semi-structured interviews with youth and adult program participants.

Findings from this analysis have the potential to appeal to scientists and designers of learning environments seeking to build broadening participation environments for youth from non-dominant communities that leverage mentors, contemporary science, and design contributions from multiple stakeholders. In 2014 COOL was contacted by a grant writing support organization based at our university as a potential resource for scientists seeking to put together competitive federal grants. Further interactions with scientists earlier this year have led me to believe that this will be a welcome addition to the literature that informs the creation of NSF required broader impact program descriptions.

**Article 2**

**Deep Hanging: Mentors learning and teaching in practice**

Article two introduces the concept of Deep Hanging by exploring the experiences of mentors in the 2011 Cohort. This paper responds the following research questions: (a) What is

Deep Hanging and how does it manifest in the ways that STEM disciplinary experts tell reconstructive narratives about how they came to be and become scientists? (b) How does Deep Hanging factor into the ways that mentors position themselves and youth with respect to STEM? Mentors in this year of the program were graduate students all seeking new ways to participate in STEM. There were three mentors in the 2011 Cohort: Eva, Jessee, and Angelica. All there were women from non-dominant groups and all three were also members of the local chapter of the Society for the Advancement of Chicano and Native American Scientists (SACNAS).

Data for this analysis come from semi-structured interviews with mentors from iteration 2 of the COOL program. This study aims to gain a better understanding of the ways that scientists from non-dominant groups describe their experiences coming to understand that they could be and become scientists. I leveraged the cultural learning pathways framework (Bell et al., 2012a) to build case studies of mentors and compare their experiences learning they could be and become scientists.

Findings offer an alternative to other theories of learning in practice. Mentors in the 2011 Cohort felt Legitimate Peripheral Participation (Lave & Wenger, 1991) was too teleological and that their experiences involved a more agentive process. This perspective led mentors in the program to position youth in a more agentive way with respect to the disciplines of science in which they may have wanted to participate. Mentors saw broadening participation for youth as a process of getting young people to a vantage point with respect to STEM disciplines so that they could make decisions about their own future learning pathways.

## Article 3

## Deep Hanging: Being and becoming a STEM mentor

The third article is about mentor learning through their participation in the afterschool program in response to the following research question: What and how do mentors learn in a chemical oceanography afterschool program? The following sub-questions drive the analysis: (a) How do mentors work to make their own science-relevant experiences visible to youth? (b) How do mentors build and leverage relationships with youth participants? (c) How do mentors come to find a role for themselves in relationship to science and youth learning? (d) How do these beliefs influence the ways they position themselves in their work with youth?

Within the COOL Program, the term mentor refers to undergraduate students from a variety of backgrounds who leverage their science relevant expertise to work with youth form non-dominant groups historically underrepresented in the sciences. Project COOL Mentors and middle school youth participated in the study, with mentors serving as key informants. I used three sources of information about mentors to build case studies of each mentor's learning and deepening participation in the COOL Program. Data for this analysis comes from three main sources: pre and post interviews of mentors in the program, observations of mentors working with youth, and video club with mentors where they talk about why they do the things they have done with youth.

Focusing on mentor's cultural learning pathways (Bell et al., 2012a) helped to build case studies that showcased mentor learning. This analysis centers on better understanding how and what mentors are learning through their participation in broadening participation efforts. Mentors played a documented role in broadening participation for youth, however we have yet to gain a nuanced understanding of mentor learning. This study seeks to fill that hole in the literature.

An additional goal was to create a typography of ways that mentors worked with youth similar to Barron et. al's (2009) adult learning partner typography. Parents in Barron et al.'s typography worked with youth in a variety of ways that supported learning as: teachers, learning brokers, project collaborators, resource providers, non-technical supporters, learners, and employers. This article focuses on ways that mentor's approaches to working with youth mapped onto these adult partner-learning roles. Pilot research on mentors in the 2011 Cohort suggests that their ways of working with youth may also be based upon their own prior experiences learning about science. In this way, Deep Hanging plays a key role in how mentors learn they could become and do become STEM educators.

## Implications

The analyses in this dissertation offer insight into the science of broadening participation. Article one pushes on the science of broadening participation while simultaneously questioning some of the metaphors that shape current narratives about non-dominant community participation in STEM.

Articles two and three leverage case study analysis (Merriam, 2009) to introduce and expand upon the concept of Deep Hanging as a theoretical and analytical construct. Chapter two analyzes the experiences of mentors from non-dominant groups as they navigated their way into STEM disciplines. It also includes an exploration of the link between mentors' Deep Hanging experiences and the ways they choose to work with youth. Chapter three delves into the Deep Hanging experiences of mentors in the 2014 cohort by triangulating three types of data: semi-structured interviews, cognitive maps of mentorship, and video of OST sessions. Bell et al.'s cultural learning pathways framework helps to chart the mentor's experiences during their participation in COOL preparatory course and the out-of-school time programming (2012a).

The overarching goals of the dissertation are to document learning processes and associated educational design knowledge developed in the COOL program over a five-year period. Looking at the affordances and constraints for mentor learning as they worked with youth has the potential to speak to the design of STEM OST programs that leverage mentors' personal histories, and contemporary STEM practices for the purposes of developing equity and social justice focused learning environments. With this dissertation, I am also interested in developing a better understanding of what and how mentors learn through their participation in designed broadening participation learning environments because developing a better understanding of the experiences of mentors in informal learning environments has the potential to inform the design of robust and sustainable STEM broadening participation environments for youth from non-dominant communities.

# Chapter 2. DESIGNING FOR BROADENING PARTICIPATION: FOUR YEARS OF DESIGN-BASED RESEARCH IN A CHEMICAL OCEANOGRAPHY OUT-OF-SCHOOL TIME PROGRAM

Designing for broadening participation:

Four years of design-based research in a chemical oceanography out-of-school time program

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University of Washington

**Abstract**

This article examines the ways that a design-based research project sought to broaden participation in STEM for youth by engaging adult mentors as informal educators. This paper pushes on current definitions of broadening participation that only focus on increasing numbers to broaden involvement by underrepresented individuals and groups in STEM careers and fields. Rather, I explore how opportunities for acting, authoring, and authenticating shaped youth and mentors' participation in the designed learning environment of an after-school chemical oceanography program. I link designed elements to observed outcomes for both youth and mentor participants. Findings suggest broadening participation was supported by designed elements that created opportunities for acting, authoring, and authenticating. Implications share lessons learned from a sequence of enactments and the subsequent revisions. Finally, I offer design principles developed during four years of program enactments and three major program iterations.

*Keywords:* Design-based research, broadening participation, youth, mentors, afterschool

Designing for Broadening Participation:

Four years of design-based research in a chemical oceanography afterschool program

Science, Technology, Engineering, and Math (STEM) fields have an underrepresentation problem. The representation by individuals from non-dominant communities does not reflect proportions in the larger society. Women and other non-dominant groups continue to be underrepresented in STEM degrees and careers. The data in figure 1 (below) show that while participation is trending upwards we are far from reaching parity (NSF, 2013).

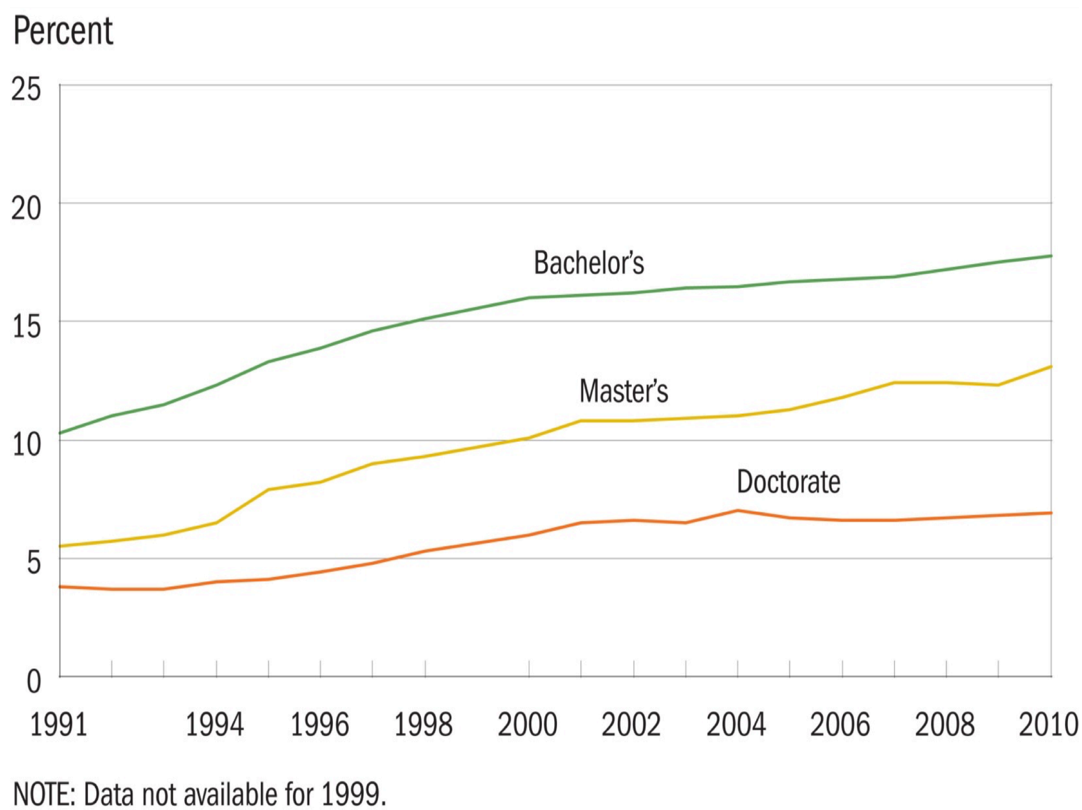


Figure 1. Science and Engineering Degrees Earned by Underrepresented Minorities: 1991–2010 (NSF, 2013)

There are simply not enough participants from underrepresented minority communities receiving STEM degrees and participating in STEM fields. The goal of increasing participation by individuals and groups who are currently underrepresented in STEM careers and fields aligns with the National Science Foundation’s (NSF) 2008 report on the importance of broadening participation. The NSF identifies the following groups and individuals as underrepresented in STEM: women, persons with disabilities, ethnic groups; institutions that serve women, rural, and non-dominant communities. The data in Figure 1 also show diminished participation from bachelors through to doctorate degrees for non-dominant groups. This decline in participation is part of the pervasive underrepresentation problem, and it has negative consequences on the quality of scientific progress (NSF, 2008).

A 2008 NSF report outlined a set of action steps to help broaden participation across the NSF portfolio. The NSF used the term “participants” as a broad category that encompassed individuals and institutions that had not been previously included in the foundation’s funding portfolio. The NSF listed individuals and institutions of higher education that served historically underrepresented groups like women, Indigenous communities, Hispanics, and African Americans. They also mentioned two-year and rural institutions. The approach to broadening participation laid out in the report included increasing diversity amongst the NSF’s merit review boards and reminding applicants that all new proposals for funding needed to include a broader impacts section. Requiring that funded project include broader impacts sections was one concrete way to make researchers dedicate attention to building educational and research capacity, broadening participation for underrepresented groups, building collaborations with underrepresented groups, enhancing dissemination of findings, and considering benefits to society. Remediating this situation is one of the major motivations for the design work associated with this project.

**Reframing Broadening Participation**

Definitions of broadening participation in STEM have historically involved underrepresentation narratives when framing participation for non-dominant youth and communities. Addressing underrepresentation is vital given the dismal statistics that show minimal improvements in addressing underrepresentation of participants from non-dominant groups (NSF, 2013). The underrepresentation narrative and leaky pipeline metaphor (NCES, 2008) have served the fields of STEM education and policy well (see Figure 2 below).

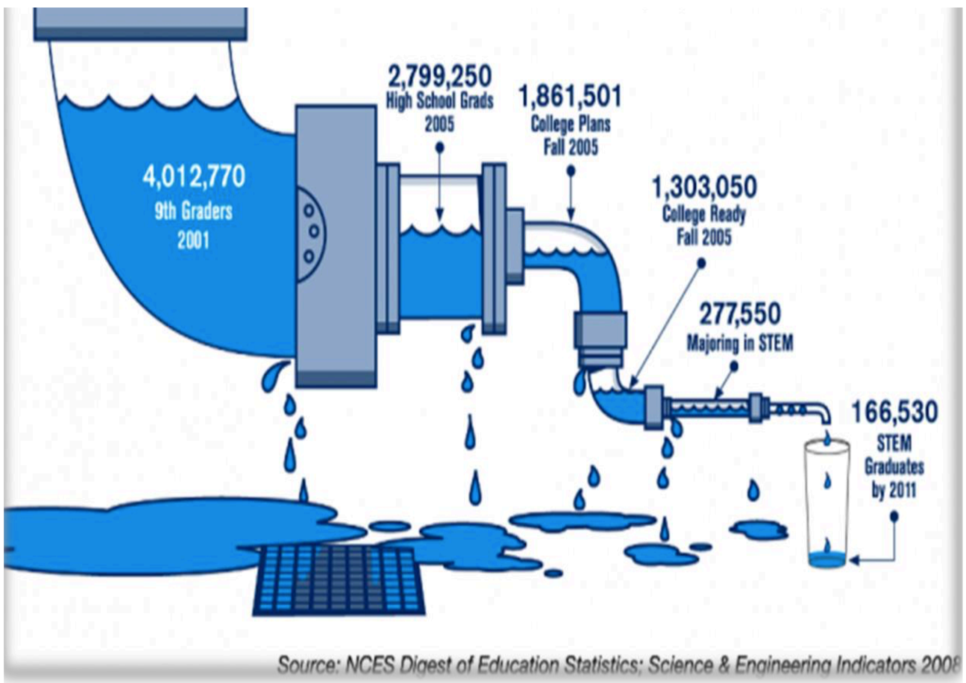

Figure 2. The Leaky Pipeline (NCES, 2008)

Together the underrepresentation and leaky pipeline narratives have worked to sensitize the larger society and funding agencies to the ways that participation in STEM communities is connected to longer trajectories for non-dominant communities. The choice to become a STEM participant does not happen when a student enters college. Rather, resources, investments, mentoring, sense of belonging, and identification with the domain have shaped the “choices” of members of non-dominant groups long before they arrive at the “decision” to pursue a STEM career (Tai et al., 2006). The leaky pipeline metaphor (Blickenstaff, 2005; NCES, 2008; 2011) has served to focus the STEM education and policy fields on the factors that can increase participation for youth and young researchers from non-dominant communities.

The pipeline metaphor shifts the focus to choice points and ways to plug the pipeline and get more individuals to join STEM careers and participate in STEM fields. These frames have led to monetary investments and programming geared towards increasing STEM participation by plugging the pipeline. Continuing the metaphor STEM educators and policy makers would become plumbers intent on creating programing that would plug the pipeline at strategic points. It is completely reasonable that this pervasive problem might have led to the leaky pipeline metaphor. However, there is a problem with the prominent underrepresentation narrative and the leaky pipeline metaphor.

**Troubling the Pipeline**

The economic and structural power in the ability to participate in STEM disciplines and careers cannot be ignored. When individuals and communities have access to STEM careers they can change the field, and they can participate in STEM inquiry in ways that support the needs and concerns of their communities. Increasing access to STEM careers is an equity issue but there is deep tension between ideologies that are currently bound up in STEM knowledge and participation and other ways of knowing (Bang & Medin, 2010). Critical ethnographers (Calabrese Barton, 2001; Nasir & Hand, 2006; 2008; Nasir & Saxe, 2003) have pushed STEM educators to consider the implications of expecting non-dominant youth to participate unquestioned in existing STEM education paradigms. Groups and individuals from non-dominant communities have been engaging in complex community-based STEM practices and Indigenous scholars have been pushing on the existing STEM and STEM education paradigms

(Bang & Medin, 2010; Brayboy & Maughan, 2009; Bell, 2009; Bricker & Bell, 2014; Hudicourt Barnes, 2003; Kawagley, 2006; Nasir & Hand, 2008).

Megan Bang and Doug Medin (2010) have rightly described the unquestioned focus on increasing numbers of STEM participants as assimilationist. They propose a more nuanced picture of broadening participation with youth and participants from non-dominant communities that actively engages this work with epistemic plurality. An assimilationist approach privileges the disciplinary norms and expects that broadening participation will entail underrepresented individuals learning to fit into the discipline, as it exists. Assimilationist paradigms are most problematic when Euro-centric forms of science prevail within STEM disciplinary communities. An assimilationist approach would suggest that organizations seeking to have a more diverse workforce would do their part to broaden participation by creating access points for people from historically underrepresented groups. A model based upon equality not equity will fail to broaden participation in respectful and productive ways. Equality here would mean striving for parity in representation whereas striving for equity brings up a set of more productive questions like: What does it mean to participate? What counts as participation?

I approach broadening participation work with two main goals: getting more people from non-dominant groups involved in STEM careers and changing the definitions of what it means to participate in STEM fields. In this article, I explore the connections between a theory of action, which emerged from lessons learned over four years of design-based research in a chemical oceanography out-of-school time (OST) program, and outcomes for the youth and mentors. The theory of action involved programming that created opportunities for acting, authoring, and authenticating. Broadening participation in the COOL program meant more than adding youth or mentors from non-dominant communities to existing STEM education paradigms. Rather, the picture of broadening participation that guided this design innovation attempted to thread the needle between the need to provide access by increasing representation and to honor, surface, and engage with epistemic plurality (Bang & Medin, 2010; Medin, Lee & Bang, 2014).

The following research questions guide this work: 1) How do we collaboratively design an out-of-school broadening participation program that works to create opportunities for youth to agentively act, author, and authenticate as they engage in contemporary scientific practices? 2) What lessons can designers of learning environments learn from COOL OST as an example of a collaboration between multiple stakeholders to create an environment where youth can engage in contemporary disciplinary practices?

I will begin by exploring the conceptual territory related to acting, authoring, and authenticating. Then, I will describe the iterations through narratives that capture the characteristics of the enactment and the changes to the design. Next, I will discuss acting, authoring, and authenticating across iterations. The discussion begins with a section about the interconnections between acting, authoring, and authenticating as they related to shifts in participation for youth and mentors in the program. Finally, I will offer some design principles that emerged from our broadening participation effort to aid in the development of new programs that can offer youth opportunities to engage in acting, authoring, and authenticating.

## Conceptual Framework

Broadening participation entails changes to the discipline as new members bring new perspectives, practices, and ideas. Taking up this idea places the onus on STEM educators and practitioners to identify the science in the contributions of youth from historically underrepresented groups (Pothier, Ogonowski & Pothier, 2003). This orientation also encourages the field to redefine what it means to do science and be a scientist in collaboration with community (Bang, Medin & Cajete, 2009). This is related to the work of identifying the mathematics or science in the ongoing work of individuals and families (Bricker & Bell, 2012; 2014; Bricker, Reeve & Bell, 2014; Goldman & Booker, 2009; Nasir, 2002; Reeve & Bell, 2009; Tzou, Scalone & Bell, 2010; Zimmerman, 2012; 2014) or the link between signifying and making sense of metaphor and simile in canonical literature (Lee, 2006; 2007). In the following section, I will propose a conceptual framework for the design of broadening participation learning environments in STEM disciplines.

Alexander Calder's mobiles are excellent visual metaphors for the relationship that I envision between acting, authoring, and authenticating. Calder's mobiles are dynamic and represent a system in constant tension and balance. Removing any single part of the system would throw the balance off. However, you can envision the entire system shifting dynamically in the changing winds of new partnerships or contexts yet finding balance once again and coming to rest in equilibrium.

Acting, Authoring, and Authenticating are interconnected principles. They exist in creative tensions and balances. Taken together these three principles facilitate learning in designed environments. These three constructs are aimed at broadening participation for youth and mentors from non-dominant communities. During the development of these three constructs, I took a stance towards the need for active and dynamic words when describing learning (e.g. Herrenkohl & Mertl, 2010). While the individual elements are visible and distinct the mobile is a dynamic system (see Figure 4). Each program iteration offered different kinds of opportunities for youth and mentors to act, author, and authenticate however the program continued to broaden participation for youth and mentors because the dynamic balance between the three constructs was maintained.

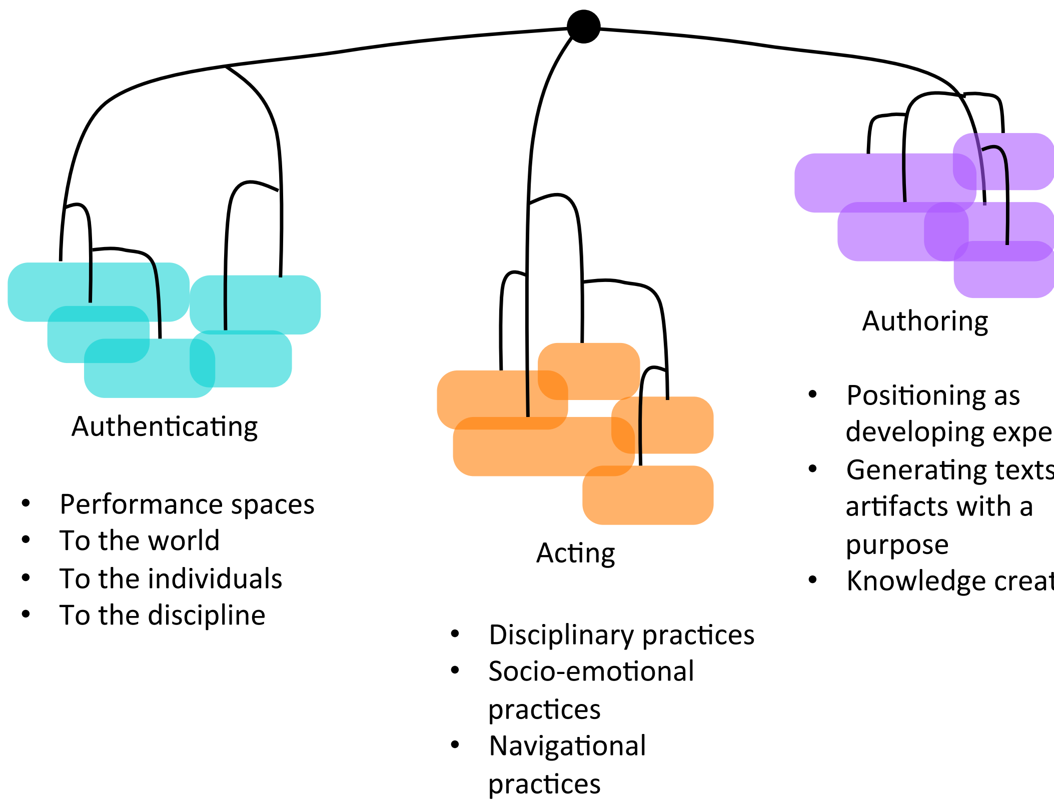


Figure 3. The Interconnected Constructs of Acting, Authoring, and Authenticating*
*Visual created in digital collaboration with Danielle Keifert (2015)

**Acting**

As program designers, my team and I were motivated by the need to allow youth to take action in STEM learning contexts. The next generation science framework (NRC, 2012) and standards documents (NGSS Lead States, 2013) released by the national research council made a strong call for grounding science education efforts in practice. Practices in NGSS include inquiry skill, cognitive, and sociocultural visions. Here, I am taking a cultural focus. "Practice is a way of talking about the shared historical and social resources, frameworks, and perspectives that sustain mutual engagement in action"(Wenger, 1998). Wenger's statement highlights the mutually constitutive nature of people, contexts, and actions, i.e., practices. Practices are actions that people can take in learning contexts. Nasir et al., (2006) offers a more multifaceted picture of practices nested within their definition of culture, “practices are constituted by the tools they use, the social networks with which they are connected, the ways they organize joint activity, the discourses they use and value (i.e. specific ways of conceptualizing, representing, evaluating, and engaging with the world)" (p. 489). Practices link to equity in substantial ways when all students are given space, resources, and opportunities to engage in sets of scientific practices that relate to the kinds of things scientists and engineers do as part of their ongoing work.

Learning in practice contrasts with knowledge-based learning frameworks and foregrounds learners as participants in multiple “structures of social practice” (Dreier, 2009; Bell et al., 2012). Dreier (2009) argued that critical psychology needed to study “persons in the overall structural nexus of their immediate situation” (p. 194). His stance was that persons could not be understood outside of the structures that make up the scope of their social practice. Dreier’s framework distributes agency across the configuration of persons, contexts, and resources. This is a fundamentally sociocultural stance and it aligns with learning in practice (Penuel, 2014), communities of practice (Lave & Wenger, 1991), hybrid worlds (Calabrese Barton, Tan, & Rivet, 2008; Warren, Ogonowski, & Pothier, 2003), authenticity of tasks (Bouilion & Gomez, 2001), and lines of practice (Azevedo, 2011). In the following sections I will describe the opportunities for action across program iterations. Each iteration offered slightly different but related opportunities for youth to act by participating in contemporary science practices.

**Authoring**

Authoring relates directly to the creation of knowledge within the focal discipline in epistemologically pluralistic ways (Bang & Medin, 2010). Authoring also relates to the active creation of knowledge that contributes to the disciplinary canon in order for a necessary multivoicedness that has the potential to shift definitions of participation (Bang & Medin, 2014). One of the design principles built up from years of iterative design work within the LIFE center is a focus on "positioning youth as developing experts." Experts would be considered full participants whose participation is sanctioned by their ability to engage in the knowledge economy of their discipline. They understand knowledge that has been created by other experts within their discipline and for them to gain true expert status of their own, they must eventually begin to create their own knowledge—they must become authors.

Thus, authoring stands as one of the principles that must be part of the experiences/ opportunities/ access points for traditionally underrepresented participants especially if our goal is to help them begin to see themselves as part of the discipline. As youth participate in broadening participation programming they are also authoring new identities as people who do science and can become scientists. When I say authoring I also mean the state of writing, creating, and causing. The most basic definition of authoring is creating text but I would like to also consider structuring and managing conversations as part of the process. Here, I will take the broadest definition of text used within the realm of discourse analysis and argue that texts can be anything—conversations, books, presentations, visual representations, posters, songs, websites, articles, etc. (Eggins, 1994; Gee, 1999). When designers of learning environments engage with the principle of authoring they must consider ways that participants will have opportunities and meaningful reasons to create multimodal texts. Within COOL we also considered ways that youth would structure and manage conversations with different communities while navigating multiple epistemologies (Bang & Medin, 2010).

Questions of equity are bound up in the principle of authoring. Peer review and other disciplinary norms typically determine who can participate in generating knowledge that is deemed a contribution to the field. Experts are viewed as full participants who generate new knowledge though funded research projects and communicate new knowledge in socially recognized ways such as journal articles, conference presentations, or reports. In the following section I will compare opportunities for authenticating across the iterations of the program.

**Authenticating**

Authenticating is perhaps the odd one out in the framework. It seems to be of a different kind because we typically think of authenticity as a characteristic of a learning environment, an activity, an experience, a performance space, or even a person. However, in this case I want to position authenticating as a practice-based principle of design because it is nuanced and ever changing. Heath and Mclaughlin (1994) foregrounded youth perceptions in their analysis of fifty out-of-school (OST) learning environment and defined authenticity as "the degree to which students not their teachers or curriculum designers map their learning activities to the external world" (p. 487). Considering the youth participants' understanding of and chances to learn to authenticate is an important step when designing for broadening participation.

If youth do not have a sense that the actions they are taking are central to the formal or informal practices of science they are unlikely to have identity broadening experiences. Multiple studies have demonstrated that even youth working alongside experts in laboratories and in settings that would be considered authentic both from the perspective of designers of learning environments and their scientists collaborators did not necessarily experience authenticity (Barab & Hay, 2001; van Eijck & Roth, 2009). Archer et al. (2010) suspected youth's perceived sense of authenticity in real contexts was due to differences in youths' expectations of what science would be like based upon popular culture portrayals and their data suggested that youth could do science but still not have a sense that they themselves were becoming scientists. This is disappointing outcome when you consider that most approaches to broadening participation entail having youth from a variety of backgrounds engage in contemporary science practices. While we cannot necessarily change popular culture portrayals of science, we can mitigate their impact by checking on the ways that youth are experiencing the broadening participation programming we create. Authenticity when considered a property of environments or activities has the potential to reify existing definitions of STEM participation, however when designers and educators remain responsive to the experiences of youth and focus on the process of authenticating experiences there is great potential for shifts in identification with respect to STEM to occur (Scalone, 2015; Stromholt & Bell, in preparation; Van Horne & Bell, 2014; Warren, Ogonowski & Pothier, 2003).

The quest to authenticate something requires a design orientation, it is a way of considering in complex ways what is real to participants, real to the world, and real to the discipline (Tierney & Scipio, 2014). This three pronged approach to thinking about authenticating as a design principle takes in to consideration the perceptions and experiences of multiple stakeholders. It also problematizes the sense of authenticity that designers of learning environments seek to sink into experiences and makes revisiting design decisions an essential aspect of architecting learning environments.

Another important aspect of authenticating relates to the ways that youth feel comfortable bringing their whole selves into their learning spaces (Carlone et al., 2014; Calabrese Barton et al., 2008; Calabrese Barton, 2001). In spaces that allow youth ways to merge their science selves with their other intersectional identities (Nasir & Hand, 2008). Personal relevance is another important consideration for the construct of authenticating in broadening participation contexts (Bevan, Bell, Stevens & Razfar, 2012). Understanding how youth see the work they are doing as important or relevant for their own interests and those that pertain to their community (Goldman & Booker, 2009). Within the program we saw youth developing "signature science artifacts" (Calabrese Barton et al., 2008) which merged their burgeoning science identities with aspects of their home and community identities.

**Project COOL**

The Chemical Oceanography Outside the Lab (COOL) program was a collaboration between the a learning sciences research lab, a chemical oceanography lab, local middle school OST programming, and undergraduate mentors. COOL stood as an empirical data set that allowed me to explore implications for design of this kind of broadening participation environment. COOL was a design-based research initiative to introduce youth from non-dominant communities to practices of the geosciences through a chemical oceanography afterschool program. The COOL program echoed design principles advanced by The Institute for Science and Math Education (http://sciencemathpartnerships.org/) and the Learning in Informal and Formal Environments (LIFE) Center.

As designers, my team and I positioned youth as developing experts and sought to build bridges from youth's everyday knowledge of science and technology to discipline specific modes of inquiry and participation. Designed learning spaces brought youth and experts into collaboration to accomplish projects that had personal, community and disciplinary relevance. We believed a learning ecology built around these commitments would create a robust and productive learning environment likely to enable shifts in youth and mentor identification with STEM domains.

## Methods

Design-based research is a multistep process, "premised on the notion that we can learn important things about the nature and conditions of learning by attempting to engineer and sustain educational innovation in everyday settings" (Bell, 2004). COOL was a design-based research initiative aimed at building an afterschool learning environment that would support participant STEM learning and simultaneously allow us to formulate a science of broadening participation. Many of the initial design decisions were made based upon our knowledge of best practices for broadening participation from literature and prior experiences with STEM learning environments by researchers who were part of the LIFE Center and the Institute for Science and Mathematics education (ISME). Other decisions were associated with an intentional attempt to instantiate and put new design conjectures related to learning and identification in play in everyday settings so they could be studied. Throughout the design process we paid particular attention to elements that we felt were going to be most beneficial to the youth and to the mentors in their cultural learning pathways (Bell et al., 2012). We created many opportunities for acting, authoring, and authenticating by youth and mentor participants. We positioned youth as developing experts in the context of community-relevant science investigations. We offered mentors the chance to develop relationships with the students over the course of the quarter, encouraged them to take the lead when they could on activities, and consistently asked them to step up to share their knowledge and experience with the students. With appropriate levels of scaffolding and feedback, we offered youth participants the chance to design their own chemical oceanography experiments, author scientific artifacts for rigorous disciplinary communication, and present their work in a variety of authentic performances spaces.

**Data Selection**

Data for this analysis were collected over five years of design-based research program development (see Table 1). Data include field notes from program meetings, video and audio collected during OST programming, youth and mentor generated artifacts, curriculum documents, and interviews with multiple participants. Drawing upon ethnographic fieldwork collected over the course of multiple years, I examined how designed elements created broadening participation opportunities for youth and mentors in the COOL program.

Table 1. Amount and Types of Data Collected

| | **Iteration 1** | **Iteration 2** | **Iteration 3*** |
|---|---|---|---|
| **Fieldwork Duration** | 9 months | 6 months | 20 weeks |
| **Field sites** | SoundCitizen Lab | Marble middle school | Marble, Agate, & Topazmiddle schools |
| **OST Program Meetings** | 40 sessions (~ 120 hours) | 28 sessions (~ 56 hours) | 16- 20 sessions (~ 32- 40 hours) |
| **Planning & Debrief Meetings** | ~ 80 meetings (COOL research staff, PIs & program staff) | ~ 40 meetings (COOL research staff and lab liaison) | ~ 12 meetings (COOL research staff, undergraduate mentors, and lab liaison) |
| **Interviews** | 8 youth | 14 youth and 4 adults | 13 youth and 10 adults |
| **Mentor Generated Artifacts** | Conference poster, youth-authored zine, student filmed video, | Conference presentations, student and mentor reflections, youth-authored song, audio and video of OST settings | Conference poster, Student & mentor science notebooks, mentor curriculum modifications, youth-authored song, audio and video of OST settings, and undergraduate class |

*Iteration 3 consisted of two year-long enactments.

I was a participant observer in the COOL program. As the program coordinator during all three iterations, my role changed over the course of the program. I began as an employee of one of the community based organizations we partnered with during the first iteration of the program. I coordinated the program, liaised with mentors, school administrators, teachers, parents, and family members. I organized field trips, managed supplies, made calls to collaborators, and facilitated the successful completion of the COOL program from end to end. I co-taught and co-designed the curriculum. During COOL sessions, I often took on the role of lead instructor. With the mentors in the program my role was that of pedagogical mentor and guide into the world of science education. These positions gave me a unique perspective on the program activities and an intimate relationship with youth and mentors that allowed me to member check my perspectives on the interviews, on COOL and OST sessions, and my analysis of program data.

**Data Analysis**

Data analysis was ongoing while I collected data. As a participant observer and given my role on the project, I was often unable to write field notes during program sessions. I wrote daily reflection notes, drafted analytical memos about program activities, and wrote about individual youth and mentor participants. I used the daily agendas for the COOL program during 2010-2011 years and then relied upon the curriculum and field notes from 2012-2014. We began to collect video and audio data in 2011 and this corpus of data served to help triangulate instances of acting, authoring, and authenticating.

My research team and I drafted sets of codes related to our individual interests on the project. My interests were related to changes in participation for youth and adult participants. Tracing the elements of the design that were associated with changes in youth an mentor participation led me to develop sets of codes related to the LIFE design principles—related to youth participation, positioning of youth as experts, and multiple sets of practices listed in recent consensus volumes related to STEM learning in formal and informal environments (NGSS Lead states, 2013; NRC, 2009). When building codes related to actions, I leveraged the sets of practices listed in LSIE and NGSS. Building codes related to authenticating was a more involved process.

Along with the theoretically driven coding I also developed sets of codes from grounded theory analysis of youth and mentor interviews (Strauss, Anslem, Corbin & Juliet, 1990). I began by using a grounded theory approach to identify ways that youth and mentors were making sense of their experiences in COOL. Using this approach, I built a set of emergent codes related to newness and discovery. Although I initially coded them as nature of science, I realized that authenticating would work as a superordinate code to encompass youth comments related to their experiences of newness and discovery. As an example, youth comments like "scientists do what we did, we found out things, we collected data, we had experiments, we let others know and we dug deeper into the pie" (Sage, 2011) were coded multiple times as practices, youth as experts, and authenticating. Comments like "at COOL we learned something completely new. It was something that wasn't recorded" (Keisha, 2011) were also coded as authenticating. While none of the youth in the program used the term authentic, all of these comments were related to the sense of doing something new and discovering information that wasn't already out in the world.

Given that the youth in the program seemed very aware of authenticating and consistently spoke about it across all the years of interviews, I next went to my field notes to identify moments during the OST sessions that corresponded to this phenomenon. These moments were transcribed and analyzed using codes related to the three components of my theory of action for broadening participation: acting, authoring, and authenticating. In addition to analysis of the sets of activities that youth referred to as authentic, I used video and audio of the OST programming to triangulate on the ways that youth and mentors engaged in the activities in the COOL program.

The goal of this analysis was to explore the ways that each design iteration broadened participation for youth and adult participants by creating opportunities for acting, authoring and authenticating. In the following section I begin by describing the designed features of each Project COOL enactment in a design narrative. The design narratives focus on the features of each enactment, the partners, and the final projects. When I say enactment I mean a single cycle of program implementation. Each enactment had partners who were often program and design collaborators. The enactments also incorporated different designed features and final performance spaces.

Following each enactment the COOL research team came back together to discuss the learning outcomes for youth and mentor participants. These conversations leveraged student-generated artifacts, semi structured interviews, video and audio recordings, field notes, and our own lived experiences of the enactment. The team then made choices about designed elements to keep in play or discard in future iterations of the program based upon the ways they facilitated or constrained broadening participation opportunities for all program participants. Many of the design decisions, which led to new program iterations, were motivated by external pressures, shifts in collaborator capacity to support COOL infra-structurally, or personnel changes. The duration of each enactment also varied. Iterations one and two were each based on a one-year enactment. Iteration three was based on a three- year enactment, where we have been continuing to refine a more stable model of the program. In what follows I report on three iterations of the program that took place from 2010- 2014.

## Findings

I begin the findings with a design narratives section, foregrounding the changes in each iteration of the program, collaborators, participants, and final products. Each program iteration presented new design challenges and affordances for the design and enactment of COOL as an out-of-school time (OST) learning environment. In the following section, I focus on the design narratives in order to contextualize the upcoming sections on opportunities for acting, authoring, and authenticating across iterations. My goal is to demonstrate the ways in which each designed iteration offered different kinds of opportunities for youth to act, author, and authenticate.

## Design Narratives

**Iteration 1: Science Apprenticeship—Engaging youth in the ongoing work of a scientific laboratory.** We called the first iteration of the program the SoundCitizen Science Apprenticeship (SCSA) Program. Youth came to the SoundCitizen lab on the university campus once a week for nine months. The SoundCitizen lab was engaged in a series of ongoing actions or practices that youth were apprenticed into over the course of their time in the SCSA program. Youth learned to process SoundCitizen samples and through out their time in the laboratory they contributed to the SoundCitizen database. The program was a collaboration between two research laboratories and two community-based organizations (CBOs). The young people who participated in the program were from multiple schools. Four of them were male alumni from one CBO, the others were female alumnae from the other CBO.

SCSA came about because the collaborating organizations were interested in broadening participation in the geosciences by creating a new space for youth from non-dominant groups historically underrepresented in the sciences to engage in the full set of scientific practices around an authentic investigation of interest to the youth and their broader communities. The goal was to broaden the citizen science definition of participation as data collection to involve youth in designing research questions, collecting data, and analyzing data. Calling the program an apprenticeship and paying students for the time they spent in the laboratory were both strategic design decisions that were intended to broaden participation and push for equity. We were aware that asking high school youth to commit to an afterschool STEM program was also asking them to give up on other opportunities to make money during the afterschool hours.

***Program collaborators.*** Four organizations collaborated to bring eight youth to the university to be apprentices in the SoundCitizen lab and work alongside scientists. Two of the collaborating organizations were labs located at a research-oriented university in the Pacific Northwest: a chemical oceanography laboratory called SoundCitizen and a learning sciences research institute. Sound Citizen was a chemical oceanography lab that conducted citizen science work on the waters of Puget Sound. Using a network of regular citizens who sent in water samples from storm drains, home gutters, puddles, streams, creeks, and all parts of Puget Sound, SoundCitizen used the public to collect data on the chemistry of water systems. The materials for collecting samples were packaged kits that went out to the public and came back to the lab to be processed. Once samples came into the laboratory they were filtered, acidified, cartridged, eluted, and concentrated. These purified, super concentrated versions of the samples were then run on a gas chromatograph mass spectrometry (GCMS) machine. The GCMS was used to identify the specific chemical compounds and their concentrations present in the water samples. Using its network of volunteers to collect data, SoundCitizen was able to build a profile of the chemical compound (e.g., spices, fragrances, industrial chemicals, etc) present in the Sound.

The other two organizations were CBOs where environmental experiential learning programs that took youth into the wilderness to go backpacking, camping, hiking, and rock climbing. Both organizations began with an interest in broadening participation in STEM through environmental sciences but mission creep led both organizations to develop expedition-based leadership programs that rarely focused on STEM learning in an intentional way. Each CBO provided single-gendered programming for young women or young men, but it was decided to combine both populations in the SCSA program.

***Participants.*** There were four young men and four young women participants in this iteration of the program. All participants were members of non-dominant groups and alumni of outdoor programming hosted by our CBO partners. All the youth participants in Iteration 1 self-identified as members of non-dominant groups—Lisa, Mary, Nick, Joseph, and Mikey all self-identified as African-American, Alma as Somali, Hannah as Burmese, and Ronnie as Latino. They were in 8-12 grade and committed to participate in the program as apprentices for a nine-month period from October through June 2011.

***Final products.*** During the first program iteration, youth created three final products: a scientific poster, a ‘zine, and a video. In collaboration with SoundCitizen scientists the youth designed a final project where they collected samples around the Puget Sound region and leveraged the resources of the laboratory to test them for plasticizers—compounds that give plastics their malleability and have been identified as endocrine disrupting compounds (EDCs). The youth presented their scientific poster of their findings at an international geosciences conference called the American Geophysics Union (AGU). They were the youngest participants in their poster session and among the youngest at the conference. After we returned from the conference presentation we turned our attention to ways to communicate the apprentices' scientific findings to their home communities. Whereas the poster was an example of youth being apprenticed into a professional form of communicating science, the zine and video were youth-led science communication initiatives in more pop cultural forms.

Working with my colleague Shelley Stromholt, three of the young women on the project put together a zine about plasticizers. The zine included poetry, word searches, and other youth friendly information about Sound Citizen. There were articles about plasticizers and the work that the apprentices did in the lab at the university. I worked with the remaining apprentices to make a video to share their knowledge about plasticizers. The video was an homage to police procedurals like *Crime Scene Investigation* CSI and featured two of the apprentices playing the role of detectives who arrested a plastic bottle. They interrogated the plastic bottle and took a statement before handing a “sample” over to two other apprentices playing the role of lab technicians. The plastic bottle was booked for the crime of containing endocrine disrupting compounds.

The apprentices helped to organize a final celebration that was held at the headquarters of one of our CBO partners. Youth invited family members, friends, and CBO staff to participate in the event. The apprentices screened the video, gave out copies of the ‘zine, and shared the AGU poster with their audience. We borrowed a tradition from the hosting CBO and made this event into a graduation ceremony from the SCSA program. Shelley and I read descriptions of each youth’s participation in the program overtime and gave them a certificate of completion. As I will elaborate on in the subsequent sections, these opportunities to participate in disciplinary and community science communication spaces created opportunities for youth to navigate multiple epistemologies while taking action; to author new kinds of selves; to position themselves as scientists within disciplinary and home communities; and to authenticate these experiences by participating in and co-constructing new knowledge, artifacts, and spaces for communicating their scientific findings (Bang & Medin, 2014; Bell et al., 2012; Markus & Nurius, 1986; Warren, Ogonowski & Pothier, 2003).

***Affordances & Constraints.*** There were many affordances to the science apprenticeship model in iteration one. Apprentices were fully engaged in the work of the SoundCitizen laboratory, they were able to use the infrastructure of the existing laboratory to ask and answer personally, community, and disciplinary relevant questions. They were positioned as collaborators and developing experts as they designed a research study with scientists. They went on to create two kinds of science communication artifacts that had purposes within authentic contexts. The apprentices authored of the aforementioned poster for AGU and they also created community-based science communication artifacts- a ‘zine and a video to tell their community about the presence of plasticizers in marine environments and their impacts on humans and animals.

There were also a variety of constraints that led to major changes in iteration two. The apprentices as they describe within the poster- were geographically dispersed around the city. They attended seven different schools and as a result did not create a community beyond the time that they spent with us at the university. We wanted the youth in the program to identify with a disciplinary community but it was also important to us that they also connected the work they were doing with a home and/or school community. Transportation was not simply a matter or logistics but an important part of designing for equity within the program. Transportation was an enduring and precarious issue for youth in the socioeconomic brackets we were serving. Many of our participants and their families had been priced out of housing within in the city limits thus, solving the seemingly logistical issue of transportation was an essential part of designing for equity.

Designing for equity also made us consider the ways youth in the program were apprenticed into complex scientific practices. Working in the lab offered direct, sustained, and scaffolded access to a set of STEM-specific sociomaterial affordances (access to scientists, machines, instruments, and materials), but it meant that we could only serve a limited number of students.

In future iterations we wanted to address these concerns while continuing to draw upon the three design principles—acting, authoring, and authenticating—which had developed through reflection on the strengths of this first iteration. Our goal was to mitigate constraints and maximize affordances through the design of iteration two.

**Iteration 2: Science Mentorship—Bringing youth and STEM mentors together in an afterschool program.** One of the first changes we made to the program was to rename it. We decided to call it Project COOL: Chemical Oceanography Outside the Laboratory. This name change represented our departure from an apprenticeship within a laboratory model into a mentorship into science at local middle schools. This was one of the biggest changes and led to a series of design decisions aimed at maximizing opportunities for youth to act, author, and authenticate within specific school communities. The decision to move the program out of the SoundCitizen laboratory into a middle school was in an effort to focus on working with established communities of youth and to mitigate the impact of transportation on youth which was one of the biggest constraints we faced in the first iteration of the program.

We also saw this iteration as an opportunity to serve more youth than was possible with the apprenticeship model. We felt that moving into a middle school gave us the opportunity to concentrate our efforts on bringing the COOL staff and scientists to and from the University on a weekly basis rather than moving youth from all over the region to the University once a week. This iteration was the beginning of a university student mentorship model for the COOL program a move that necessitated the addition of new program collaborators.

***Program Collaborators.*** The COOL program was still a collaboration between multiple organizations. In addition to the SCSA collaborators (two research laboratories and two CBOs) we developed new relationships with Marble middle school and the local university chapter of the Society for the Advancement of Chicano and Native American Scientists (SACNAS). Moving into a middle school context necessitated some research on our part, into the demographics and socioeconomic make up of middle schools in the city that offered Out of School Time (OST) programming. OST programming within the city provided snack and regular school transportation after school for all participants. Our research led us to Marble middle school. Marble was a medium-sized middle school located south of the University. Marble was a great fit because they had a strong commitment to building community between the school, students, and their families; a large population of students from historically underrepresented groups; a proactive science department and leadership that wanted to connect with us; and a well connected head of OST programming who ran the school's community learning center. When we approached Marble to begin building our professional working relationship, they asked us to make the program girls only because there was no other single gender programming aimed at broadening participation in STEM for young women at the school. We viewed this change, as an opportunity to reach young women from historically underrepresented groups and as a result COOL became a girls only program at Marble. The move to the middle school also allowed us to serve more youth. We worked with two cohorts of students, six 6$^{th}$ graders in the Fall and Winter, and eight 8$^{th}$ graders in the Winter and Spring. We worked with each group for eight months once a week at Marble. We took all participants on a series of field trips to the aquarium, to the SoundCitizen lab, to present their work at a local student conference, and on a science research cruise.

Adding university student mentors was another important adaptation in this iteration. In SCSA, the SoundCitizen scientists worked alongside the youth on a weekly basis in the laboratory but once we moved to the OST program site at Marble mentors became the connection between youth and the SoundCitizen lab. At the start of iteration two, the SoundCitizen lab hired a research scientist to be the permanent liaison to the COOL program and to work on other outreach initiatives from the lab to the community. Eva served as a mentor within the program, she helped to build curriculum, and co-taught in the OST program. She was also one of the founders of the local chapter of the Society for the Advancement of Chicano and Native American Scientists (SACNAS) and helped to recruit additional mentors from SACNAS to join the COOL program.

The SACNAS mentors who joined us, Jes and Angelica, were both women of color pursuing advanced degrees in STEM. They came to COOL just at the point when they were seeking to transition from STEM bench science careers into other ways to do science and be scientists (Scipio, 2014). There were also three undergraduate students who were working in the SoundCitizen lab over the course of the academic year who Eva and I invited to participate in the afterschool program and the work happening in the OST program at Marble. These undergraduates worked with Eva to design and run a set of activities when the OST youth visited the SoundCitizen lab on a field trip. The day-long field trip included a panel discussion where youth could ask questions of the undergraduate students working in the SoundCitizen lab, a visit to a scale model of the Puget Sound and collecting and filtering their own water samples in the lab.

***Participants.*** Fourteen young women participated in COOL. They were divided into two cohorts based upon when they participated in the program. Cohort A (Six of 6$^{th}$ graders) did the program in from September through April and Cohort B (eight 8$^{th}$ graders) did the program from January through June. In the 6$^{th}$ grade cohort, Mika self-identified as Filipino, Cynthia as Chinese, Maria as Latina, Francine as African American, and Lauren and Sage as White. In the

8th grade cohort, Jackie, Keisha, Mercedes, Natalie, and Sharon all self identified as African American, Hadya as Somali, and Elena as Latina.

***Final products.*** Three final products emerged from this iteration: two youth research projects and a COOL OST curriculum. The COOL OST curriculum was developed in partnership with the SACNAS mentors. Most specifically Eva who served as mentor and liaison to the SoundCitizen laboratory. Eva had just finished her Master of Sciences in aquatic and fisheries sciences and had deep, relevant scientific knowledge. Eva and I worked closely together during the year to build a curriculum that would give youth the greatest opportunities to act, author, and authenticate. Youth in the sixth-grade cohort got interested in learning more about endocrine disrupting chemicals in health and beauty products. They designed a protocol for sampling water in their community and sent their samples to the SoundCitizen lab to be run on the gas chromatography mass spectrometer. They were also interested in understanding the social use and knowledge of the other sixth-graders at Marble. They designed and administered a survey during lunchtime to find out about product use, knowledge of EDCs, and what additional informal people would like to know about plasticizers in health and beauty products. They gathered the information and worked collaboratively with the mentors in the COOL program to prepare a presentation for the Salish Seas student science symposium a local youth-centric conference. They presented a PowerPoint presentation about their work at the conference.

The youth in the 8th grade cohort were also interested in health and beauty products but they wanted to know more about the presence of micro plastics in toothpaste and body wash. They used information from the SoundCitizen database and developed a protocol for testing body wash and toothpaste for the presence of micro plastics. They also used a survey to gather information about product use amongst their peers. The 8th graders asked their science teachers to administer the survey during their classes. They used the information they gathered to make evidence-based statements about micro-plastics in health and beauty products. They also constructed and presented a research PowerPoint talk at the local conference about their work. Both groups used multimodal scientific representations to share their findings (e.g., they included graphs of their data and pictures of themselves carrying out procedures or collecting data), articulately described their findings to an audience, and fielded questions from peers, scientists, and community members. The conference was a great place for youth to present their work and it seemed like a wonderful substitute for the AGU conference as an authentic performance venue. Similar to the experience of youth in iteration one at AGU, youth in iteration two presented their work to a room full of peers, scientists, and additionally community members. Youth fielded questions after their presentation from the audience and the opportunity to participate in the conference as attendees during the other sessions.

***Affordances and Constraints.*** Giving up regular access to the lab was certainly a constraint that we had to deal with in the second iteration. However we made up for this loss by developing a rich curriculum that was an affordance moving forward. As we developed the curriculum we realized that mentors played an important role in helping youth engage in the science practices within the OST. The mentors filled the role the research laboratory scientists had in the previous iteration. Unfortunately, it was very difficult to pay mentors who were graduate students. Most STEM graduate students at our University were funded via teaching or research assistantships, and they were expected to fulfill at least 20 hours a week at work in addition to their own load of classes and work on their personal research projects. The mentors who joined COOL in this iteration were transitioning away from work in a lab so they had a strong incentive to volunteer with us. We discovered very quickly that that was not going to be the case for all graduate mentors. We started the year with three mentors: Jessee, Angelica, and André in addition to Eva. André was a wonderful addition to our program but he had to leave us to find a job that would pay him. This led us to research another way to build a mentorship component into the COOL program. We reached out to the an undergraduate serving program called Wildehall to offer a class for undergraduates that would allow them to develop their teaching skills and connect us to a pool of mentors that we could pay with college credit.

**Iteration 3: Training undergraduates to be science mentors—Engaging undergraduates as facilitators and mentors in the COOL OST program.** Iteration three involved two years of enacting variations on the ultimate model that had been developed. Our initial goal with these enactments was to study different models of scalability for the COOL program. The biggest change we made to the program in iteration three was to bring in undergraduates as mentors and facilitators for the OST program. Given the trouble we encountered trying to pay graduate students to work with our youth we felt it was necessary to make a change that would allow us to offer something of value to our adult participants. The time commitment to fully participate in COOL was unreasonable for STEM graduate students trying to balance research and teaching responsibilities within their departments. Our decision to work with undergraduates prompted us to develop a two-quarter training class for mentors. One quarter prior to their work with youth and the second quarter while they were working in the OST program with youth. We developed the course with the vision of introducing undergraduates to research-based best practices around STEM teaching, giving them opportunities to work with youth in school settings prior to COOL, collaboratively designing lessons, and offering undergraduates opportunities to develop STEM and pedagogical expertise. It mirrors many of the elements of pre-service teacher education in this way.

While we did not make major changes to the model for working with OST programs, we added a two-quarter mentor training course for undergraduate mentors. We choose to scale the program by adding another layer of facilitators to the program—undergraduate mentors. Over the course of the summer between iterations two and three I spent a great deal of time meeting with colleagues from the teacher education program at our university because the first quarter of the COOL class was essentially a teacher-preparation course designed to help undergraduates orient to doing STEM broadening participation work with middle school youth from non-dominant communities. During the second quarter, the course was geared towards planning and reflection. We focused on creating ways for mentors to learn from their own teaching by asking them to write reflections after each day in the field and to participate in video club where they watched and commented on their own teaching practice. During the class we also created a space for planning in a supportive atmosphere with access to the COOL research team as resources and collaborating teachers.

We also developed new relationships with two new local public middle schools: Agate and Topaz during iteration three. We worked with two schools during each enactment. Agate and Marble were our partner schools during enactment one. Topaz and Marble were our enactment partner schools during enactment two. The program design shifted as we explored scalability in COOL by training mentors to facilitate the program with varying amounts of facilitation from the COOL research team. During iteration two, I took on the role of liaison and program coordination at Marble while developing the partnership with the new program context. I spent time building relationships with teachers, OST staff, students, families, and front office staff at Marble. These relationships allowed us to navigate the school's infrastructure and set up field trips for youth and communicate effectively with families. During enactment one of iteration three, we decided to test the necessity of this close support by eliminating the role of the liaison. Our experiences at Agate and the process of developing new partnerships with these schools taught us a lot about the role a liaison plays in a program like COOL. We decided to return to a more collaborative and supported model for the rest of the iterations and reinstated the liaison role for each school in the second year.

***Program Collaborators.*** At the beginning of iteration three, we reached out to the an undergraduate serving program called Wildehall to offer a class for undergraduates that would allow them to develop their STEM teaching skills. Wildehall was an excellent partner because they connected us to a pool of mentors that we could "pay" with college credit. The partnership with Wildehall allowed COOL to connect with undergraduates from many different backgrounds and we viewed this as a benefit to the program. Throughout the recruitment process we focused on finding undergraduates from varied backgrounds. This balance of mentors with strong science backgrounds and mentors with more pedagogical or teaching backgrounds has served to broadening participation for adult participants in the COOL program. The relationship with Wildehall lasted one year. Afterwards we were able to connect with the college of education on campus and build a course for undergraduates that could be offered as part of the minor degree in education.

***Participants.*** Thirteen young women participated in COOL during Iteration 3. During enactment 1 there were three consented students across two sites. At Marble, we had a repeat participant and who had done COOL during her 6$^{th}$ grade year. Maria self identified as Latina and towards the end of the program she brought two of her friends to join the program although they did not want to become part of the research study. At Agate, only two young women chose to participate in the research study although there were 12 participants total. Tammy and Ayana both self identified as African American and were in the 8th grade. There were ten participants in the second year of iteration 3 at two schools: Topaz and Marble. Two young men and three young women participated at Topaz, and three young men and four young women at Marble. At Topaz, Crystal and Elizabeth self-identified as Chinese, Amir self identified as Somali, Ingrid as Pacific Islander, and Jamal as African American. At Marble, Jonas self identified as Filipino, Isaac as Latino, Kassandra as African American, Madeline as African, and Jack as White.

***Final products.*** Youth in the first enactment of iteration three of the program presented a scientific poster about fish feminization and endocrine disrupting compounds at the same local conference as the youth in the second iteration. New pictures of final products emerged in subsequent enactments due to changes at the organization that typically hosted the community-based student conference. Their calendar changed and it meant that our students were unable to complete their projects in time given youth were still deciding what they wanted their projects to be about and starting the data collection process. We again had to seek out a new venue for our youth to celebrate their participation and share their work with an authentic community. In enactment 2 youth presented their work at a school-based conference. They helped us design a flyer and made an invitation list. They chose to invite friends, OST staff, and some teachers to hear them present their work on projects related to water in Puget Sound or on other planets in the solar system and models of underwater volcanoes. When youth took ownership of this performance space, it allowed them to construct their own meanings of science communication within the COOL framework. This co-constructed science-based performance space represented a dramatic shift in youth's identification with the domain of science within their school space due to their participation in informal spaces (Birmingham & Calabrese Barton, 2014; Bransford & Schwartz, 1999; Calabrese Barton et al., 2013; Heath, Paul-Boehncke & Wolf, 2007).

We also hosted a COOL carnival, which we considered a different type of youth centered event. We had music playing and youth were free to move from station to station. There were multiple activity stations set up in the classroom we typically used. When youth joined us we introduced each station and youth were free to choose what they wanted to do during the day. There was a station where youth could make EDC free compounds, test models of underwater volcanoes, redesign watershed models, make turbulent orbs, or decorate lab coats. Each station was based upon activities we had previously done as part of the COOL project or geared towards what we knew about the interests of each youth participant. The mentors helped to design and facilitate the activity stations.

**Opportunities for Acting**

Table 2 (below) shows the opportunities for acting across program iterations. Each iteration included practices like working in the SoundCitizen Laboratory or doing sets of activities in the OST context. In iteration 3 we worked with mentors who also had opportunities to act.

Table 2. Opportunities for Acting Across Iterations

| Iteration 1 | Iteration 2 | Iteration 3 |
|---|---|---|
| • Working in the SoundCitizen laboratory<br>• Contributing to the SoundCitizen data base<br>• Designing an experiment to measure plasticizers in marine and terrestrial waters | • Local conference presentation<br>• OST curriculum<br>• Field trip to UW<br>• Field trip onboard research cruise<br>• Field trip to the Aquarium | Youth:<br>• OST Curriculum<br>• Internet research<br>• Creating final conference<br>• Making EDC free products |
| | | Adult mentors:<br>• Facilitating OST activities |

**Opportunities for Acting in Iteration One.** The program broadened participation by bringing new youth into the ongoing contemporary practices of the lab. It also broadened participation by bringing new practices to the lab. Youth in this iteration of the program were incorporated into the SoundCitizen laboratory as apprentices in a rather formal and full way. During the study, the SoundCitizen laboratory was processing samples from the public and youth were apprenticed into this ongoing practice. They learned how to use equipment in the lab, how to follow and note lab procedures, and their work contributed to the SoundCitizen database. They learned in practice and became so familiar with the entire process that they processed their own water samples as a group once they had collected them—and provided a context for science-linked identification through participation in epistemic practices (Stromholt & Bell, in preparation). SoundCitizen typically processed samples that the public sent in, sometimes they would make a special request on their website for water from storm drains or drainpipes. There was a vast existing data set to which the apprentices were contributing. Despite the fact that they had access to the Sound Citizen data, because of a particular set of interests developed by the group, they choose an alternative research focus. Youth were interested in learning more about the impact of plastic bottles on their health and Puget Sound waters. The youth were motivated by the fact that they and their families drank water out of plastic bottles on a regular basis. These bottles were sometimes left in the car or frozen so that the water would be cold at lunchtime. During their time as apprentices, youth were introduced to plasticizer compounds. Plasticizers are a family of chemicals that give plastic items their malleability. Plasticizers have also been classified as endocrine disrupting compounds due to their impacts on biological organisms (Diamanti-Kandarakis et al., 2009; Keil et al., 2011). The apprentices worked with the principal investigator (PI) of the chemical oceanography lab and the lab technicians to develop a sampling protocol that would allow us to identify plasticizers in Puget Sound waters. The SoundCitizen lab used a gas chromatograph with a mass spectrometer attached to identify presence and concentrations of various chemicals in the water samples, including the plasticizers. The Sound Citizen scientists recognized, nurtured, and created opportunities for the apprentice's interest in studying plasticizers to develop over time. This began with the PI sharing information from the literature with youth, then inviting Eva—during her gradate degree to speak with the youth about the impact of EDCs on fish embryo development. This collaboration contributed to changes in the practices of the SoundCitizen laboratory.

Up until this point, the bottles in the SoundCitizen kits were made of plastic so that they could travel between the lab and the volunteer population through the mail. However, the apprentices' desire to study plasticizers (the chemicals that give plastic bottles their malleability) necessitated a new sampling protocol and the introduction of a new set of material artifacts in the lab. The new protocol included using glass bottles and creating new kits to hold them because there would have been no way for the GCMS to distinguish between the plasticizers in the container and those that might be present in the water sample. Beyond the introduction of new artifacts, the apprentices' new research protocol also required the scientists to develop new protocols for the GCMS so that it could test for specific plasticizers that the apprentices' study of the literature indicated were most likely to be present in water samples. This collaboration broadened the set of practices and artifacts within the SoundCitizen lab and signaled to the youth that there were participating in a professionally authentic, unfolding investigation. The methods section of AGU poster that the apprentices and scientists jointly authored shows the impacts of this collaboration on their research. The apprentices described the practices they did with help from the scientists and then went on to describe the practices that went on without them. In the next section, I turn my attention to the opportunities to act in iteration two.

**Opportunities for Acting in iteration two.** Adapting the SCSA program for the middle school context meant that we had to develop a more stable curriculum. Even though, the locus of activity had shifted from work in the laboratory to an OST program we wanted to maintain a high-degree of scientific rigor within the context of geoscience research. We developed a curriculum, which I describe in more detail below, around a local ocean chemistry mystery and finding ways to engage youth in purposeful actions like learning the practices of the SoundCitizen laboratory. We saw the second iteration of the program as an opportunity to build upon the work that had already been done by the apprentices in iteration one on plasticizers. Xenoestrogens and plasticizers are both part of the family of chemicals known as endocrine disrupting compounds (EDCs) that the youth in iteration one studied in the SoundCitizen lab. EDCs are found in many health, beauty, and personal care products. EDCs travel through the wastewater treatment system and out into the waters of Puget Sound.

In collaboration with Eva in her role as liaison we modified an existing high school curriculum developed through our research institute called *My Place in Puget Sound* (Tzou et al., 2010) for the middle school OST context. The central mystery of the curriculum came from a peer-reviewed paper (Johnson et al., 2008) about the potential causes for fish feminization in Puget Sound. According the peer-reviewed paper, xenoestrogen exposure was causing male English sole fish at various sites around Puget Sound to start producing a protein used in egg production called vitellogenin (Vtg). This process was called feminization since male fish were beginning to demonstrate female characteristics. Johnson et al. (2008) collected male English Sole fish at various sites around Puget Sound and tested them for the presence of this protein, based upon their knowledge of these sites as locations where the fish had been exposed to xenoestrogen. The Johnson et al. (2008) paper was full of disciplinarily dense representations of Puget Sound and graphs of the study findings (see Figures 5 & 6 as examples).

Our design goal was to make the information accessible so that youth could engage in the NGSS practice of reasoning with evidence. We wanted the young women in our program to engage with the data in the same way that the scientists had—to conduct a second-hand investigation using scientific data (NRC, 2005). This led us to create a series of activities that would help youth in our program develop an understanding of what EDCs were and to understand enough about the processes in the SoundCitizen lab to determine how they could leverage the lab infrastructure to ask and answer their own questions about EDCs. We were seeking to make them active participants in their own learning.

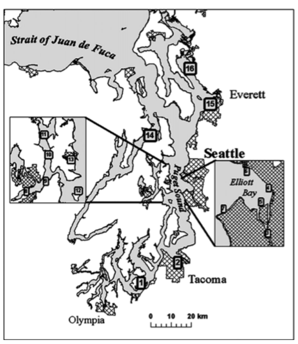


Figure 4. Map of Sample Sites in Puget Sound from Johnson et al. (2008)

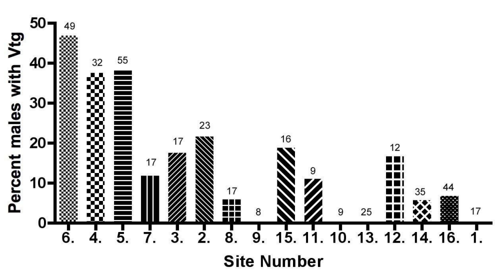


Figure 5. Graph Showing Percentages of Feminized Males by Site from Johnson et al. (2008)

These representations made perfect sense to a disciplinary expert and as someone trained in fish reproductive biology and oceanography; Eva was able to pull salient information from the graph and map as they were presented. However, she readily admitted that it would be difficult for the youth in the OST program to engage in the same sense making. The graph (Figure 6) is a highly specialized representation of scientific data, and the accompanying map (Figure 5) also requires information about bathymetry (underwater topography), and familiarity with Puget Sound to be decoded. As part of the curriculum development for the OST program, Eva and I worked to turn these opaque figures into data that the girls could manipulate.

We leveraged the Professional Vision (Goodwin, 1994) Eva possessed, and her deep knowledge of Puget Sound, chemical oceanography, and fish reproductive biology to plan this particular series of activities (Scipio & Shouse, in preparation). We decided that we would render the information from the graph and map back into numbers of feminized and normal male English Sole fish and have the youth interact with the data in much the same way that the scientists must have. Black dots represented normal male English Sole and red dots represented feminized male English Sole (See Figure XX for an example). When the girls were done we took the plates and stuck them to a projected map of the Puget Sound at each sample location. The conversation that followed led to the young women saying things like, “we live in a feminized fish area,” (Lindsey, 2011) to explain the high concentration of feminized fish she noticed clustered around the urban center where they live. This was one of the findings that the scientists shared in the peer reviewed paper, scientists mentioned that a local bay “in which five sites were sampled, was the most urbanized area and had the largest number of male sole with detectable levels of Vtg” (Johnson et al., 2008).

The young women also pushed for more data, “and they're (sample sites) not over here and if there was test over here I would be happy” (Lindsey, 2011). Lindsey was standing at the board while she said this and indicated an area of the map without any sample sites when she said “if there was a test over here I would be happy.” This echoes one of the areas that the scientist identified for further study following this research More work is needed to characterize the concentrations and distribution of xenoestrogens in Puget Sound” (Johnson et al., 2008). Young women in the study under took the actions of scientists and came to the conclusions that scientists did. In a follow up interview about her experiences in Project COOL we asked Sage what she thought scientist do, her response captured the reason we believe actions lead to broadening participation, “scientists do what we did” (Sage, 2011). This statement was a strong identity warrant grounded in engagement in disciplinary practices around scientific data. Scientists were people who did things and they were the same things Sage and her colleagues did in Project COOL.

**Opportunities for Acting in iteration three.** Adult mentor participants in the third iteration were engaged in facilitating the OST programming. During both enactments mentors worked directly with youth with support from the COOL research team. More so than in any other iteration of the program, mentors organized the activities and managed the facilitation on their own. While COOL research team was present, the learning environment was shaped by the mentors’ actions in the OST contexts. For some of the mentors in the program, this was their very first time working with youth in a leadership capacity. Other mentors were much more familiar with facilitating informal or formal learning environments. I will fully explore the learning trajectories of the mentors in the 2014 cohort in subsequent chapters of this dissertation.

However, for the purposes of this analysis I want to introduce the concept of mentor's experience of the OST sessions as places where mentors engaged in pedagogical practices.

**Opportunities for Authoring across iterations**

Table 3. Opportunities for Authoring Across Iterations

| Iteration 1 | Iteration 2 | Iteration 3 |
|---|---|---|
| • Designing a poster to present at AGU<br>• Writing a script<br>• Filming a video<br>• Writing a zine | • Songs about project COOL<br>• Surveys to administer to peers<br>• Evidence-based explanations<br>• PPT presentations for local conference | Youth:<br>• Songs about project COOL<br>• Surveys to administer to teachers<br>• Video about project COOL<br>• Poster for local conference<br>• PPT presentations for school-based conference |
| | | Adult Mentors:<br>• COOL Logo<br>• Philosophy of Education<br>• Designing COOL activities |

Table 3 (above) shows the opportunities for authoring across iterations. Iterations 1 and 2 offered youth many opportunities to author, e.g., designing a poster for AGU, writing a zine, and a move script. Youth and mentors in iteration 3 were able to author disciplinary and hybrid STEM identity artifacts. Mentors' opportunities for authoring included designing new curriculum activities, modifying existing activities, and even creating their own hybrid STEM identity artifacts.

**Iteration 1. Authoring** played a major role in this iteration of the program. Early in the year, while youth were learning about the practices of the SoundCitizen lab, the scientists put in a poster proposal for the SCSA project at the American Geophysics Union annual meeting which was going to be held within a few hours drive of the University. While the scientists submitted the proposal to AGU, the apprentices made the project their own. Authoring encompasses the creation of texts that Gee would describe as a central part of constructing local meaning (Gee & Green, 1998). The apprentices worked with scientists to jointly author the poster for the AGU conference. Youth brought their ideas and creative construction while scientists' brought their knowledge of the norms and expectations of the poster medium, the math and science necessary to interpret the data (see Figure 7).

Youth played different roles with respect to building the poster. Some apprentices worked on the text, others made graphs, and others described the methods. The border of pictures was created by Hannah whose family emigrated to the United States a few years before she joined the program. Hannah's story is told more fully in a upcoming paper by my collaborators (Stromholt & Bell, in preparation). Hannah was a very active SCSA participant and while she was not as comfortable contributing to the written parts of the poster, she fully participated in authoring the text by curating the pictures that form the border of the poster. Hannah and the PI scientist sat together working on the border of the poster. This contribution to the poster echoed the practices that the PI used in his own work—he always adds a picture to his slides so that people attending his talks have something look at while he talks. He shared this practice with Hannah and helped her to participate in the science communication aspect of the project. When we asked Hannah what she felt SCSA was about she responded, "we collect the water in our locations then we return, we test it, we get the information then we report it" (Hannah, 2010). Hannah's sense of what it meant to be an apprentice and to be part of the program was connected to acting "collecting water in our locations…we test it" and also to authoring, "we get the information, then we report it."

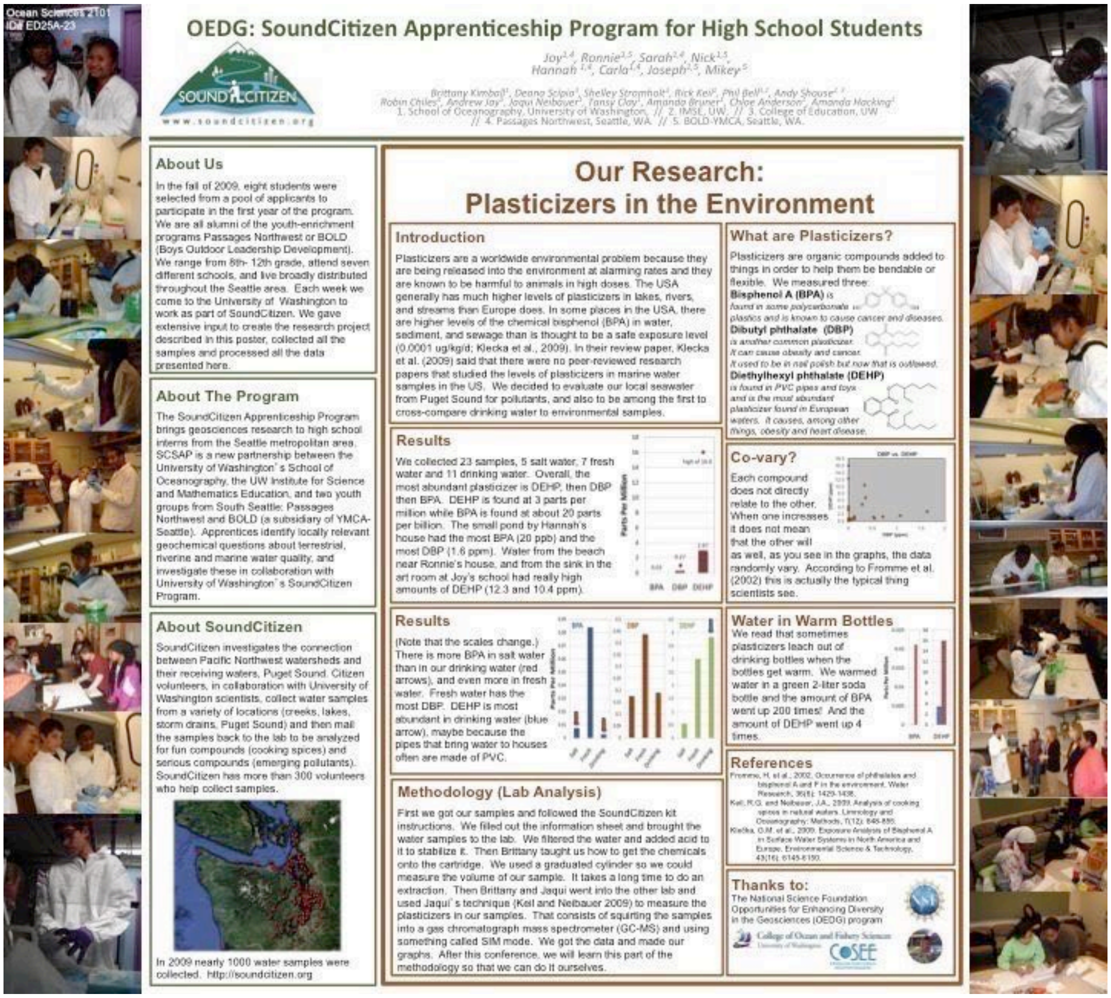


Figure 6. Apprentices' Poster Presented at AGU.

Sarah and Carla wrote the "about us" text, which described the apprentices who appeared as first authors on the poster. The last two lines in the "about us" text read, "each week we come to the University to work as part of SoundCitizen. We gave extensive input to create the research project described in this poster, collected all the samples and processed all the data presented here." This text highlighted the ways that the apprentices authored a text that contributed to a disciplinary conversation and shared their identity with a novel community. They were able to identify themselves as scientists who “work at the University as part of SoundCitizen.” They described the ways that their actions in the laboratory, as designers of a research study, and as data analysts played into the material artifact that they took with them to present at AGU. This demonstrated an ownership of the material that we saw during their presentations at AGU. The apprentices worked in teams to present their work and each took the lead on explaining one component of the poster when people came up to ask questions. They were articulate and well prepared to tackle any question that came their way.

**Iteration 2.** The youth in the second year of the program had an opportunity to design and conduct their own research projects as well within the classroom space. While they did not leverage the lab as closely as the apprentices did in year one but they were able to conduct research at their school using portable materials from the laboratory. Their questions centered on the topic of endocrine disrupting compounds. The young women in the sixth-grade cohort chose to study EDCs in health and beauty products while the ninth-grade cohort chose to study micro plastics in toothpaste and body wash. Both cohorts authored surveys to find out about the ways that people in their school community used health and beauty products that contained the products they were interested in testing. Both cohorts shared their developing science selves with their school communities in order to administer the surveys. The sixth-grade cohort set up a table during lunch time and made an announcement to their entire grade during lunch to ask their colleagues to come and take the survey. They authored the entire experience by going to the school staff member in charge of the lunchroom to ask her permission, they also wrote out a speech to read to their classmates. From a design perspective, we viewed this a successful outcome of relocating the COOL program to a school setting. The young women in their first year at a new school came together during the OST and viewed themselves as the young people who did COOL at their school. Speaking before the entire sixth-grade during lunch was a positioning move—the young women saw themselves as experts with a desire to gather data. Similar to the way that the youth in iteration one felt about the data they gathered in the SoundCitizen laboratory, the young women felt ownership over the data they gathered.

The eighth-grade cohort achieved the same ends by asking the science department to administer the survey during class. As individuals they went to their science teachers and asked them to give the survey during class. In their role as science students they explained what the needed the survey for and asked their teachers if they would give it to the eighth-grade in science class. Both groups of students made a part of their STEM identities public to their school communities. We viewed this as a sign that they were willing to take risks to collect the data that they needed. When the young women chose to share their science selves with their school communities, we felt this was an indication of the ways that their participation in STEM practices was broadening. We took it as an indication that their identification with STEM domains was increasing as well given that they were comfortable sharing this with their school community. As opposed to the youth in Iteration 1, both cohorts of youth at marble had developed an identity that spanned from their participation in the COOL program into the larger school community. They were also able to share this identity with the disciplinary community through their participation in the local Ocean sciences conference.

**Iteration 3.** Youth and mentors in the third iteration had multiple opportunities to author artifacts and identities. Youth participated in the local student conference during enactment 1 and in a school-based conference in enactment 2. Youth collaboratively designed a poster for the local conference, and created computer-based presentations for the school-based conference. In both contexts, youth were intimately involved with the research and designing the communication artifacts for both types of presentations. During the second enactment youth presented at the school-based conference created an agenda for the day, presented in a predetermined order, and answered questions from their audience with aplomb. Youth presentations included reporting on research they did on the presence of water on other planets, the results of a survey about general knowledge of micro-plastics in the school community, and Internet research on endocrine disrupting compounds (EDCs) and their impacts on biological systems. Each group of students authored a PPT and practiced their talking points to prepare for the school-based conference.

This authoring of personally relevant STEM research artifacts connected them to disciplinary contexts. Youth positioned themselves as experts who fielded questions from peers and adults about their findings and the purpose of their studies. I agree that positioning is an authoring move. Seeing yourself as the kind of person who can engage in scientific talk about a topic of your own interest is a step towards authoring a new possible self (Markus & Nurius, 1986) that includes a STEM identity. For the young people in the third iteration of the COOL program, positioning themselves as people who enjoy science was an authoring move especially in the presence of peers they had invited to join the school-based conference. As Nasir and Saxe (2003) remind us, youth from non-dominant communities often find themselves caught between a strong academic or ethnic identity. Youth in the COOL program bridged these two identities in the OST space. The school-based conference was still a highly curated space for the youth in the program but many invited friends who had chosen not to participate in COOL personally yet still found time to celebrate with their friends on the final day of the program.

Mentors in iteration 3 were also involved in various kinds of authoring including creating modifications to existing COOL OST curriculum. During iteration 3, Emily who had a background in early childhood education modified one of the COOL activities to make it more hands on (see Figure 8 below). The activity was a way to get youth talking about chemicals by placing them into dichotomous categories like safe/dangerous, human made/natural, and part of my life/ not part of my life.


Figure 7: Manipulatives Created by Emily to go Along with the Chemical Sorting Activity

The original activity used index cards with the names of the chemicals written on them. While these seem very similar, Emily's change made the activity more accessible to youth with all levels of language proficiency since the cards themselves now helped explain what the chemicals were. Emily authored a new approach to the activity that helped broaden participation for youth. We kept this change in subsequent iterations of the project.

During iteration 3 Steve authored two major artifacts that became part of the COOL program. I will discuss one of them here and the other in the discussion. Steve's modified a puzzle activity to make it more active by turning it into an icebreaker. I had taken a presentation provided by a local waste water treatment plant describing the steps of the waste water treatment system and created a puzzle that youth could collaborative assemble. My goal was to make the process visible and to make it easier for the youth to engage in putting the puzzle together as a group. Steve wanted to try turning the puzzle into an icebreaker. He returned to the original puzzle and in collaboration with my colleague Elaine Klein, he made each component of the puzzle a single slide with a picture of the puzzle piece on one side and a definition on the other. He introduced the activity as a challenge, had each young person take a piece of the puzzle, and asked them to put themselves in order to solve the puzzle. It was a big success and we have continued to use his version when introducing the activity to the next cohort of mentors in iteration 3 of the program.

**Opportunities for Authenticating**

Table 4 shows opportunities for authenticating across program iterations. In iteration 1 youth presented their work at an international conference and a community event. They conducted their work in the SoundCitizen laboratory at a research-based university and they were able to take fieldtrips that positioned them as experts.

Table 4. Opportunities for Authenticating

| Iteration 1 | Iteration 2 | Iteration 3 |
|---|---|---|
| • International Conference<br>• Community Event<br>• Working in the SoundCitizen lab<br>• Aquarium behind the scenes tour<br>• Research Cruise<br>• Visit to parallel lab | • Local student conference<br>• UW Lab visits<br>• Research Cruise | Youth:<br>• Local Conference<br>• School Conference<br>• COOL Carnival<br>• UW Lab visit<br>Adult Mentors:<br>• Facilitating OST programming |

During iteration 2 youth gave presentations at a local student conference and only created science communication artifacts for that disciplinary space. During iteration 3 youth and mentors' opportunities with authenticating were varied, youth participated in the local student conference, a school-based conference or a COOL carnival. They also visited the UW laboratory on a field trip. Mentors facilitated OST programming and this was an authentic opportunity for them to learn in practice.

**Iteration 1.** Youth apprentices in the program responded to many of the aspects of the designed learning environment that can be linked to authenticating. In the follow-up interviews the apprentices called out many things as real and helping them feel connected to the work they did for SoundCitizen: working in the lab, getting to filter their own samples, presenting their work at a conference, speaking about their work to adults and scientists, self direction, and developing their own program of research. Apprentices were paid during the first year of the program many of them spoke about having a job at the University in interviews—the program provides them with financial capital that they could trade as social capital. "I'm going to work on Tuesday, you hear the word job and people start to pay attention" (Sarah, 2010). Sarah was speaking about the sense of legitimacy that came from telling people she had a job at the university. Three of the other apprentices also talked about the positive aspects of having the apprenticeship as a job. They saw the fact that they were getting paid as an indication of their authentic position within the oceanography research lab. They also talked about what it was like to be able to tell their friends about the job they were doing at the University.

Authenticating also played a role in motivating youth participation in the laboratory. Nick said, "I was happy to filter my sample and everything from the different waters I took samples from"(2010). Nick's comment captured the ways that many of the youth talked about their time in the laboratory. He felt connected to the actions he was taking in the lab to process his own samples. They were connected to his own research and yielded data that he fount to be directly useful. This comment shows how authenticating plays into acting and authoring. These interconnected design principles helped the apprentices to fully participate in the discipline of chemical oceanography.

The science conference was another time when youth felt they were engaged in the kinds of things that scientists do. Hannah talked about the fact that they were the only high school students presenting their work to a room full of adult scientists, “I feel special because we are only just high school students were there and other like doctor or like scientist people” (Hannah, 2010). Having a legitimate role within the community really mattered to the students. It was one of the things that motivated their participation and fueled their participation and identification.

**Iteration 2**. One of the interesting themes that emerged in the follow-up interviews with young women was how authenticating played into their understanding of themselves as scientists and fed into their continued desire to do science. Sage from the sixth-grade cohort captured this well when she said that science was kind of boring for her before COOL because she thought it was the teacher’s job to make it fun. She went on to say, “I didn’t realize it was my job to make it fun” (2011). This statement showed Sage taking charge of her own learning in a very agentive way. She went on to say that she discovered that science could be fun when she was doing it with her friends. Sage’s knowledge of science as fun was an important change for her development of a STEM identity and identification with the domains of science. This realization that science could be fun motivated Sage to find ways to make it fun in other contexts rather than waiting for her science teacher to make it fun for her. Sage was not the only young person whose experiences authenticating led her to participate more fully in science. Kelly's story from the eighth-grade cohort is another story of the ability to authenticate motivating participation.

The young women in the eighth-grade cohort were struggling to find their way near the end of the program, there was opposition to the idea of preparing to go to a student-centered conference. Some of them wanted to quit the program and others wanted to bow out of the presentation altogether. Kelly described COOL as a place where she felt connected to newness and discovery as part of the things she did as part of science within the COOL program. She cited her trip to the SoundCitizen laboratory as a time when she felt trusted to enter an important place where people we doing science (Tierney & Scipio, 2014). This sense that she was a scientist and a trusted participant helped to authenticate the experience. This ability to authenticate motivated her to make her contribution to the STEM fields by designing a study and carrying it out with her colleagues. Kelly was the driving force in the push to complete a project in time for the student conference.

**Iteration 3**. We were concerned about what loosing the local science conference as a venue might do to youth' ability to authenticate the experiences in COOL. Our concern was that they might not experience the opportunities to authenticate their experiences if we did not have a disciplinary performance space. However, the youth chose to make their own spaces. At Marble we worked with the youth to create a school-based performance space that was similar to the community event that we hosted in collaboration with the youth in iteration 1. Youth chose to invite friends, teachers, and OST staff members. They presented their research as computer-aided presentations and one Bill Nye style demonstration of a model of an underwater volcano. Developing the model of the underwater volcano was connected to the youth's interest in the kinds of chemicals that could be released into the water around an active volcano on the sea floor. In the presentation they discussed their research on the chemicals released by underwater volcanoes and used the presentations to bring others into their fascination. Youth took ownership of the performance space, creating signs and taking invitations to their friends and teachers. Given their enthusiastic participation we had to revise our initial assessment of the nature of an authentic performance space. The two initial spaces we found for our youth were related to disciplinary performances and practices, at the international and local conferences youth were able to participate in science specific spaces. However during iteration 3 they were able to participate in making their own performance space with features that meant something to them.

The youth-centered design was an important step in our understanding of the role of performance space for the COOL program. While the international science conference and the local student conference offered youth opportunities to present their work to a disciplinary community, they did not actually offer youth a chance to share their burgeoning science identity with their school or home communities. During our six-year tenure at Marble middle school, we did not always do a good job of communicating the science that youth were doing in our program to their classroom teachers. There is social capital bound up in science success and youth who find personally relevant connections to science do not always translate that into academic capital in their classroom learning contexts (Bricker & Bell, 2012; 2014). Inviting youth to showcase their science research projects in a school context helped the teachers at their schools to see them in a different light. When youth invited teachers into the informal space to see how they were authoring new science research and communication artifacts, it allowed teachers to understand youth interests, knowledge, and science-linked identities (Birmingham & Calabrese Barton, 2014; Calabrese Barton et al., 2013). One of the OST coordinators came to the conference and initiated the following exchange.

In this exchange I want to focus on two main things, Amy's line of questioning and the ways that the youth's responses echo the stance that COOL has taken towards developing youth's scientific literacy (Feinstein, 2009; 2010).

Table 5. Youth and OST Coordinator Discourse During School-based Conference

| **Line Numbers** | **Discourse** | **Actions** |
|---|---|---|
| 1-2 | Amy: I have a question for you guys, so for those of you…Would anyone be willing to share with me why you wanted to take this class, afterschool? | |
| 3 | Jack: 'cause I like science, science is fun | |
| 4-5 | Amy: but you've never done OST before, I've never met you before this class, so what is that why? Just because you like science? | Turns to Jack |
| 6 | Jack: Well I'm in 6th grade | |
| 7-8 | Amy: So you met them and you liked that and you wanted an opportunity to do some cool science stuff? Ok. Madeline? | The youth all begin to talk at the same time and move around in the room, making too much noise for Amy to hear Madeline. |
| 9 | Amy: Hold on you guys I want you to be able to hear other people's answers. Madeline? | Amy raises her hands over her head and looks around the room. |
| 10-11 | Madeline: Well I've always been interested in science but at the same time when Déana explained it, it sounded really cool. | Madeline points at Déana at the front of the room |
| 12-13 | Amy: Ok. So you've always liked science. Ok. How many of you have always liked science or science was interesting to you? | Amy looks around the room. Youth responses are inaudible. Seven out of ten youth raise their hands in response to her question. Some kids put their hands straight up in the air, others tentatively, one young woman waggles her hand back and forth indicating that she's on the fence. |
| 14 | Amy [overlapping]: How many of you? | |
| 15 | Jonas [overlapping]: Science is pretty easy | |
| 16-17 | Amy: You said it's easy...How 'bout you, I've never met you either. What made you want to do this class? | Amy points at Jonas |

| | | |
|---|---|---|
| 18-19 | Jonas: I don't know. It's because everyday I get bored afterschool so I just took this class 'cause I like water. | |
| 20 | Amy: you like water? Hmm | |
| 21 | Jonas: I get bored sometimes after school so I just took this class | |
| 22-23 | Amy: How many of you think you might want to do something with science as a profession for work? Like be a scientist or do something that involves science? | Four out of 10 youth present raise their hands. |
| 24 | Amy: And that could include like in the medical field? | |
| 25 | Kassandra: Photography needs chemicals | |
| 26 | Amy: Photography, engineering, medical fields, biology, a doctor. | Youth start calling out all the professions that require science and types of science that they might do. Amy re-voices their words. |
| 27 | Jack: I'm definitely a mad scientist | |
| 28 | Amy: just be a mad scientist? | |
| 29 | Jack: My hair | Jack nods and points at his head. He has spiked his hair with gel. |
| 30 | Amy: You have to with your hair. | Amy nods and smiles at Jack. |

Amy's line of questioning (lines 1-2, 12-13, 22-23) highlighted the ways she was coming to view the youth in the program. Some of the youth she had never met before (lines 4-5 & 16-17). As the assistant coordinator of OST programs at the school's community learning center, Amy got to know some of youth and their families through a series of events that the CLC hosted over the course of the year (lines 7-9). While Amy was not an academic staff member, her knowledge of youth and their interests could play into their abilities to engage in other school programming at Marble. Amy was a learning broker at Marble, an adult who could help youth engage in enrichment opportunities and connect to new learning contexts. Once the youth in COOL were on her radar as young people who were interested in science, she could connect them to additional resources and opportunities to deepen their participation in STEM learning contexts.

As designers of a learning environment for youth from non-dominant communities that leveraged contemporary science, our goals were to engage youth in STEM practices in ways that felt authentic to them. We wanted them to see their interests in the work that they did as well as connect to large disciplinary expectations. As a program we were interested in broadening participation by helping youth see themselves in STEM rather than focusing our efforts on trying to produce the next generation of geoscientists. While we were delighted when participation in COOL opened new pathways to STEM careers for youth, we saw a broader set of ways that youth could participate in STEM in personally and community relevant ways (NRC, 2009; 2012). I recognized Kassandra's contention that "photography needs chemicals" (line 25) as a warrant that her interests also fit under the umbrella of science. She was claiming that as a photographer she considered herself a science participant.

Adult mentor participants in the third iteration were engaged in the authentic space of facilitating the OST programming. During both enactments mentors worked directly with youth with support from the COOL research team. More so than in any other iteration of the program, mentors organized the activities and managed the facilitation on their own. While the COOL research team was present, the mentors' acting in the OST contexts shaped the learning environment. For some of the mentors in the program, this was their very first time working with youth in a leadership capacity. Other mentors were much more familiar with facilitating informal and formal learning environments. I will fully explore the learning trajectories of the mentors in the 2014 cohort in subsequent chapters of this dissertation. However, for the purposes of this analysis I want to introduce the concept of mentor's experience of the OST sessions as authentic pedagogical practice learning environments.

As designers of the COOL program we also created a learning environment for mentors which included the two quarter class sequence at the university focused on preparation in the Winter quarter and support in the Spring. The design team and I leveraged Grossman et al.'s (2009) three-step process for the adult learning of a complex practice: representation, decomposition, and approximation. During the winter preparatory course mentors experienced representation and decomposition. They experienced the OST curriculum as if they were participants and then we asked them to put on their pedagogical hats to think through the design decisions and pedagogical strategies. During the spring quarter, prior to working with youth mentors got to approximate teaching during rehearsals in the undergraduate class setting. We used video club to help them reflect on their teaching experiences and learn from their approximations. Then when mentors were in their OST placements, they got to teach youth and continue to learn by reflecting on their teaching experiences.

Although I have spoken about opportunities to act, author, and authenticate as separate in the above sections as I move onto the discussion section I will begin by looking at the ways that we saw broadened participation outcomes for youth and mentors through the interconnections. In what follows, I will discuss two main points. First, designing for broadening participation in the COOL program as a means of increasing participation for youth and mentor participants. Secondly, building STEM identities and identification through participation in COOL as an informal learning environment focused on broadening participation.

## Discussion

### The interconnections between acting, authoring, and authenticating

For the youth and mentors in the COOL program, authoring texts was an action that led them to authenticate their experiences. One example of this was the apprentices in iteration 1 authoring the poster that they took to AGU. The data they analyzed came from their actions in the laboratory and allowed them to author a text that had an authentic purpose in the world—as a science communication artifact at an international conference. As a design team, we leveraged many resources to create this opportunity to broaden participation for the youth in the program. One of the designed activities involved having the apprentice review the posters hanging on the walls in the laboratory that showcased previous presentations by scientists on the floor. We also showed the youth YouTube videos of poster sessions so that they could envision the organized chaos of a poster session with everyone talking at the same time, people coming up to your poster while you were in the middle of talking to someone else, and a room full of people with questions about your poster. This helped the apprentices to understand the poster as a disciplinary artifact that facilitated scientific communication. We also worked with the apprentices to create elevator pitches so that they could speak succinctly about their research. By the time they got to the conference they were able to participate as researchers and scientific communicators in the AGU community.

The "methodology (lab analysis)" section of the poster highlighted another interconnected moment of acting, authoring, and authenticating. In this section the apprentices wrote about the parts of the process that they participated in. They named the scientists whose work contributed to their joint activity of designing and conducting a research project. This description of themselves as part of the process played a role in how they came to identify with the geosciences domain. The apprentices saw themselves as collaborators and creators of knowledge. As the apprentices authored the poster they were simultaneously authoring new identities for themselves. As youth worked with scientists to design a project that felt authentic to them and to leverage the resources of the laboratory to answer questions that mattered to them and their communities, they changed the work of the laboratory. In essence they authored not only new identities for themselves but also for SoundCitizen as an organization. This is an excellent example of broadening participation as changes in what it means to participate. The questions the apprentices asked reshaped what it meant to process samples within the SoundCitizen laboratory as the scientists had to investigate new procedures for the instruments that measured presence, absence, and concentration of chemicals in water samples.

Beyond the AGU poster and presentation, the apprentices took another important step that demonstrated the impacts of acting, authoring, and authenticating when they re-authored their work to present it to their home community. When we returned from the conference the SoundCitizen scientists were eager to travel to the apprentices' schools and share the work they did together. However, the youth were quietly resistant to the idea. We realized that because the apprentices were scattered at schools around the region they had not built community around their science work in their schools, or did not want to share their science selves with their school communities (Zimmerman & Bell, 2014). We decided instead to create a space for them to share their work and the findings from their study with their home community by collaborating with the CBOs. Authoring entered the equation again but now the apprentices were creating new science communication texts that blended their home and science selves: a video and a zine. This happened in the video, when youth appropriated a popular media trope to communicate science, representing a true synthesis of youth and science disciplinary learning. The apprentices understood their research and findings on plasticizers to the extent that they could incorporate popular culture into their authoring of new science communication texts.

The interconnection between authoring, acting and authenticating in iterations 2 and 3 led youth in COOL to build hybrid STEM identity artifacts—things within the designed activities that we did not anticipate. Calabrese Barton et al. (2008) called these signature science artifacts and highlighted their autobiographical nature. These artifacts captured parts of who the young people were in their everyday lives and merged them with the youth's burgeoning science identities. Youth in Calabrese Barton et al.'s study engaged in similar activities like writing songs or making physical artifacts that used resources in sanctioned and unsanctioned ways. In COOL we sanctioned all the resources that youth wanted to bring into the learning environment. The following artifacts created by youth in COOL fit into this category where youth merged science and personal resources to create hybrid STEM artifacts.

In iteration 2, the young women in the 6th grade cohort were working on making the representation for the data rich mapping activity and they brought their personal selves into the action of making the representation. The figure below (Figure 9) shows our example plate and two of the plates that the young women created. Here I want to draw attention to the fact that the adult made plate in the above figure has uniform dots laid out in rows and columns while the youth made plates demonstrate their personalities. For example, Mika one of the young women

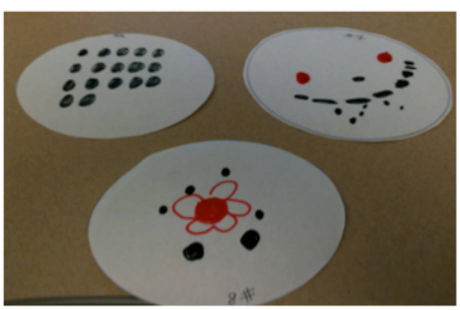

Figure 8: Example and Student-generated Data Representations

in the program who loved gothic things made the plate with the vampire smile. She read manga voraciously and carried a notebook full of illustrations of her favorite characters and story ideas with her every time we saw her. We considered this infusion of her own identity and interest in vampires into the STEM space an example of merging her pop culture self with her science self. The youth representations are accurate and highlight aspects of their personality.

Lindsey, one of the young women in the sixth-grade cohort, wrote a song about her experiences in COOL to the tune of a Justin Beiber song. She was a huge fan of his music and given the opportunity would often burst into a Beiber song. When we hosted a talent show at the end of the first quarter with the sixth-grade cohort, she sang the following song:

*Whoa-ah Whoa-ah Puget Sound*
*Whoa-ah Whoa-ah Puget Sound*
*Whoa-ah Whoa-ah Puget Sound*

*You're swimming in it*
*And it's co- ld*
*We're join' sailing*
*Cuz we're bo- ld*
*It is the sea, it is the sound*
*And it will always, always, always be around*

*There is too much trash*
*It's getting dirty*
*We've got to save it*
*For fish and birdies*
*And for the salmon, and for the bears*
*So it will always always always be there*

*And I was like Puget, Puget, Puget Sound, Oh*
*Puget, Puget, Puget Sound, Oh*
*Puget, Puget, Puget Sound*
*I thought you'd always be mine, mine*

*We studied water*
*In Project COOL*
*Girls in science*
*We always rule*
*We'll keep on learning and go to school*
*And we will always always always be cool*

*And I was like Puget, Puget, Puget Sound, Oh*
*Puget, Puget, Puget Sound, Oh*
*Puget, Puget, Puget Sound*
*I thought you'd always be mine, mine*

Figure 9: Lindsey's COOL Song (Sung to the tune of *Baby* by Justin Beiber)

Lindsey's song was similar to the work the apprentices did in iteration one when they re-authored their work on plasticizers for a lay audience and leveraged pop culture to do this. This song counted as a hybrid STEM identity artifact (Calabrese Barton et al., 2008) because it was a mix of STEM content and a pop cultural reference with which Lindsey already identified. The song showed how she identified with the problem space we had set up during the first quarter in the COOL program. She saw herself as someone who belonged to the place where Puget Sound can be found and included actions that she had done on the water. She also saw herself as someone who was capable of doing something about the problem of Puget Sound "getting dirty."

The next words described the reasons that it needs to be saved, "for the fish and the birdies, for the salmon, and for the bears, so it will always, always, always be there."

She also identified herself as a member of Project COOL and someone who does science "Girls in science we always rule." Her identity warrant was linked to actions that she had taken and was going to continue to take. From a program evaluation standpoint, this hybrid STEM identity artifact was a record of how Lindsey saw herself and the role that she could play in making change in her community. During iteration 3, youth also created a song and shot a music video that we considered a hybrid STEM identity artifact. Their song was written to the tune of cups performed by Anna Kendrick in the movie *Pitch Perfect*.

*I've got my lab coat for the long way round*
*Two bottle chemicals for the way*
*And I sure could use some sweet company*
*Join Project COOL, what do you say?*

*EDCs, EDCs*
*You're gonna learn about EDCs*
*You're gonna learn about Puget Sound, you're gonna learn about pollution, Ooh*
*You'll be an expert when we're gone*

*I've got my water for the long way 'round*
*The one with the smelliest of fumes*
*It's got bacteria, it's got chemicals*
*It's got bark looks like cereal*
*But it sure would be cleaner with you*

*EDCs, EDCs*
*You're gonna learn about EDCs*
*You're gonna learn about Puget Sound, you're gonna learn about pollution, Ooh*
*You'll be an expert when we're gone*

*You're gonna learn about Puget Sound, you're gonna learn about pollution, Ooh*
*You'll be an expert when we're gone*

Figure 10: Tammy & Ayana's Project COOL Song (sung to the melody of The Cups song from *Pitch Perfect*)

Tammy and Ayana's song echoes the spirit of Lindsey's and highlights the ways that they were aligning parts of their academic and personal identities. There is a similar sense of ownership of their science identity and the role that they played with respect to COOL in the lyrics of the song. The song was written as an advertisement for future project COOL participants to tell them a little bit about what they'll learn and to get them excited about participation in COOL during OST. The images in the second verse were directly related the Ayana's experience of a water filtration activity that we asked the youth to complete on their first day in the program. She looked at the bottle of dirty water and said, "that looks like you all have some cereal up in there." The fact that this terminology made it into her song about her experiences in the COOL program underscores that this song was indeed a record of her own participation in the program. The girls go on to let their listeners know that "You're gonna learn about Puget Sound, you're gonna learn about pollution, Ooh you'll be an expert when we're gone." I coded this as a positioning moment and an identity warrant. The young women were positioning themselves as part of the community of people who participated in project COOL and as people who could make new experts. Youth in the program were not the only ones whose authoring merged moments of acting and authenticating. During iteration 3 Steve created a logo for the COOL program that we continue to use to this day (See figure 12 below).

Steve came into the program with some strong ideas about science as an objective discipline. When we asked him to keep a science notebook that was intended to be a space for reflective and reflexive (Kleinsasser, 2000) writing. In January 2014, when the preparatory class started, Steve was reluctant to try this kind of writing. He felt that his ability to write reflexively had been trained out of him. He conceded himself an objective recorder of data and was not certain that he could write about what he called "the feels". However, Steve also had a deep practice as a visual artist.

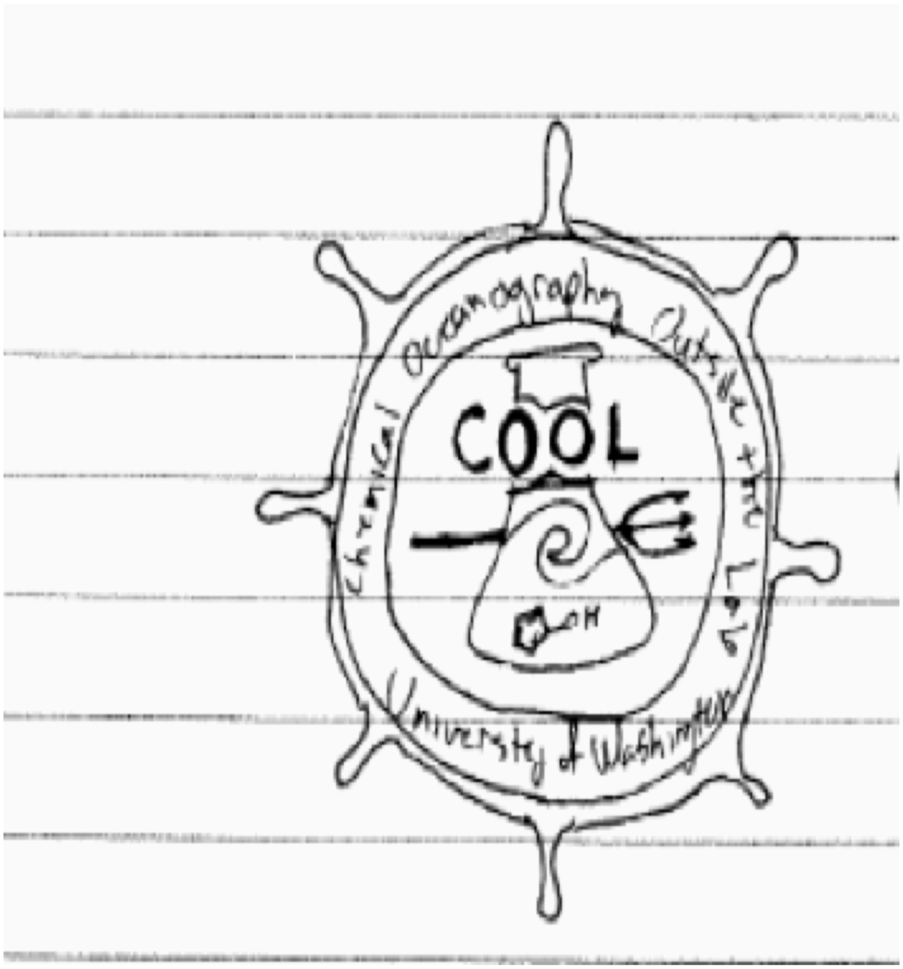


Figure 11. Page from Steve's Notebook

The above logo in his notebook emerged in February—a month into his experience in COOL, he had begun to author a new possible science self (Markus & Nurius, 1986) that could include more of his personal identity. I coded this as a hybrid stem identity artifact akin to the songs that youth in iterations 1 and 2 wrote as they integrated aspects of things their personalities with their new STEM identities. Calabrese Barton et al. (2008) explain "signature science artifacts served as resources for entering into the science classroom discourse community with positions of authority without having to assimilate into the normative culture of the science classroom" (p. 83). The songs and the logo served a similar function for the youth and mentors in the COOL program entering into the discourse of the science community without having to assimilate.

**Designing for Broadening Participation**

Within the COOL program there were multiple dimensions focused on broadening participation. In the undergraduate context, we were working with students from a variety of backgrounds who were being apprenticed into working in informal environments. This level of broadening participation connected to teacher learning goals and concepts (Grossman et al., 2009; Luehmann, 2009; Windschitl et al., 2011). Within the OST contexts, we were working with youth from non-dominant groups historically underrepresented in the sciences. We were apprenticing them into authentic STEM practices and the ongoing work of a chemical oceanography laboratory. Finally, the interdisciplinary research team was itself learning about how to focus and deepen elements of the program on these dimensions of broadening participation.

Broadening participation in STEM had two related meanings within this study—one connected to the question of who participates and the other was related to question of what it meant to participate. This two-pronged approach to thinking about broadening participation arose from the literature and also empirical work within the COOL program. Bell et al. (2009) and Bang & Medin (2010) among others have argued that broadening participation initiatives based largely on research conducted with White youth, families, and communities would be unlikely to provide solutions for youth from underrepresented groups. Assimilationist theories of science equality proposed that youth from non-dominant did not participate because they did not have access to STEM learning contexts or lacked motivation to participate. Proponents of this stance offered solutions based on giving youth from underrepresented groups access to the same kinds of learning opportunities aimed at increasing participation for youth from dominant groups. However, research on African American and Indigenous communities demonstrated deep cultural expertise and repertories of practice that were already well suited to understanding the phenomena of the natural world (Bang & Medin, 2010; Basu & Calabrese Barton, 2007; Calabrse Barton, 2001; Hanson, 2007). In contrast, everyday science literature was built upon the premise that youth's everyday practices (argumentation, modeling, asking questions, gathering data) should be related to scientific practices in ways that may not have been recognized as scientific by teachers or other gatekeepers (Bricker & Bell, 2014; NRC, 2014; Toomey Zimmerman, 2012).

As I mentioned in the introduction, responding to the question of who participates entails considering ways to broaden the kinds of people who have STEM identities and identify with the domains. That is, we want youth to come to see themselves as capable of engaging in STEM and consider themselves part of the STEM community. This might include increasing opportunities to engage in STEM practices through apprenticeship or mentorship as we did in COOL by creating situated events where mentors and youth could collaboratively engage in chemical oceanography practices within the SoundCitizen laboratory. This might also include changing ways the youth are positioned as developing experts who can not only consume knowledge but also author it and contribute to the ongoing disciplinary practices. Within the COOL program this meant that youth chose personal, community, and discipline relevant projects and mentors supported their work.

Broadening participation also calls for a response to the question what does it mean to participate. Science education literature demonstrates a multitude of reasons to participate in STEM. Scientific literacy arguments (NRC, 2014; Polman & Hope, 2014) and competent outsider (Feinstein, & Meshoulam, 2014) focus on preparing youth to engage in STEM for personally relevant reasons. Scientifically literate individuals should be able to make decisions using STEM information and practices to help themselves and their communities. We want youth to be able to make informed decisions about whether or not they want to pursue the learning of STEM for career purposes based on an understanding of it. Within the frame of broadening participation—this also means changing the definition of what it means to participate. The STEM pipeline is one of the more pervasive framings on STEM participation. From this view, broadening participation could mean rehabilitating the drips and considering other choices and activities as part of the STEM community. Within historically underrepresented communities, there is a vast archive of STEM-related knowledge that has either been ignored or undervalued by many STEM disciplinary communities (Bang & Medin, 2010; Bang, Medin & Cajete, 2009; Hudicort Barnes, 2003). Broadening participation in ways that consider the needs and perspectives of non-dominant communities would entail asking questions about the purposes of broadening participation efforts in order to make visible the intentions of disciplinary communities. This kind of approach might help to illuminate existing connections between the experiences of non-dominant communities and the disciplinary expectations. This approach has the potential to highlight everyday STEM expertise and position it alongside disciplinary ways of understanding scientific phenomena (Bell et al., 2012; Tal & Dierking, 2014; Warren et al., 2003). It would mean making the science learned as personally relevant as possible—at least in significant ways—by overlapping curriculum and program experiences with the lives of youth and communities (Bell et al., 2012).

**Building STEM Identities and Identification with STEM domains**

In the COOL program, broadening participation involved building STEM identities and identification amongst non-dominant youth and mentors. Developing STEM identities and coming to identify with the STEM domains are vey complex practices for youth and especially for youth from underrepresented groups (Archer, 2010; Azevedo, 2011; Bell et al., 2012; Bricker & Bell, 2014; Nasir et al., 2006). While identity was presumed to be a static and inherent quality of individuals, research on learning in cultural communities has demonstrated that identities are multiple and exist in relation to knowledge, practices, contexts, resources, preferences, expectations, and value systems (Archer et al., 2010; Azevedo, 2011; Bouilion & Gomez, 2001; Eisenhart, 1996; Gutiérrez & Rogoff, 2003; Herrenkohl & Mertl, 2011; Nasir et al., 2006).

Nasir et al. (2006) discussed the role that a sense of safety and belonging played in non-dominant youth participation. Attending to safety entails overcoming stereotype threat (Steele & Aronson, 1995) and organizing practice around real roles and relationships in deepening and dynamic ways. They discussed trajectories for competence, which "provide novices a clear view of more expert practice" (p. 492). These trajectories for competence also connect youth to pictures of people they could become through engaging in practices.

Archer et al. (2010) reported on STEM identity development in a 5-year longitudinal study of identity as an embodied and performed construction that was produced by individuals and shaped by their specific structural locations. They found identities to be discursively and contextually produced, profoundly relational, multi faceted and complex. This is congruent with the construction of persons learning in multiple, intersecting structures of social practice (Bell, et al., 2012; Dreier, 2009). Archer et al. (2010) grounded the research on "notions of identity" and highlighted the potential mismatch between "popular representations of science" and "the developing identities of young adolescents" (p. 2). They explained "at stake here is the potential to construct and inhabit an intelligible science identity" (p. 12). This relates to Nasir and Saxe (2003) who found that minority students often feel they have to "choose between a positive ethnic identity and a strong academic identity" (p. 14). Their analysis explored ways to study emerging tensions between academic and ethnic identities in practice.

While, I used Eisenhart's (1996) analysis to highlight navigation, she also discussed ways that STEM disciplines and experiences in training programs "produce identities." Eisenhart showed that the meaning of the term scientist varied in relation to the kinds of work valued in particular contexts "different contexts offer structural alternatives for expressing the meaning of being a scientist" (p. 183). She cited a 1991 study by Hewitt and Seymour that suggested that students who switch out of "hard science" programs like physics and "non switchers" actually encounter similar issues but "non-switchers" developed specific identities in relationship to the domain that allowed them to "live with their discontents." This study suggests that a STEM identity is not a fixed, box-like construct but is malleable. Developing robust, respectful, and flexible STEM identities is an important practice if we intend to broaden participation for youth from non-dominant groups.

## Conclusions & Implications

This paper sought to advance a theoretical framing for the design of learning environments geared towards broadening participation in STEM specifically for youth and mentors from non-dominant communities. Given that COOL was a design-based research program conducted over six years across multiple sites, the findings from this analysis of program design features allowed me to explore the link between the designed features and the opportunities they created for acting, authoring, and authenticating. In this final section, I offer some design principles that emerged from our own years of trial and error, which may be useful for teams seeking to build programs that leverage the science of broadening participation.

*Specific Design Principle: In order for youth to see themselves as the kinds of people who can be and become scientists they need to engage in contemporary science practices. As students engage in these practices, the unsettled character of contemporary STEM topics can expand or constrain opportunities for youth to engage in act, author, and authenticate.*

Designing and conducting a research study within the SoundCitizen laboratory and on a topic that the scientists were also learning was a major identity building experience for the youth in our study. Moving forward we sought to find ways for youth to experience newness and discovery within the context of contemporary science practices. Unsettled science is a necessary component of this kind of work—and has many pedagogical advantages (Bell, 2004). Finding ways to engage youth in discovery and newness. Youth recognize this as of a different kind than the work they are typically asked to do in science classrooms. Finding a lab that was engaging in unsettled science was necessary. Secondly, we as educators needed to find new ways to make connections and allow youth to navigate unsettled science through sets of practices that the lab was already engaging in or that educations were engaging with. Our practices in Iteration 2 and 3 however were tied to settled methodologies and this is the space for future work. Thirdly, our choice of a topic was deeply related to science that had political and personal/social implications (Bang & Rosebery, AERA 2015). The science of endocrine disrupting compounds and their impacts on biological systems was the unsettled science that worked for the COOL program.

*Specific Design Principle: Solving logistical problems related to transportation, snack, and stipends are essential components of designing for equity.*

Many youth from non-dominant groups have afterschool responsibilities that entail helping their families with younger siblings or in small businesses. Two of the youth in iteration 1 of the program needed to go straight home from school to care for younger siblings. Neither Sarah nor Hannah would have been able to participate in SCSA had the scientists and research team not committed to picking them up at their homes on a weekly basis. Sarah needed to be home to meet her older sister whose developmental disabilities required someone to be with her at all times.

Nick, another iteration 1 participant, lived with his Aunt almost two hours away by bus from the university. The program ended at 6:30pm and his Aunt called me during the first week of the program in a panic because she did not have a safe and reliable way to get him home. She was prepared to pull him from the program if we were unable to find a solution. Luckily, Ronnie another SCSA participant lived close by and offered to take him home after every session. Designing programs with afterschool transportation in mind is an essential component of designing for equity.

*Specific Design Principle: Youth need opportunities to communicate the findings of their research to multiple audiences in authentic and meaningful ways. Hybrid STEM identity artifacts demonstrate the ways that youth identity blooms in designed environments that leverage acting, authoring, and authenticating.*

Informal learning environments have the added benefit of being able to sanction all resources that youth may bring in as affordances for STEM learning. As young people seek to find themselves within STEM contexts, it is also important for them to be able to bring their identities with them (Barton et al., 200x; NRC, 2014). The addition of new ideas and selves has the potential to change to our definitions of what it means to participate in STEM. The young women in this iteration of the program spoke about the fun they had engaging in chemical oceanography and doing science in OST. During the exit interviews youth spoke of their changed reports of their identification with STEM fields and the ways that they were prepared to continue to participate in the future. Not every student wanted to become a scientist but they took ownership of a STEM project and felt that it was an option that was open to them should they choose to pursue it.

*Specific Design Principle: Analyzing and explaining real scientific data help youth build disciplinary understanding and identification as scientists.*

Creating activities for young people that leverage real science data and allow youth to engage in the practices of science is an important design consideration for developers of learning environments. We had to pull together a team with multiple disciplinary expertise to creating this particular activity: learning scientists, chemical oceanographers, and fish biologists. It was important that we brought the right people to the table to build an activity that was scientifically rigorous, connected to the discipline, and allowed youth to engage in scientific practices (Linn et al., 1999). We were lucky to have Eva who was simultaneously our expert in fish biology and chemical oceanography. It was a long process to develop an activity that allowed space for acting, authoring, and authenticating.

*Specific Design Principle: Adults are also learners when they participate in designed environments aimed at broadening participation for youth.*

The graduate mentors who worked with us in COOL cited many learning and growth experiences from the roles they played within COOL. All three of them went on to work in science education related careers. Jesse left her biology lab and went onto a masters in teaching. She is now a science teacher at a local high school. Eva, has gone on to direct a STEM leadership program at a local college that serves 200 students. When this article was written she had an administrative position in the college as the director of student transition programs. Angelica left her botany lab and got her masters in museum studies. When this article was written Angelica was a researcher for a museum evaluation company. There was a strong link between their prior experiences navigating their ways into science and the role they wanted to play as mentors in COOL (Scipio, 2014). This prompted us to turn our attention to the learning and development of mentors in the COOL program.

Researchers have a very important role to play as learning brokers for scientists and youth, as liaisons between stakeholders, and as pedagogical coaches with the charge to help scientists learn to navigate their way into productive relationships with youth that facilitate broadening participation. Researchers also have a lot to learn about creating these kinds of mutually beneficial relational learning environments. Understanding capacity building and collaboration across stakeholder communities in ways that can aid in the design and development of designed learning environments is an important aspect of developing the science of broadening participation.

# Chapter 3. DEEP HANGING: MENTORS LEARNING AND TEACHING IN PRACTICE

Deep Hanging: Mentors learning and teaching in practice

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Abstract

This article is a comparative case study of the experiences of mentors in a chemical oceanography afterschool program. The study explores Deep Hanging—the term one mentor used to describe her experiences learning about the culture of science, scientific research processes, as well as learning she could be- and become- a scientist. Deep Hanging entails authentic tasks in rich contexts, providing access, capitalizing on opportunity, and building interpersonal relationships. Data include reconstructive history interviews with mentors and video of their interactions with youth in the afterschool program. The conceptual framework for this paper explores the ways that constellations of situated events lead to changes in participation in sociomaterial practices over time. Findings suggest that surfacing and exploring mentors' self-position with respect to STEM is crucial to understanding how they will position youth. These findings have implications for the design of learning environments that seek to broaden participation for non-dominant groups in the sciences.

*Keywords:* Deep Hanging, mentors, out-of-school time, STEM

## Deep Hanging: Mentors learning and teaching in practice

Youth from non-dominant communities face barriers to Science, Technology, Engineering, and Mathematics (STEM) learning based upon the ways that they are typically positioned with respect to the domain of science. Postionality with respect to science domains and practices interacts with race, Socio-Economic Status (SES), gender, English language learning, epistemological commitments, family expectations, and cultural repertoires of practice (Bell et al., 2009; Calabrese Barton, Tan, & Rivet, 2008; Czujko, Ivie & Stith, 2008; Hanson, 2007; Lee, 2007; Nasir et al., 2006). Bringing educators and experts together to create rich disciplinary focused learning environments for youth has the potential to broaden youths' pictures of the types of people who can do science (Barab & Hay, 2001; Hsu et al., 2009; Polman & Miller, 2010; Stromholt & Bell, in preparation). These programs operationalize learning in practice by making ways of knowing and doing in the sciences visible to youth and engaging them in contemporary scientific practices.

This paper is a comparative case study focused on the experiences of mentors in a 2011 chemical oceanography out-of-school time (OST) program. This study explores Deep Hanging—the term Eva used to describe her experiences learning about the culture of science, scientific research processes, as well as learning she could be-and become- a scientist. The following research questions guided this work: (a) How does Deep Hanging manifest in the ways that non-dominant scientists tell reconstructive narratives of how they came to be and become scientists? (b) How does Deep Hanging factor into non-dominant scientists' mentoring practices in broadening participation programming for youth?

In the sections that follow, I begin with a discussion of the relevant literature that guides this analysis. Next, I discuss the theoretical frame and elaborate on the cultural learning pathways framework (Bell et al., 2012a) as lens for understanding mentors' experiences learning they could be and become scientists. In the methods section, I include a description of the Chemical Oceanography Outside the Laboratory (COOL) program in greater detail as the designed-learning context for this work. The findings section begins with three cases of mentor learning leading to an exploration of Deep Hanging as a theoretical and analytical construct. Then, I turn to the parallels between the three mentor's experiences with Deep Hanging and their work with youth in the COOL program. Finally, I turn in the discussion section, to the ways that Deep Hanging relates to broadening STEM participation for mentors and youth from non-dominant communities.

## Conceptual Framework

### Learning as participation in social practices

A sociocultural view of learning as participation opens up the opportunity to consider the roles of learners, environments, material and cognitive supports, peers, and adult learning partners (Barron et al., 2009; Engeström, 2000, Dreier, 2009). Defining learning as participation in social practices allows me to consider how agency, identity development, and identification with the domain impact different forms and timescales of participation for learners. Viewing learning as participation builds upon the rich body of research on the affordances of culture in learning (Lee, C., 2007; Nasir et al., 2006; Rogoff, 2003). Using this construct of learning in STEM contexts shows how science learning is deeply cultural (Basu & Calabrese Barton, 2007; Calabrese Barton, 2001; NRC, 2009, 2012).

Critical scholars are working to debunk stereotypical perceptions and deficit-based explanations for lack of non-dominant community member participation. Specifically, scholars continue to argue against perceived lack of preparation to participate in STEM majors (Cjuko, Ivie & Stith, 2008), or imagined lack of family support (Hanson, 2007), and insidious questions about individual engagement (Basu & Calabrese Barton, 2007, Calabrese Barton, 2001). These critical analyses have the potential to reframe the conversation about STEM participation by non-dominant community members. This opens up a space to consider the role of youth-centered learning environments in broadening STEM participation.

Youth-centered learning environments that leverage mentors can offer youth opportunities to think like scientists, engage in authentic practices, negotiate identities, answer personally relevant questions, and learn about disciplinary specific cultural tools (Calabrese Barton, Tan, & Rivet, 2008; Cornelius & Herrenkohl, 2004; Polman & Miller, 2010; Tabak & Baumgartner, 2010). Harré et al. (2009) defined positioning as a triangle of speech acts, storylines, and stances taken together these constructs shape the ways individuals develop within structures of social practice (Dreier, 2009). Positioning theory frames the ways that constellations of interpersonal interactions and social learning facilitate shifts in sociomaterial practices over time (Bell, et al., 2012a).

Theoretically speaking learning as participation allows me to leverage asset-based frameworks that rely upon deepening participation in disciplinary practices overtime such as lines of practice (Azevedo, 2011), cultural learning pathways (Bell et al., 2012a), professional vision (Goodwin, 1994), legitimate peripheral participation (Lave and Wenger, 1991), and apprenticeship (Rogoff, 1990). A focus on asset-based frameworks represents a shift away from deficit-based frameworks that tend to position learners from non-dominant communities in a negative light. A focus on the processes by which mentors and youth from non-dominant communities experience broadening participation programing focuses the attention on ways that individuals and groups are actually learning and developing. This approach to study can help to shape new conceptual spaces for learning and development.

**Broadening Participation as a Programmatic and Scientific Focus**

Broadening participation efforts have been aimed at increasing recruitment and retention in Science, Technology, Engineering, and Mathematics (STEM) for young women, youth of color, English Language Learners (ELLs), people with disabilities, as well as youth from rural and urban communities of poverty. Youth from these groups have been referred to by various names in the scholarship- non-mainstream, marginalized, disengaged, minority, or underrepresented. I choose the term non-dominant (Nasir et al., 2006) because it links to my definition of learning and helps place the focus on the larger societal forces that confer power or dominance to some groups. Learning is a process characterized by deepening participation in sociocultural activities embedded in overlapping communities of practice (Banks et al, 2009; Bell et al., 2012a; Lave & Wenger, 1991; Lee, C., 2007; Rogoff, 2003; Wenger, 1998). Wenger (1998) described learning as deepening participation in a community of practice as both an action (engaging in practices) and a sense of belonging (identity and identification). Communities of practice can include hobby groups, church groups, afterschool activities, drama clubs, sports teams, and other voluntary learning communities. Let us think about practice as "a way of talking about the shared historical and social resources, frameworks and perspectives that sustain mutual engagement in action" (Wenger, 1998, p. 5).

Within the COOL program there were multiple levels of broadening participation. In the undergraduate context, we were working with students with a variety of backgrounds who were being apprenticed into working in informal environments. Within the OST contexts, we were working with youth from groups traditionally underrepresented in the sciences and apprenticing them into authentic STEM practice and the ongoing work of a chemical oceanography laboratory. In the midst of all this work it was essential that we consider the implications of broadening participation programming built within the underrepresentation frame especially as the potential existed for this framing to lead to developing programming with assimilationist leanings.

Bell et al. (2009) argued that broadening participation initiatives based largely on research conducted with White youth, families, and communities would be unlikely to provide solutions for youth from underrepresented groups. Assimilationist perspectives on science equity propose that youth from underrepresented groups lack participation due to lack of access, or interest, or capacity to take up the dominant form of STEM work. Proponents of this stance offer solutions based on giving youth from underrepresented groups access to the same kinds of learning opportunities aimed at increasing participation for youth from dominant groups (Harackiewicz et al., 2012). However, research on African American and Indigenous communities has demonstrated deep cultural expertise and repertories of practice that are well suited to STEM participation—although often under-acknowledged by dominant groups (Bang & Medin, 2010; Basu & Calabrese Barton, 2007; Calabrese Barton, 2001; Hanson, 2007). Everyday science literature builds upon the premise that youth's everyday practices—including argumentation, modeling, asking questions, gathering data—map onto scientific practices in ways that may not be recognized as scientific by teachers or other gatekeepers (Bricker & Bell, 2014; Warren, Ogonowski & Pothier, 2003; Zimmerman, 2012).

Understanding some of the theoretical approaches to broadening participation as a programmatic and scientific focus pushes me to hold the potentially conflicting stances of seeking to bring more participants from non-dominant communities into STEM and pushing on STEM fields to change expectations and definitions of participation. COOL was built on the stance that mentors have a major role to play in broadening participation work.

**Using Mentors to Extended Learning**

Barron et al. (2014) describe the rich and rigorous learning environment that mentors can nurture in collaborative work with youth. Mentors in the digital-youth network (DYN) were expert artists and musicians who worked collaboratively with youth to accomplish personally relevant projects. Barron et al. (2014) defined mentors as “positive role models and guides to help youth access digital tools and build technological fluency” (p. 61). This approach to thinking about the role of mentors in shaping youths’ development and fluency helped to build an instructional theory of action. The DYN instructional theory of action linked mentor’s practices and pedagogical moves to learning outcomes for youth.

They described an active mentor preparation program that developed overtime to ensure that mentors were prepared to meet the unique needs of youth as DYN transitioned into the more formal learning space of a K-12 context. Mentors in the DYN space were creators in their own right. This kind of relationship to the discipline is also typical for mentors in arts-based learning environments (Heath & Smyth, 1999). Learning environments designed to leverage everyday science practices have the potential to make use of mentors in order to incorporate diverse ways of knowing and thus provide space for youth from non-dominant groups to participate in STEM. Yet questions remain about the best ways to help youth establish a link between their everyday science expertise and formal STEM domains. Involving mentors as brokers in these learning environments is one way to address this problem.

The Society for the Advancement of Chicano and Native American Scientists (SACNAS) is an organization built upon the premise that mentors can build educational and professional bridges for young scientists from non-dominant groups. While organizations like Big Brothers/ Big Sisters of America focus on youth development and the socio emotional impacts of long term mentoring, SACNAS goes beyond socio-emotional mentoring to leverage the hybrid space between personal and professional relationships. SACNAS focuses on building networks to catalyze processes that lead to identification with STEM domains, persistence in achieving degrees, and careers for scientists from traditionally underrepresented groups (SACNAS, 2015). SACNAS frames the work they do through the lenses of equity, broadening participation, contemporary work in STEM-related fields, and global competitiveness.

They maintain that a strong domestic STEM workforce must draw on the strengths of all Americans. SACNAS approaches this work by "providing resources, mentoring, motivation and perhaps, most importantly, community" for undergraduates, graduate students, and professionals all along the career pipeline (SACNAS, 2015). SACNAS is an example of an organization that sees the value of sense of community or relationship on creating spaces for professional development, building identities, and identification with STEM domains. SACNAS mentors are also skilled at passing on navigation stories and helping novices learn about the unspoken expectations in STEM learning environments. In the COOL program we called adult participants mentors because we wanted them to see themselves in the role of bringing about these changes in the lives of young people. Mentoring in the COOL OST contexts sought to leverage the expertise of the adult participants as navigators and scientists to help youth learn that they could be and become scientists.

Heath (2012) described intimate strangers as leaders and facilitators in youth and community organizations. These intimate strangers "guided the young people under their charge into understanding concepts related to time, respect for the property and privacy of others, and appreciation for rules and their sources and enforcers (p. 47). Intimate strangers in Heath's study passed on opportunities for new experiences by connecting youth to internships or apprenticeship opportunities in this way, they introduced new lines of practice (Azevedo, 2011) or shared new interests with youth.

**Cultural Learning Pathways**

Harré et al. (2009) defined positioning as a triangle of speech acts, storylines, and stances. Taken together, these constructs shape the ways individuals develop within multiple, intersecting structures of social practice (Dreier, 2009)—for example, those associated with geosciences research, afterschool programming, and early adolescent behavior. The conceptual framework in this paper leverages positioning theory and a sociocultural lens on learning. Positioning theory frames the ways that opportunities for participation in constellations of interpersonal interactions and social learning shift over time during engagement in sociomaterial practices (Bell, et al., 2012a).

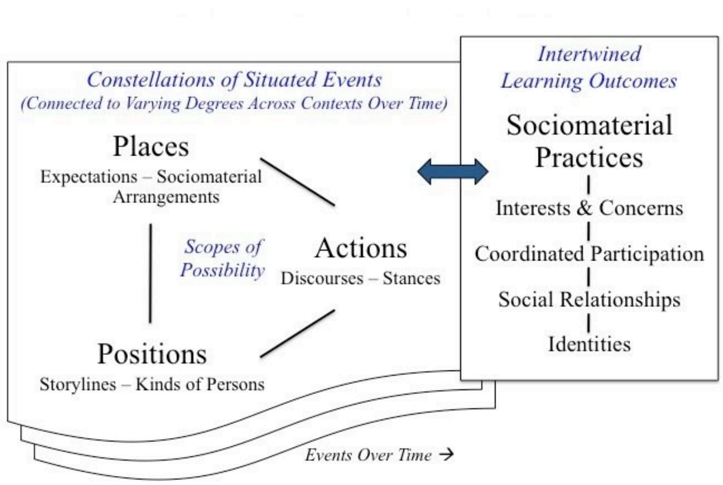


Figure 1. The Cultural Learning Pathways Framework (Bell, Tzou, Bricker, & Baines, 2012)

The cultural learning pathways framework focuses on the constellations of situated events on the left-hand side of Figure 1 above (Bell et al., 2012a). As youth and mentors interact in a learning environment designed to allow for co-constructed moments of coordinated participation in chemical oceanography practices, we can observe the ways that mentors and youth's access to places, positions, and actions shape their scopes of possibility. Specifically, we can observe ways that mentors' moves grant youth access or constrain opportunities for youth to participate in chemical oceanography practices in this out-of-school time (OST) environment.

As youth and mentors in the COOL program interacted in a learning environment designed to allow for co-constructed moments of coordinated participation in chemical oceanography practices, I was able to observe the ways that mentors and youth's access to places, positions, and discourse shaped their scopes of possibility. Specifically, I focused on the parallels between mentors' experiences learning they could be and become scientists and their approaches to broadening participation work with youth in the COOL OST program.

## Methods

### Context

**The COOL program.** The Chemical Oceanography Outside the Lab (COOL) Program is an ongoing collaboration between a Parks and Recreation afterschool space, an oceanography lab, and a Learning Sciences program. COOL is a design-based research (Bell, 2004; The Design-based research collective, 2003) initiative to introduce young women of color to practices of the geosciences through engagement with a six-month chemical oceanography afterschool program. The COOL program echoes and studies extensions of design principles advanced by staff of the Institute for Science and Math Education (http://sciencemathpartnerships.org/) and the Learning in Informal and Formal Environments (LIFE) Center (http://life-slc.org/index.html) and research by the Everyday Science and Technology group (Bell, et al., 2012b).

Designers positioned youth as developing experts and sought to build bridges from youth's everyday knowledge of science and technology to discipline specific modes of inquiry and participation. Designed learning spaces brought youth and experts into collaboration to accomplish projects that had personal, community and disciplinary relevance. We believed a learning ecology built around these commitments would place youth and adults into a robust and productive learning environment likely to enable shifts in youth identification with the domains of science. The theoretical framework used in this paper explores the types of places, actions, and positions that led to changes in youth and mentors' sociomaterial practices (Bell, et al., 2012a).

Sociomaterial practices are social arrangements involving material resources that support particular lines of practice. In the COOL program, we created constellations of social arrangements that included people, materials, and activities to make complex scientific knowledge. We focused on a peer-reviewed paper about fish feminization in the Pacific Northwest (Johnson et al., 2008) and created a mapping activity that would allow youth to collaboratively create a representation of the locations and numbers of feminized fish. Then we overlaid maps that showed population density and wastewater treatment overflows. Once youth participated in building this representation they tended to come to the same conclusions that the scientists did in the discussion section of their paper (Scipio, in preparation). This sociomaterial arrangement of materials, people and activities allowed youth to participate in data analysis and think in ways that scientists did about their data.

**Middle school contexts.** COOL collaborated with Marble, a middle school with a rich tradition of youth programming in the out-of-school time (OST) space. The collaboration allowed us to leverage existing OST infrastructure like, snack, afterschool transportation, and classroom space. Marble had a dedicated staff person who administered the OST and ran additional enrichment programming through the school's community learning center. The OST sessions ran concurrent with the middle school's semesters. In the Spring OST time ran from 2:30- 4:30 daily and took place from August 2010 through June 2011.

**Participants**

Three professional scientists participated in the program as mentors to youth (see Table 1 below). These mentors were all women from groups traditionally underrepresented in the sciences. They were in the process of or had already attained graduate degrees in the sciences. There were fourteen female participants from sixth and eighth grades in the afterschool program (eight African-American, two White, one Filipina, one Asian-American, two Latina).

Table 1. COOL Program Mentor Backgrounds and Affiliations

| **Mentor** | **Ethnic Affiliations** | **Educational Background** | **Current Position** |
|---|---|---|---|
| Eva | German & Latina | MS in Aquatic and Fisheries Sciences | Student and enrollment services director at local university, Director of a STEM enrichment program |
| Jesse | Diné, Hopi & Ute | MS in Molecular & Cellular Biology- Developmental Biology; MIT Secondary Education | Upward bound student services educator for local community college |
| Angelica | Bolivian American | MS in Botany; MA Museology | Research Analyst at Museum Consulting firm |

The description of participants would not be complete without a description of my own positionality with respect to this project. As an Afro-Caribbean woman, I had many things in common with the largely African-American eighth-grade COOL participants, as we were all members of the African Diaspora. Yet, as an Afro-Caribbean woman and an adult I was not a full community member able to leverage in-group language, references, or certain shared repertoires of practice with the youth participants.

Within the COOL program, I was a full participant observer. I co-taught and co-designed the curriculum. During COOL sessions, I often took on the role of lead instructor. With the mentors in the program my role was that of pedagogical mentor and guide into the world of science education. Eva, Jesse, Angelica and I spent many hours debriefing the program sessions. We would talk about individual youth's developmental learning trajectories, flow of lessons, youth development, and pedagogical moves. Eva and Jesse have both gone onto science teaching roles in the local community and I have continued my role as pedagogical mentor and learning scientist. This largely entails fielding questions about problems of teaching practice, approaches to teaching STEM content, and youth development work.

Outside of COOL sessions, I coordinated the program, liaised with mentors, school administrators, teachers, parents, and family members. I organized field trips, managed supplies, made calls to collaborators, and facilitated the successful completion of the COOL program from end to end. These positions gave me a unique perspective on the program activities and an intimate relationship with youth and mentors that had a positive impact on the interviews, my perspective on COOL sessions, and my analysis of program data.

**Data and Analytical Approach**

The data used in this analysis were collected over a nine-month period in 2011 during the second year of the COOL program (see Table 2 below). Data sources for the analysis in this paper included field notes of mentor and student interactions, and 1.5 hours of interviews with youth and adult mentors. The entire data corpus includes over 33 hours of video, field notes for each program session, mentor and youth written reflections, and 6 hours of interviews. The interviews chosen for this analysis were the reconstructive history interviews with mentors conducted at the beginning of the COOL program in fall 2010.

Table 2. Participants, Amount, and Type of Data Collected

| Data Type | Amount | Participants |
|---|---|---|
| Video of OST Program sessions | 28 sessions (~ 56hours of video) | Eva, Jesse, Angelica, Researchers and 14 youth. |
| Semi-structured Interviews | 3 reconstructive history (6 hours)<br>2 practice-focused (3 hours) | Eva, Jesse, Angelica<br>Eva & Jesse |
| Mentor Generated Reflections | 7 post-program | Eva, Jesse, Angelica |
| Fieldnotes & Analytical memos | Multiple per session | Eva, Jesse, Angelica and 14 youth |

Table 2 highlights the specific data used for this analysis. My goal here is to understand the similarities between mentors' individual experiences learning they could be and become scientists by presenting and analyzing their experiences through reconstructive history interviews. Reconstructive history interviews were administered in the middle of the program (2010) and intended to surface mentors' prior experiences learning they could be and become scientists. Interview questions included the following types of questions (a) tell me a little about your background; (b) how did you get to where you are now?; and (c) is there a particular person or event that caused you to become interested in science? Each reconstructive history interview was transcribed and coded using a grounded theory approach (Merriam, 2009).

All interviews were transcribed and analyzed using a hybrid of emergent coding and codes built using the cultural learning pathway framework (Bell et al., 2012a). This analysis surfaced a mentor generated analytical construct called Deep Hanging. Over the course of grounded theory analysis (Merriam, 2009), I developed Deep Hanging as an analytical construct for understanding the ways that professional scientist mentors positioned both themselves and youth in the COOL program with respect to science: as an enterprise and as a set of practices.

Fieldnotes and video of the OST sessions were used to explore mentors' work with youth in the OST program. Videos were content logged and coupled with fieldnotes taken during and after program sessions to identify patterns of behavior considered characteristics of mentors' practices in the OST sessions. Once a Deep Hanging profile had been built for each mentor, I returned to the video of mentor and youth interactions from the afterschool program sites and coded for ways that mentors positioned youth through stances, sociomaterial arrangements, and actions (Bell et al., 2012a). I also leveraged possible future selves (Markus & Nurius, 1986) as a way of linking mentors' past experiences with ways that they envisioned themselves working with youth and the ways they were able to see themselves as people who could be and become scientists through their Deep Hanging experiences. The analysis surfaced places, actions, youth, and mentor positions related to STEM practices as they related to mentor's cultural learning pathways (Bell et al., 2012a). Finally, mentors' reflections and interviews were used to illuminate patterns in their approaches, rationales, and goals with respect to broadening participation for youth in STEM.

## Findings

My focus in this article is on describing and developing Deep Hanging as a theoretical and analytical construct. To accomplish this, the first section of the findings is a comparative case study of three mentors' experiences realizing that they could be and become scientists, followed by a section on Deep Hanging as an empirical phenomenon. Then, in the next section I turn my attention to the ways that mentors worked with youth in the COOL OST program. I use illustrative examples from each mentor's practices in the OST program to highlight the parallels between mentors' approaches to working with youth and their own Deep Hanging experiences. Two claims about Deep Hanging emerge from this work (a) Mentors had similar experiences learning that they could be and become scientists i.e. Deep Hanging and (b) Parallels existed between mentors' Deep Hanging experiences and their individual approaches to engaging in broadening participation work with youth in COOL OST.

**Becoming scientists: Personal narratives**

**Eva.** Eva self-identified as a woman of mixed German and Latina descent. She lived in Chicago until she was eight and moved to the Pacific Northwest with her family. She was eight when she saw the ocean for the first time but she fell in love with aquatic sciences at an even earlier age, when she saw *Fantasia* for the first time she vividly recalled the scene in the beginning with all the sea creatures.

Eva was the first person in her family to get a college degree and to become a credentialed scientist. When Eva graduated from her undergraduate degree with a degree in biology she went to work for a cancer research laboratory as a lab technician. She really enjoyed her time there and was a valued member of the research team. After she has been working at the lab for a while, Eva met with the Principal Investigator (PI) of the lab where she worked and Eva really realized that she could be and become a graduate student and scientist during her time at the cancer research center. The PI told Eva that she was doing a good job as a technician and that she could continue to engage as she had been or she could do something more.

Her family always supported her interest in science, “my mom and dad just encouraged that interest.” (10/15/10). Although she always had interpersonal support, at times her parents did not understand her, “I think if you family is educated it’s easier for you to navigate into that space. If your family is educated its easier to navigate into that space of becoming a scientist” (05/01/11). Eva mentioned two interconnected components to this ease of navigation (a) familial relationships that helped to facilitate access to gaining lab experience and (b) shared experiences that helped your family understand why graduate school is a good fit for your professional trajectory. These two components rely upon interpersonal relationships and the ways that they facilitate opportunities to engage in science as a career.

In her STEM career and in the work she did in COOL Eva was a builder of community, a resource provider, and a network connector. She believed in firmly in the power of relationships to offer new avenues to participation and to shape opportunities for youth and for her peers. Even before she started her Master in Science, Eva was motivated to start a chapter of the Society for Chicano and Native American Scientists (SACNAS) at her prospective university:

> "As I progressed through education I became more and more aware of how fewer and fewer of my peers looked like me or had a similar background so before I started graduate school I got involved in starting a SACNAS chapter on the campus here" (10/15/10).

Eva knew what kind of community she wanted to participate in as a graduate student and researcher in a science laboratory and took steps to build the community she wanted to have. Here, Eva's words demonstrate a desire to take agentive steps to make a community that would meet her needs as a person navigating multiple identities during her graduate school career. She wanted to make sure that she could connect to a peer group that would support her as she continued to develop her scientific self.

Project COOL was not Eva's first foray into work in education. "I didn't really realize I could do science and teaching and mentorship, like really authentic and deeply engaged mentorship until I had had a year of experience as a GK12 fellow" (10/15/10). Eva's GK12 fellowship was a National Science Foundation sponsored program for STEM graduate students aimed at providing additional training. She used her GK12 teaching fellowship to gain more classroom teaching experience. She worked closely with a high school teacher during her fellowship and viewed it as "an opportunity to build more tools." Eva was particularly interested in becoming an effective educator so that she could operationalize her passion for giving back to her community.

As a woman, a person of color, and a first generation college student Eva was a member of three non-dominant communities historically underrepresented in STEM. She had a great desire to build community, support her peers and prospective scientists, and to share her strategies for navigating into STEM research spaces. In her role as a research technician, it was difficult for Eva to see herself as the type of person who could go to graduate school for science. Eva attributed some of this difficulty to the perceptions of her extended family. They viewed leaving her position to go to graduate school as an unnecessary risk. They viewed her position in the lab as “the definition of success” because she already “had a 401K, I had medical benefits, I was doing research.” Her extended family didn’t understand her desire to “walk away from that and get more training” (05/01/11).

During the follow up interview she joked about things she had heard from her extended community. Comments like “haven’t you been in school long enough,” and “why would you do that?” were typical responses to saying that you were planning to go to graduate school. Since she was already considered successful, the idea of putting that aside to get more training made no sense to Eva’s family. She contrasted that what with the experience of some of her peers in graduate school where the familial expectations were different.

> “I think if the family expectation is that going to graduate school is the norm, i.e. having that expectation that of course you’re going to go to graduate school, of course you’re going to get your PhD, of course that’s a normal course of action. Which is very different from my experience which is “what? You’re going to do to graduate school? Why would you do that?” (05/01/11)

In the above quote, Eva was describing two different developmental trajectories: (a) the experience of individuals who gain their desire to go to graduate school from family expectations (b) people whose desire to go to graduate school goes against familial expectations. Though she started off as someone whose experiences placed her in the 2nd group, she reached the same goal- attending graduate school. Eva needed support to step outside of this picture of success and become the type of person who would go to graduate school in the sciences. Eva began to get a picture of the things she could do and the things she could accomplish by going to gradate school. Through prolonged authentic engagement in the practices of a science laboratory, working alongside graduate students and post docs as colleagues, she began to change her picture of the type of person she could be and become.

Eva ascribed the change in her sense of who she could become to her mentor, the woman who was her boss in her first post-undergraduate position. Although she had been hired as a laboratory technician, Eva's mentor gave her the choice to make the job a nine to five position or to be integrated into the full and complex practices of the lab.

> "My mentor was incredible. She gave me the freedom to choose, let me know these options were available, and because I like challenges and I enjoy learning new things I said, 'well of course I want the second one.' I had all of these amazing opportunities because of that. (05/01/11)

In the above quote, Eva's words foregrounded the affordances, value, and opportunities she gained through the interpersonal relationship with her mentor. While her mentor provided access, Eva jumped at the chance to benefit from the full engagement with complex science practice that was made available.

Eva considered the time that she spent with graduate students and post-docs who were working in the lab at the same time particularly instrumental in her decision to go to graduate school. Thanks to the intersession of her mentor, Eva spent a lot of time with a group of people who were making the choice to pursue graduate STEM degrees. She worked with graduate students and post-docs on projects, went on research trips, and got to know them as individuals. In the follow up interview on practice, Eva mentioned that these experiences gave her “an opportunity to get to know them, to understand why they were in graduate school. What they were doing and to see what that process was like.” Again Eva did not dwell on the things she learned during her years in the laboratory but the focus was on the interpersonal connections i.e. the relationships that she built. It was through these interpersonal relationships that the prospect of going to graduate school became a possibility. Through “deep hanging” with graduate students and postdocs, Eva became the type of person who could see that going to graduate school made sense. “I hung out in that space for four years so I really had an opportunity to see what graduate school was, what could I get out of it, and did this make sense for me” (10/15/10). By spending time with the graduate students talking about science content, what she could expect as a graduate student, and relying upon information gleaned from people she had come to trust through interpersonal relationships Eva was able to determine if graduate school would “make sense for her.” Figuring out whether going to graduate school would “make sense” was wrapped up in Eva’s ability to see herself as the type of person who could go to graduate school.

I first met Eva when she came to volunteer at one of our first year COOL sessions. Eva was conducting her research in a fisheries lab on three spine stickle back fish. Her work consisted of studying the effects of endocrine disrupting compounds (EDCs) on fish embryonic development. She was exposing fish eggs and embryos to different levels of endocrine disrupting compounds at various stages of development. This project aligned perfectly with questions that we were exploring with the first year COOL apprentices about EDCs on local riverine and marine ecosystems. She volunteered to come in and speak with the youth in our program about EDCs and share a little bit about her experiences navigating into a M.S. Program in Aquatic and Fisheries sciences. Eva connected to the ways that COOL sought to serve youth from non-dominant groups that were historically underrepresented in the sciences.

The theme of giving back was a leading edge of work for Eva, "through SACNAS and through building this community with graduate students it's really powerful and important to me to give back to my community and open up more educational opportunities" (10/15/10). Eva spoke about the ways that getting a degree in STEM fields could potentially feel very isolating and selfish especially for people who considered community responsibility and giving back as part of the work they need to do in the world. Eva identified finding a way to give back as a coping mechanism for her and other mentors in the program "because getting through a science degree is really difficult and I think one of the things the [SCANAS] chapter has provided on campus is a sense of community and part of that community is doing outreach" (10/15/10).

Eva was committed to giving back to her community, building relationships, engaging in authentic scientific practices, and helping others—both youth and mentors, navigate their own personally relevant trajectories into STEM fields.

**Jesse.** Jesse grew up on a Navajo reservation. She described herself as Diné, Ute, and Hopi. She reported always having an interest in science and math. During her reconstructive history interview she spoke about experiences going back to third grade where she felt like she was encouraged to "find the science" in news stories. Her third grade teacher would read them an article from a magazine or the news paper and "we would have to try to define exactly what context of science as there so it was kind of a way to like let us see the various aspects of how science is applied" (10/15/10). She identified junior high as the place where she first thought about having a career in science. Her math teacher connected her to a summer program and took the time to explain the benefits of the program to Jesse's parents.

Jesse was successful in high school and excelled in her science classes. She described herself as driven. Conducting research made Jesse feel as sense of pride because she liked "doing something no one had done before and kind of being the first of a culture to actually be successful in research" (10/15/10). When she got to graduate school she encountered a "steep learning curve" and had negative experiences in her first research laboratory. Jesse was reluctant to describe these experiences in detail but she did speak about the steps she took to mitigate them. She reached out to get help from two sets of mentors in her life—her brother and her undergraduate research mentor.

Jesse's older brother was the first person in their family to go to college and then onto a graduate degree in electrical engineering. He had been a resource for her all the way through her education, helping her apply to college and to navigate tensions as a first generation scholar and as an Indigenous scientist. He helped her answer the questions that her experience raised for her like: "what's going on? What do I do? Is this right? Am I normal? Should I believe what my PI is telling me?" Her brother built up her confidence and sent her to seek confirmation from her undergraduate research advisor. Jesse's undergraduate advisor said, " 'you know he's wrong, it's just a really bad situation and you need to get out' " (10/15/10). Jesse took his advice and changed labs with her sense of herself as a scientist and researcher intact "I love research, I miss it actually and I don't doubt that I probably be doing it again" (10/15/10).

I met Jesse after she had already made the decision to leave her research science degree behind and go back to one of her first loves—teaching science. At the time that she began the program she was in the process of applying for a masters in teaching and COOL was a context where she could learn more about teaching science. “I had always said I wanted to be a teacher, even as a kid and it was my parents who were like ‘you know that doesn’t pay well, it’s’ not going to be very rewarding, you should try this (science)” (10/15/10). It was only after she had a similarly negative experience in a new laboratory that she began asking questions about who she wanted to be, what kind of work she wanted to do, and how she wanted to contribute to her community. This series of questions led her back to teaching. She came to COOL seeking the time to develop pedagogical strategies and to help youth see that they could do science if they wanted to. COOL was not her only teaching experience. As a member of the SCANAS chapter, Jesse was participating in tutoring for youth from non-dominant communities in a long-term partnership between SACNAS and a local youth-serving community-based organization.

Taken together these vignettes highlight the way that Jesse felt she did not make an actual decision to apply to graduate school. Rather, she felt that she had played to her strengths in science and allowed herself to be swept along from a science-focused undergraduate degree, to conducting research as an undergraduate, and into applying for a PhD program at a research-focused university. These experiences may have led to Jesse’s nuanced approach to broadening participation. She wanted youth to make agentive decisions about their own STEM participation trajectories. She wanted “them to realize ‘hey I don’t like science, I can do science but it’s not something I want” (10/15/10). Inherent in this quote is a new trajectory than Jesse felt described her experiences in STEM. She wanted youth to make decisions about what their next steps would be based upon knowledge of their strengths but also of their interests.

Jesse's experiences also foreground navigation and the role of a mentor as a guide and sounding board when dealing with identity threats in STEM context. After her experiences in the research laboratories, Jesse was left with a series of questions that demonstrated she was experiencing attacks to her sense of self and ability to participate, "what's going on? What do I do? Is this right? Am I normal? Should I believe what my PI is telling me?" She reached to her mentors and support system to help her truth the narrative that was being told about her intelligence and her ability to participate in STEM research contexts. Also visible in the series of questions is a plea for help navigating an identity threat experience. Jesse reached out to her brother and her undergraduate mentor to help answer the questions about her identity but also to help her learn how to navigate the situation.

**Angelica.** Angelica really liked learning about animals and plants when she was a kid. She self identified as Bolivian American. She described an experience when she was in second grade where her teacher's sister brought in snakes and reptiles for the class to engage with. She was fascinated, "I loved it. I loved it, I couldn't wait to touch the snakes" (10/15/10). Similar to Eva and Jesse, Angelica also expressed an early interest in science. Angelica loved biology, ecosystems, and wanted to know more about the impact that people could have on the environment. She remembered pouring over National Geographic magazines and collecting endangered species cards from chocolate bars.

Angelica described herself as a very shy person. She went to an all female high school because she thought it would be an environment where she could be more herself and where she "could learn and be comfortable with speaking out more" (10/15/10). She got her undergraduate at a private liberal arts college in California. When Angelica was an undergraduate one of

Ecology professors invited her to do research in her lab. Her experiences with this professor helped Angelica to see that she could become a scientist.

> "She was great, she was just really fantastic, she would give me papers to read and we would talk about them. It was so comfortable. She was great in helping me figure out what to do next, just talking to me. I think that just the fact of being very comfortable and being able to tell her this is kind of what I've been thinking, just the mentoring" (10/15/10).

This experience of comfort had a big impact on Angelica. As a very shy person she felt that having an advisor and an advocate who would listen to her ideas was central to her developing understanding of herself as a scientist. She spoke of other students in her program who left science, "because they didn't have a good experience with their professors or because they felt for some reason, they were very smart, but for some reason they felt that they weren't smart enough and they switched" (10/15/10). Here Angelica's words differentiated these experiences of people leaving science from her own. She knew that these other students were as smart as she was. Smartness was not the reason that people left or stayed in science majors. "There were a lot of positive experiences that I had and it made me feel like I wanted to continue and I want to belong in that field as a teacher. Sometimes it just takes more than a personal interest in the subject" (10/15/10). Rather Angelica noted that comfort and a sense of belonging mattered, potentially more than smartness, to developing the sense that you could succeed in the sciences.

I met Angelica when she was making the decision to transition away from her research science degree in biology to a master of museum studies. Similar to Jesse, Angelica also had negative experiences in her research group. Her research with plants necessitated a long-term investment of time and capital. As a researcher she found that the only findings supported within her department were findings that could be published. Her experiment was labeled a failure not because her results were indistinct but because her advisor did not deem them publishable even though "it's good information to know and it's valuable to the science I'm going, it's not the kind of information that can be put into a journal" (10/15/10). Thus, Angelica's science was called into question not for the intrinsic value of the information but because it was not deemed a contribution worthy of publication.

As a graduate student, Angelica sought out a community on campus where she could feel comfortable. She found SACNAS. "I went to the meeting and I liked the group of people that attended the meeting, but I also believed in their mission because it resonated with my experiences" (10/15/10). Angelica's experiences learning that she could be a science participant were connected to her own experiences of navigating multiple identities, finding a way to feel comfortable doing science, and connecting to a community of like minded people when she got to her higher education context.

**Becoming scientists: Interconnected narratives.**

All three women were members of the local chapter of the Society for the Advancement of Chicano and Native American Scientists (SACNAS). SACNAS is a national social and academic organization that brings scientists at all stages of career development together to build supportive communities for non-dominant groups. SACNAS believes in the power of developing social relationships that facilitate scientific learning. SACNAS gatherings in member's homes included food, music, and professional relationships blended into friendships. Other SACNAS gatherings at the university were often focused on individual members presenting their work or guest speakers sharing research findings or strategies with the group. Although SACNAS members came from a wide variety of backgrounds and research disciplines, there was a sense of conviviality and support for the struggle to hold multiple identities simultaneously.

Eva, Angelica, and Jesse were friends and colleagues before they came to the COOL program. It was actually Eva's relationship with Jesse and Angelica that helped us recruit them as mentors. She hosted our first meeting with Jesse and Angelica who were SACNAS members and our prospective COOL mentors in her living room. She saw COOL as a way to facilitate multiple learning opportunities for youth by connecting them to professional scientists and for the SACNAS mentors by creating a space for mentors to find a way to give back.

Prior to their work in COOL they had all worked together to plan conferences, to organize social events, to do outreach in the community. They celebrated life events together, hosted dance and dinner parties. At the same time, they worked together as colleagues in science spaces.

The mentors in the COOL program were not passive drips falling out of the STEM pipeline. They were agentive decision makers who chose to step away from the bench to bring youth into the practices of STEM education by sharing their navigation stories, along with their professional and disciplinary expertise. Their goals were to make the complex practices of science visible and accessible to youth from groups traditionally underrepresented in the sciences. By sharing their own journeys into science careers along with lessons learned along the way, the COOL mentors shared more than the master-novice relationship with youth in the program. The COOL mentors were pushing for the youth to have had enough experience with STEM practices and identities to make an informed decision about what they wanted out of their own interactions with STEM. Their stance echoes a more expansive version of STEM literacy advanced by Noah Feinstein (2009, 2010), Joseph Polman et al., (2012), and the committee who developed the NRC Framework (NRC, 2012) suggest that STEM literacy needs to be functional in the lives of students as community members and individuals making decisions that have impacts on their health, communities, and career trajectories.

**Deep Hanging as a common experience across the cases.**

In the following section, I will highlight the common themes that exist across mentor cases and make an argument for Deep Hanging as a finding of this study, a theoretical phenomenon that mediated mentors approaches to working with youth in broadening participation programs.

Deep Hanging was Eva's term. She used it to describe her learning experiences, the ways that she was brought into science, and came to recognize that she could be- and -become a scientist. She referred to the research cycle—i.e. the things that scientists do to complete a research project—in her description of her learning process. Eva maintained that while your advisor should facilitate this process it is actually through the interaction with peers and "just being part of it" that people learn complex scientific practices. Eva was describing a process of learning in practice. The following quote is Eva's response to a question about how people learn complex science practices.

> I think part of it is the "deep hanging" that you do. Ideally, it should be through the mentorship of your advisor…Your peers are going through the process, you're discussing things…So being able to understand where you fit within that cycle, I think comes from just being part of it. I think a lot of it is the socialization that happens (05/01/11).

Eva described a socialization process that does not happen through direct instruction from a single more competent other—from your advisor but it actually came from "just being a part of it." Learning to be and become a scientist happened in practice with peers and through work with colleagues. As a research scientist, Eva participated in the cultural practices of science within her lab and used science to make sense of the world.

Deep Hanging as Eva described it was a process that helped change her sense of who she could be and become. I will use Deep Hanging going forward to explore the STEM induction experiences of mentors in the 2011 COOL cohort. This construct has four interconnected characteristics as Eva described them: Deep Hanging entails:

1) Authentic tasks in rich contexts,

2) Direct access and engagement with novel practices,

3) Leveraging interpersonal relationships to facilitate participation, and

4) Interpersonal relationships that encourage deepening identification with the discipline.

I will unpack each Deep Hanging in the following sections and add complexity to the character tics with data from the three mentor cases. In the following sections, I will continue to define Deep Hanging and demonstrate how it applies to all three cases as a theoretical framework.

**Authentic Tasks in rich contexts.** Lave & Wenger's (1991) Legitimate Peripheral Participation (LPP) might seem like an explanatory framework that could encompass Deep Hanging. Similar to LPP, DH entails having a purposeful activity within an ongoing complex, expert practice. Eva was a technician in a local research laboratory and this role meant that she was engaged in purposeful activity during her interactions in the lab. However, there are a few key differences between LPP and Deep Hanging. Deep Hanging foregrounds the agency of participants, creates spaces for alternative pathways to successful participation in disciplinary communities, and foregrounds interpersonal relationships as means of broadening participation.

LPP focuses on the ways that novices join and come to participate in complex practices of specific social domains. Whereas Deep Hanging adds a focus on the ways that people's experiences in one community of practice (e.g., a STEM field) influence their participation in other linked communities of practice (e.g., STEM education). Eva, Jesse, and Angelica all found ways to navigate into the practices of science in their varied communities of practice and then took that knowledge into new contexts as scientists and mentors—and develop expertise associated with the new community of practice.

LPP and Deep Hanging align as well when considering the ways that multiple participants engage in and help foster novice learning as opposed to dyadic forms of apprenticeship learning (Lave & Wenger, 2001). LPP and Deep Hanging context are composed of learning networks of learners at different levels of participation. Eva, Jesse, and Angelica learned from post-doctoral scholars, graduate students, and technicians in addition to their PIs or mentoring scientists.

The "Pipeline" metaphor is an often used to describe the desired outcomes for broadening participation programs. Blickenstaff's 2005 literature review describes the reasons that the pipeline intended to carry people from an interest in STEM through high school, college, and into a STEM career disproportionately leaks women at multiple points. Given this framing, interventions would aim to plug the "Pipeline" in such as way as to allow women to stay in the pipeline all the way into careers in STEM disciplines. This framing suggests that people who leave bench science to pursue other STEM related career paths (education, communication, or policy) have fallen out of the "leaky" pipeline. By this metric, none of the mentors who participated in the 2011 COOL Cohort would have been qualified to mentor youth because they did not reach the center of STEM practice. I reject this framing of the COOL mentors because they were each negotiating new spaces for continued and broadened participation in STEM fields. Jesse, Angelica, and Eva had mentors who provided direct access to novel practices. The nature of the practices as well as the contexts in which they happened impacted the ways that

Eva, Angelica, and Jesse were positioned as authentic participants in scientific practices. The other piece of this as a learning experience was agency for them as participants. Angelica was invited to work in her ecology professor's lab, Eva was invited to participate in lab meetings, Jesse was invited to participate in undergraduate research and they each made a choice to participate in a new space. Taking that step towards agentive participation shaped their opportunities in these new learning spaces. Angelica spent time reading articles with her mentor in a context where she felt comfortable and encouraged to ask questions and develop new skills. Eva was invited to participate in lab meetings and join the full practice that was taking place in her research lab above and beyond her role as a scientist. Jesse worked with an undergraduate professor to conduct research and moved straight from her undergraduate degree into a doctoral program conducting rigorous research in laboratories all along the way.

**Direct access and engagement with novel practices.** As a research scientist, Eva participated in the cultural practices of science within her lab and used science to make sense of the world. The question of where you can fit into the culture of science was a recurring theme in interviews with other mentors and related directly to the ways they positioned themselves with respect to science. Eva acknowledged that the professional definition of science was not made accessible to everyone. "When we say science it has the Western academy picture behind it but that is not the only way of knowing or doing that helps us make sense of the world" (05/01/11). Eva believed that being able to see yourself as the type of person who can do science was key to the actual practice of doing science, and she is not alone; Herrenkohl & Mertl (2011) also described learning as a process that entailed knowing, doing, and being. Eva's words challenge us to recognize that knowing and doing are not the only important aspects of becoming a scientist.

Each mentor was navigating multiple identities as they learned they could become scientists. Jesse was navigating multiple roles and identities in her life as a daughter, a scientist, and a Native American woman,

> "Being able to identify with someone of your minority or ethnic background is even more important, it's something I never had, even now. It was difficult to find someone of Native American background and values in terms of family and cultures that were separated and taken away from that but still functioned in academia" (3/4/11).

Jesse was seeking someone to serve as her academic advisor who could help her navigate all these identities. She was looking for a role model that could help her understand how to be all of these things at the same time. She was looking for someone to help her explain her new reality to her family "you can imagine and show your family, here's this other possibility that's realistic for me and here's proof, this person who comes from a similar culture" (3/4/11). Jesse's desire to imagine a new possible self (Markus & Nurius, 1986) is a quest for someone to help her navigate her multiple identities.

The mentors in our program had their own complicated relationships with science. Mentors described the effects of the black box on their self-positioning with respect to science and the sense of responsibility they felt to their communities. Eva described science as a selfish proposition and one that caused culture clash "often in academic science, it's a very selfish endeavor that really goes against the grain…that's not the values we were raised with so you know there's lots of culture clash when you to get to academia" (Eva, 2010). Here Eva was discussing the ways that she found it difficult to reconcile her identities as an agent of change for her community and as a bench scientist.

When Eva described the time she spent alone in her laboratory as selfish she meant that she was spending time working towards findings many of which she felt would only serve her personal goals rather than ameliorating the experiences of people in her community. Eva felt disconnected from her community while pursing a degree where she studied fish in a laboratory and her career goals was publication, as opposed to an applied science where she could follow her passion for science and serve her community simultaneously. Eva was trying to learn how to navigate her multiple identities as a community member, a daughter, and as a scientist.

**Leveraging interpersonal relationships to facilitate participation.** Interpersonal relationships served multiple purposes in Eva, Angelica, and Jesse's Deep Hanging experiences. They helped to deepen participation, build community, and increase identification with the domain. Additionally, relationships helped to sustain Jesse's sense of self in the face of negative experiences such as her advisor questioning her ability to engage in science.

***Relationships that deepened participation.*** Eva described this aspect of relational learning when she said, "we're hanging out in the lab. We're going out into the field into ridiculous marshy conditions to collect fish." Here relationships helped to create opportunities for deepening participation. The interpersonal relationships functioned as an entry point to rigorous science practices. Even though Eva was a technician, she was invited to go into the field with the graduate students and postdoctoral scholars. Angelica and Eva had mentors who provided direct access to novel practices. These practices were rigorous and as participants, Eva and Angelica had authentic roles to play as participants. The relationships served as the entry points however, they both made agentive choices to engage in those practices with their mentors. Angelica spent time reading articles with her mentor in a context where she felt comfortable and was encouraged to ask questions while she was developing new skills. Eva was invited to participate in lab meetings and join the full practice that was taking place in her research lab above and beyond her role as a technician.

***Relationships that built community.*** **Eva, Angelica, and Jesse's friendship** blended the interpersonal and professional spaces. This hybridity characterized not only their individual Deep Hanging experiences but also the community they built together at the university and with youth in the COOL program. As individuals each mentor built relationships with the youth in the program but it was also important for the youth participants to see the strong relationships between these three women Eva articulated it well when she said,

> We express a strong sense of community, that helps the girls see, it gives more opportunity for the girls to potentially see themselves to self identify with us. If we come from a diverse set of backgrounds, we're not all, if they see variety in who we are, in our backgrounds in the kinds of science we do, in the kinds of things we enjoy and that we all work together it illustrates that there is a place for them even if they don't reflect what they see science as (05/01/11).

Eva recognized that her relationship with Jesse and Angelica was a resource for the work she wanted to do with the youth in the program. They knew one another well and it translated into their ease with one another in the program. Their laughter and comfort with one another was an additional support system for the youth in the program. It modeled a community of women participating in science practices and creating community that supported the work they were doing together. This was most apparent in the down time, when Eva, Jesse, and Angelica interacted with youth in the cafeteria before the program, on field trips, and when they were playing games during the COOL OST program. Eva recognized the value of their different backgrounds and even approaches to STEM work as they stepped in the role of mentors to young women from non-dominant communities.

***Relationships that increased identification with the discipline.*** For Eva, Jessee and Angelica, relationships with scientists helped to shape their ideas of who they could be- and become. Eva got to know the scientist in her lab while they were working together on purposeful project; “there was that interpersonal space being brought into your professional setting. I really got to know them and to understand why they were in graduate school” (01/05/11). Their senses of their possible future selves (Markus & Nurius, 1986) were expanded thanks to their relationships with more experienced scientists because they got to know them as people.

Eva, Jesse, and Angelica’s narratives each highlight the ways that relationships facilitated the development of their scientific identities. Relationships with scientists helped to shape their ideas of who they could be- and become. Eva got to know the scientists in her lab while they were working together on purposeful project; “there was that interpersonal space being brought into your professional setting. I really got to know them and to understand why they were in graduate school” (05/01/11). Developing relationships with people who were already scientists helped Eva to see them as people. This in turn helped her to understand how she could become a scientist as well. Eva’s relationship with the graduate students, post doctoral researchers, and research scientists in the lab while she was a technician helped to develop her sense of a possible future science self (Markus & Nurius, 1986). Angelica and Jesse had similar experiences that expanded their ideas of who they could become thanks to their relationships with more experienced scientists.

***Relationships that sustained sense of self.*** Interpersonal relationships served an additional purpose in Jesse’s experience. She had a research advisor who gave her opportunities to conduct research as an undergraduate but it was later in her narrative when the interpersonal relationships with her brother and her undergraduate research advisor helped her to maintain her sense of self. Jesse's ability to be a scientist was under attack from the PI in first lab she worked in at the university. His constant questions and critique of her work made her ask, "Is this right? Am I normal? Should I believe what my PI is telling me?" Thanks to her relationship with her brother and her undergraduate research advisor Jesse did not have to answer these questions alone. She was able to work with them to "build back up [her] confidence" (10/15/10). They shared their own perceptions of her and her work as a counterpoint to the abuse she was receiving from her PI. Jesse left the lab and described this not as a personal failure but rather, as a broken relationship with the PI and as a "personality clash." Interpersonal relationships with her brother and undergraduate research advisor protected and sustained Jesse's sense of herself as a scientist and participant in the enterprise of science in the face of direct conflicting narrative of her participation from someone in a position of power.

In the next section, I turn my attention Deep Hanging as it related to Eva, Jesse, and Angelica's mentoring practices with youth in the COOL program. Their practices paralleled aspects of their own experiences learning they could become scientists. I will begin with short vignettes describing an illustrative moment of each mentor's practice with youth. Each moment of practice highlights one of the ways that mentors positioned or engaged with youth in the COOL program with respect to science. Next I will discuss the ways that these vignettes demonstrate parallels between each mentor's Deep Hanging experience and the ways that they worked to broaden participation for youth in the COOL OST program.

**Mentors Deep Hanging with youth**

As mentors in the COOL OST program, Eva, Angelica, and Jesse worked with two cohorts of youth participants for nine months. Eva spent the most time in the OST space as a liaison from Sound Citizen—our collaborating laboratory on campus, a curriculum designer, and a co-teacher. Jesse and Angelica participated to varying degrees over the nine-month program period with either the participants in the sixth or eight grade cohorts.

***Eva.*** Eva's approach to working with youth entailed collaboratively engaging in disciplinary and rigorous science practices. This moment comes from near the end of the COOL OST program for youth in the eight-grade cohort in spring 2011. Prior to this moment, youth were engaged in a conversation about what they wanted to do as a culminating project. There was a lot of tension in the room as individual young women sought to use their social capital to push for their own versions of what was going to happen next. Some young women wanted to end the program right then and others were interested in completing a scientifically rigorous, personally relevant project about microplastics in toothpaste. During the planning session prior to this day, Eva had said multiple times that she wanted the young women to feel powerful and in charge of the science they were doing. During the conversation, Eva worked to position the youth as leaders i.e. people with choice and power with respect to science and the work necessary to complete the final project.

The girls tended to speak over one another and raised their voices to be heard but Eva choose to speak softly and stopped talking multiple times when other people began to speak over her. Eva was aware of the power her voice held in the room and wielded it very carefully. She remained silent for the majority of the youth participants' conversation until a moment arose for her to share her perspective. The young women were veering away from the conversation about their project work and how to accomplish it when Eva said, "it's not about being in a group, I mean to me it's like I really want to do science with you guys" (5/12/11). Eva's comment centered the group on the work that had to be done to accomplish their goals. She also positioned herself as someone who really wanted to do science in collaboration with youth. Heath (personal communication 2013) has discussed the power of orienting activities between youth and adults around publically relevant outcomes.

According to Heath (personal communication, 2013), when work becomes the focus of shared activity other concerns such as socio-emotional health and relationship building are attended to as well but within the framework of what is necessary to accomplish work that has consequence for youth and adults. Essentially, joint work with the goal of creating a product that will have an authentic role within a disciplinary community. Eva's words focused the group's attention on the science that they could do together to create a project that had worth outside of the group. We saw this productive tension between youth agency and scientific practices continue play out as an example of Eva's mentoring moves during her conversation with the young women. She went on to say:

> "Kelly, I really appreciate your question because that's exactly what we're trying to get to. Why are you in here? What do you want? And how can we support you getting there? And we can't do that if people are not bought in. If you guys can't tell us what it is you want, then we can't help you do what it is that you want to do and that's why we're here" (5/12/11).

The above comment was in response to Kelly's question: "It's a question of whether you all really want to be here. Are you just here to be here? Are you just here to be uh not at home? Or are you actually just here?" As Eva responded to the question, she leveraged Kelly's comment but also took her opportunity to push the conversation forward. She validated Kelly's question and then asked a series of questions that pushed youth to think of themselves not only in relational terms but also as people who were participating in COOL in order to engage in rigorous science. She maintained her stance as someone who was there to work with them but continued her narrative from above. It was not just about the relationship "being in a group" but Eva wanted the youth to know she wanted to do science with them. She was there to work with them, to facilitate their participation in a set of authentic scientific practices. Eva was there to help the youth successfully design their study, collect their data, analyze their data, and prepare to communicate their findings to a scientific community.

***Angelica.*** Angelica's mentoring practice was very different. She was motivated by making sure that every youth participant could feel comfortable sharing their experiences and seeing themselves as capable of participating in the COOL activities. She also had a different role in the COOL OST space. Angelica was a collaborator with youth but she did not facilitate or design activities. When Angelica came she participated fully in all program activities in collaboration with youth. This included icebreakers. We typically started each COOL session standing in a circle and sharing about our days as well as playing a game. We called them icebreakers as they were intended to bring youth and mentors closer together.

The moment that I've chosen to highlight Angelica's mentoring practice happened during an icebreaker that we were playing with the young women in the sixth-grade cohort in Fall 2010. The game was intended to help the youth understand the way the endocrine system works. The group stood in a circle with one blindfolded participant standing in the circle. The people on the outside of the circle called out and tried to get the person in the center to follow their voice and come to them. The game was intended to mimic the way the gonad of a fish had no way of knowing whether the message it was getting came from a legitimate hormone from the fish's endocrine system or from an external mimic like an endocrine disrupting compound. The game got loud very quickly with the young women yelling and trying to entice their blindfolded peer to choose them. When it was Angelica's turn she chose to listen for the quietest voice, which belonged to one of our quietest young women. In the midst of yelling and cajoling, Angelica listened for the voice of one of the young women who was quietly calling her name. After this, the young woman began to engage differently in the game. She even came over and suggested a new modification to me as I was facilitating the game.

Later that day Angelica wrote about the youth's practices and the ways they acted like scientist during that day. She said they "asked questions about how the gonad can't decide/ "see" between a hormone and an endocrine disruptor" (11/18/10). Angelica wrote about what motivated this choice in a reflection later in the year. She described her practices in the afterschool program as learning, "how to encourage quieter students to share with their groups. I asked for them to share with me and then their group" (2/1/11). Angelica's approach was predicated on making sure that youth who were quieter felt that they could participate in all the activities in the program. Angelica wanted to make sure that youth could participate fully in the COOL program and the scientific activities, she wanted all the youth to know that they could participate and that they did not need to yell or scream in order to get her attention.

***Jesse.*** Jesse's approach to working with youth in the program was typified by her desire help them understand that they could bring all parts of themselves to the table as resources in science contexts. Many activities in the COOL program were designed in order to surface youth's identities and prior experiences that would facilitate their science understanding. In her work with the young women in COOL, Jesse took a bit of a back seat and typically participated in small group work. The moment that exemplifies her navigation of multiple identities in science spaces with youth happened on the very first day of the program. We challenged youth to design a filter using coffee filters, different sizes of gravel, paper towels, and tape to get some dirty water as clean as possible. Jesse decided to work with two young women who had not volunteered much information about themselves up to that point in the program. They were both native Spanish speakers. Initially were quietly speaking Spanish to one another while trying to strategize about how they would build their filter. They stopped when Jesse approached their table but she asked them a question about how they were planning to hold their filter together in Spanish. This moment of sharing another part of her identity with the youth brought them both deeper into disciplinary practice as they smiled brightly before explaining their plan to her in Spanish. This kind of multiple identity work with youth in a science context facilitated their deepening participation.

Helping youth think through the ways that their own understandings and experiences were due to their intersectional identities was a leading focus of Jesse's mentoring practice. She described some of her own intersectional identities—Navajo, woman, and scientist when she spoke about the expectations she was trying to meet from her personal, community, and family responsibilities. In a follow up interview Jesse said, " the details that go into finding that balance and finding that calmness, comfortableness, I feel like I can do that with the girls because I feel like I've had to negotiate that" (3/4/11). Jesse's approach to working with the young women in the program parallels her own navigational experiences. She felt empowered to share her knowledge because she had been engaging in this kind of difficult navigational work herself as a woman with multiple intersectional identities (Ong, Wright, Espinosa & Orfield, 2011).

**Parallels between Deep Hanging and mentoring practices.** While this analysis surfaced striking parallels between mentors Deep Hanging experiences and their mentoring practices, I cannot say that Deep Hanging caused Eva, Jesse, or Angelica to mentor in particular ways. However, I can suggest that mentor's Deep Hanging experiences engendered particular stances, approaches, and strategies in their broadening participation work with youth in the COOL program.

Deep Hanging entailed four interconnected components (a) authentic tasks in rich contexts; (b) direct access and engagement with novel practices; (c) interpersonal relationships that facilitate participation; and (d) interpersonal relationships that encourage deepening identification with the domain.

## Discussion

The idea of navigating multiple identities is very familiar in the literature about the experiences of individuals from non-dominant community learning (Bang & Medin, 2010; Bell, Bricker, Lee, Reeve & Zimmerman, 2006; Calabrese Barton, Tan, Rivet, 2008; Carlone, Scott & Lowder, 2014; Gutiérrez & Rogoff, 2003; Luehmann, 2009; Nasir et al., 2006).

These findings- specifically the role of Deep Hanging in shaping mentors' motivations- can help us better understand what mentors are trying to do when they work with youth. Broadening participation in STEM disciplines remains a central focus of the work in COOL and each mentor's personal sociomaterial practices. However, the mentors maintained that broadening participation is more than training non-dominant youth to participate in STEM. Lingering questions about the goals of broadening participation resonate with the broadening participation literature. Scholars propose scientific literacy as a vision for youth development (Feinstein, 2009; NGSS Lead States, 2013; NRC, 2012; Polman & Miller, 2010). Feinstein (2009) offers the term competent outsider to describe the role he envisions for people coming to participate in STEM in ways that privilege personal relevance. National research council consensus documents like the

Framework for k-12 science education (NRC, 2012) and the next generation science standards (NGSS Lead States, 2013) also describe a personal relevance frame. Polman and Miller (2010) explored the “trajectories of identification” available to youth from non-dominant communities and developing understanding of possible participant roles that had the potential to welcome them into STEM communities of practice.

The mentors all came to the COOL program at a time when they were questioning their own position with respect to STEM research careers. Angelica and Jessee were particularly disillusioned as a result of negative interactions with their academic advisors—who were also running the labs they were participating in. This tension made these mentors particularly aware of the ways that COOL as a broadening participation effort positioned youth. Broadening participation efforts can be built upon assimilationist metaphors, and focus exclusively on making sure that youth from non-dominant groups gain access to the dominant ways of learning in practice—or only through more problematic memorization-focused instruction. The COOL mentors viewed broadening participation in more expansive ways. Their vision included broadening the concept of what it meant to learn to participate in STEM, suggesting that the ways that mentors position themselves with respect to science is crucial to understanding how they will go on to position youth.

All of the mentors in the program talked about the ways that they wanted the youth to see themselves as capable of becoming scientists. Youth from non-dominant groups may look at STEM careers from afar and make a decision without any knowledge of what kinds of possibilities they might hold. In essence mentors wanted to make sure that youth could make choices about participating in STEM careers with knowledge of what STEM participation entailed. In response to a question about the role she wanted to play Angelica said she wanted to:

> Just to be the kind of person that would excite students about a subject and then make them feel that you know they could do it to and feel that they could really go on and be successful or even just think that they could be a masters student or a doctoral student. Kind of like a guide, that's how I saw myself (10/15/10).

Angelica's enthusiasm for science comes across clearly in the above quote. She loved plants and enjoyed working with them. She also loved getting youth excited about understanding science content. What is unique about the above statement is Angelica's desire to engage youth agentively in the sense-making work of deciding whether or not a career in science is something that they want. This desire to have youth engage in reasoning with evidence about their own continued STEM participation was a recurring theme for the mentors. Jesse put it this way:

> Or even for them to realize, 'hey I don't really like science, I can do science but it's not something I want to do' To be able to actually comprehend the long term interest in science would be amazing, for me to see that, and to actually see that that's actually possible (10/15/10).

Neither mentor discussed the pipeline as a goal nor STEM careers as the endpoint for youth STEM participation after their experiences in COOL. They wanted youth to leave the program with a new storyline about themselves as science participants who could go on to learn and do more science. Mentors' picture of broadening STEM participation for the youth in our program connected more deeply to the concept of "possible future selves"(Markus & Nurius, 1986) as opposed to a career or work force argument (NSF, 2008).

Mentors saw themselves as identity builders, as validators of youth developing science identities. Eva agreed, "what I think is so important for the girls' identity building is to see that they *can* do science that there is an option, and that the practices they engage in are like science-in this way" (5/1/11). Positioning youth as people capable of doing science and becoming scientists as opposed to future scientists within existing STEM education paradigms balances the need to honor student agency while creating authentic access points to discipline-linked STEM participation. Jesse spoke about her own navigational experiences figuring out how to hold her multiple identities while engaging in science practices. Angelica spoke about finding ways to be herself and feel comfortable and like she belonged while engaging in scientific practices.

Eva made the most direct challenge to the idea of ushering youth into existing STEM paradigms. Eva was the most directly aware of the impact of privileging the Western definition of science when working with youth from communities traditionally underrepresented in STEM.

> There are people within the western academy who want to hold on to the profession, to the definition of science. I've seen that play out in a couple of different ways…when we say science it has the western academy picture behind it but that is not the only way of knowing or doing that helps us make sense of the world (01/05/11).

In the above quote Eva positioned herself as someone who pays attention to privileged ways of knowing within the Western academy's definition of science but goes beyond to incorporate other ways of STEM sense making. Bang and Medin (2010) speak about this tension and their concern about increasing achievement and participation while simultaneously working to hold onto "community-based understandings." They describe this work as supporting non-dominant participants as they navigate multiple epistemologies.

This was a storyline for Eva, where she saw herself as a type of person who challenged what it meant to engage in science and inherently as the kind of person who facilitated a broader sense of learning for the youth she works with. Part of this came from Eva's position as a woman of color whose role as community builder was a central part of her identity, part of this stance came from her journey of learning a disciplinary specific set of scientific practices, and all of these things came into play as she took up her role in the COOL program.

## Implications

Mentors' Deep Hanging experiences paralleled their engagement with youth in the COOL OST program. Eva's Deep Hanging experience created a hybrid environment where she learned she could become a scientist in her laboratory and become a scientist by going back graduate school by engaging in a place where interpersonal relationships and disciplinary practices overlapped. Angelica's Deep Hanging experience helped her to feel comfortable as she participated in STEM learning contexts. Jesse's Deep Hanging experience helped her learn to navigate multiple identities and to engage in scientific practices while honoring other parts of her self.

This line of research may have the potential to improve the design of programming to prepare mentors leverage their own navigation experiences in their work with youth in STEM broadening participation environments. Future work could chart the ways that disciplinary experts are prepared to leverage youths' cultural and out of school identities into STEM learning contexts by exploring their past STEM learning experiences. Additionally, we can work to understand how experts and youth position one another with respect to STEM disciplines. I contend that understanding the experiences of mentors prior to and during their participation in informal learning environments will help in the design and implementation of sustainable STEM broadening participation programming for youth from non-dominant communities.

# Chapter 4. DEEP HANGING: BEING AND BECOMING A STEM MENTOR

Deep Hanging: Being and Becoming a STEM mentor

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**Abstract**

This article is a comparative case study of three mentors' experiences learning in an out-of-school time STEM broadening participation program for middle school youth. Mentors in the program were undergraduates from a variety of backgrounds. I leverage cognitive maps as a way to track undergraduate's developing understanding of the term 'mentorship.' Findings highlight undergraduate participants' cultural learning pathways and emerging sociomaterial practices, as they became mentors to youth in the program. I discuss implications of Deep Hanging as an explanatory theory of undergraduates learning to mentor youth in an informal STEM broadening participation program. I argue for the methodological affordances of cognitive maps in conjunction with ethnographic methodology as means of capturing learning over time.

*Keywords:* Mentors, Deep Hanging, cognitive mapping, cultural learning pathways

Research on learning in out-of-school (OST) Science, Technology, Engineering, and Math (STEM) environments tends to focus on learning outcomes for those being mentored more than on those who are doing the mentoring (Barab & Hay, 2001; Birmingham & Calabrese Barton, 2014; Hsu, Roth & Mazumder, 2009; Kirschner, 2008; Polman & Miller, 2010). The learning sciences and specifically the design-based research community use ethnographic research techniques to study learning in real contexts (Bricker & Bell, 2014; Polman & Hope, 2014: Zimmerman, 2012). These rich accounts of learning and building bridges between everyday science expertise into disciplinary expertise offer insight into learning trajectories for youth from non-dominant communities. These studies have allowed researchers to consider the impacts of designed informal learning environments to support broadening participation goals with respect to youth learning and identification with STEM disciplines. These broadening participation efforts have typically relied upon the participation of adult facilitators to serve as mentors, bridge builders, and teachers.

Little research has been done on the learning experiences of mentors and adult facilitators in broadening participation programming. Within this study, the term mentor refers to undergraduate students from a variety of backgrounds who leveraged their science and relevant expertise to work with youth from non-dominant groups historically underrepresented in the sciences.

The mentors in this study all qualified as persons learning on their own time (Azevedo, 2011; Bell et al. 2012a, Heath, 2012). Their participation in the OST learning contexts did not formally count towards any academic trajectories. They were learning on their own time about themselves as mentors and how to work on science projects with youth in informal environments. They came to the program to learn about working with youth for personal and professional development reasons and to create new possible selves that included opportunities to work with youth in informal or formal learning environments or to identify as teachers of STEM content (Markus & Nurius, 1986).

Disciplinary professionals may possess substantial disciplinary expertise, although this does not automatically translate to them knowing how to teach or mentor others into the discipline (Bransford et al., 2000). However, the increase in designed informal learning environments for STEM learning means that there is a growing need to understand the experiences of adults who serve as mentors. Therefore, we need now to know as much as possible about what these adult mentors, particularly those who volunteer on a regular basis, learn in practice through their mentoring in OST STEM programs. This paper addresses that knowledge gap through the question: what do mentors learn through their participation in a chemical oceanography OST program designed for middle-school-level students? In the majority of studies of mentors and mentoring of young people, particularly those in STEM programs, the focus has been on enlisting mentors with deep STEM disciplinary content knowledge. At the outset, this study took this focus as a presupposition in the examination of three mentors through their preparation for and participation in an OST STEM project. However, in the course of the study, factors well beyond STEM disciplinary content knowledge came to define those mentors who learned the most about mentoring and program facilitation through their voluntary work. The following research question guided this analysis: What and how do mentors learn through their participation in an out-of-school time STEM program focused on broadening participation?

In the following sections I will begin with a description the COOL program as a design-based research context and out-of-school time program. Next, I will discuss the methods and analysis strategies. Then I will share the case studies of mentor learning. Finally, in the discussion I will explore the Deep Hanging as a way to understand mentors' experiences learning in practice through their participation in an out-of-school time program designed to broaden participation in STEM for youth from non-dominant communities.

**Project COOL: A project-based, chemical oceanography extended afterschool program**

Project COOL (Chemical Oceanography Outside the Laboratory) was a design-based research project and out-of-school time (OST) program and the LIFE Science of Learning Center (Learning in Informal and Formal Environments), both funded by the National Science Foundation. COOL brought together geoscientists, undergraduates, and middle school youth to engage in contemporary chemical oceanography research.

The program included a two-quarter sequence offered through a college of education at a local research-focused university. In the first quarter, the undergraduates took a preparatory class where they engaged in the OST curriculum as participants, learned about research-based teaching practices (e.g., the Next Generation Science Standards and *A Framework for K-12 Science Education*), and developed reflective practices (NGSS Lead States, 2013; NRC, 2012). Towards the end of the quarter, mentors engaged in rehearsals of lessons from the COOL curriculum (Grossman et al., 2009).

During the second quarter, the undergraduate students became mentors in the COOL program, working collaboratively with middle school youth to complete activities and original research on local ocean science. The mentors and researchers met once a week at the university so that mentors could work with researchers to plan lessons and debrief their experiences in the OST.

# Conceptual Framework

## Developing Models of Mentor Learning

Youth-centered learning environments that leverage mentors as learning partners can offer youth opportunities to think like scientists, engage in authentic practices, negotiate identities, answer personally relevant questions, and learn about disciplinary specific cultural tools (Calabrese Barton, Tan, & Rivet, 2008; Cornelius & Herrenkohl, 2004; Polman & Miller, 2010; Tabak & Baumgartner, 2010).

Theoretically speaking, learning as participation allows me to leverage asset-based frameworks that rely upon deepening participation in disciplinary practices over time such as lines of practice (Azevedo, 2011), cultural learning pathways (Bell et al., 2012a), professional vision (Goodwin, 1994), legitimate peripheral participation (Lave and Wenger, 1991), and apprenticeship (Rogoff, 1990). I argue that a focus on the processes by which mentors experience broadening participation programing can help to shape a new conceptual understanding of learning and development.

Barron et al. (2014) described the process of developing the Digital Youth Network's mentor training program. They relied upon developing an understanding of the needs of performing artists who were learning to mentor youth in informal digital media production spaces. Cole et al. (2006) study undergraduate participants as facilitators of the Fifth Dimension, an afterschool literacy and technology-based learning environment. Fifth Dimension spaces serve as learning laboratories for undergraduate students who are simultaneously taking child development courses. The DYN work helped me to connect mentor development in context to the work we were doing in COOL. However, the mentors in the DYN context were expert practitioners more akin to the mentors in the 2011 mentor cohort (see Article 2). In this study I document the experiences of undergraduate mentors in the COOL program as an instance of undergraduates learning how to mentor in practice. This focus made the Fifth Dimension work an important contribution to helping me understand structures and supports that facilitated undergraduate learning. This research has the potential to help us develop models of mentor learning in OST contexts that can in turn help designers of learning environments develop more sustainable learning environment that can facilitate learning for youth and adult participants.

**The Cultural Learning Pathways Framework**

Harré et al. (2009) defined positioning as a triangle of speech acts, storylines, and stances taken together these constructs shape the ways individuals develop within structures of social practice (Dreier, 2009). Positioning theory frames the ways that constellations of interpersonal interactions and social learning facilitate shifts in sociomaterial practices over time (Bell, et al., 2012a). The cultural learning pathways framework (Bell, et al., 2012a) serves as a conceptual lens for this work (see Figure 1 below). Tracing the constellations of situated events in the undergraduate mentors' experiences within the COOL program allowed me to examine the ways that they developed new sociomaterial practices in multiple structures of social practice. The cultural learning pathways framework was a good match for this analysis because it foregrounded the interconnected aspects of learning environments that helped to shape new scopes of possibility for each of the mentors: places, actions, and positions. Additionally, given that it considers experiences as layers that add up or lead to the development of new sociomaterial practices, I was able to more easily incorporate the undergraduates' cognitive maps into my analysis. The cognitive maps of mentorships gathered for use in this analysis were snapshots of undergraduates' developing understanding of the same concept at three different moments in the study i.e. events over time.

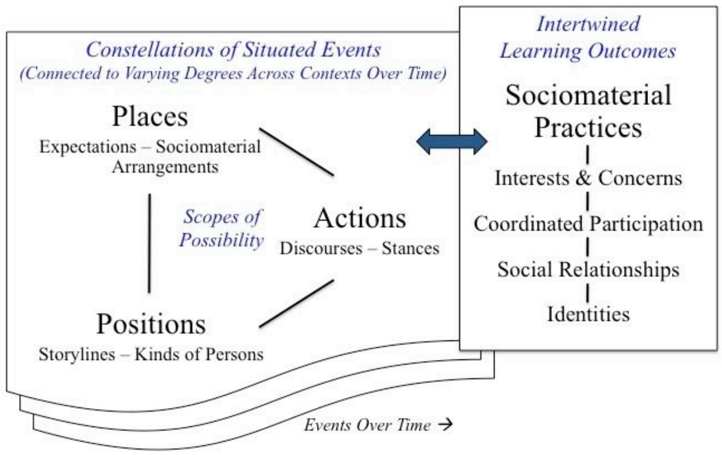


Figure 1. The Cultural Learning Pathways Framework (Bell, Tzou, Bricker, & Baines, 2012a)

As youth and mentors in the COOL program interacted in a learning environment designed to allow for co-constructed moments of coordinated participation in chemical oceanography practices, I was able to observe the ways that mentors' access to places, positions, and discourses shaped their scopes of possibility.

**Deep Hanging**

Deep Hanging was a term introduced by one of mentors in the 2011 COOL Cohort. She used it to describe her learning experiences and the ways that she was brought into science and recognized that she could be and become a scientist. Mentors in the 2011 Cohort were graduate students or recent graduates of masters in science programs. The question of where they fit into the culture of science was a recurring theme in interviews with these mentors and related directly to the ways they positioned themselves with respect to science.

I have been developing Deep Hanging as a theory of learning in practice. In earlier papers, I have described Deep Hanging in relationship to mentors from the 2011 COOL Cohort coming to understand that they could be and become scientists. In this analysis, I focus on the ways that Deep Hanging related to the experiences of mentors in the 2014 year.

## Methods

Mentors and middle school youth participated in the study, with mentors serving as key informants. I used three sources of information about mentors to build case studies of each mentor's learning and deepening participation in the COOL Program. Data for this analysis comes from multiple sources: pre and post interviews of mentors in the program, observations of mentors working with youth, cognitive maps of mentorship, and other mentor generated artifacts.

### Description of the settings & contexts

Multiple contexts made up the 2014 COOL program: undergraduate preparatory courses and two OST programming sites. See Appendix A for table that describes program sites, duration in site, and participants within each site. The undergraduate courses were offered in winter and Spring 2014. There were three main curricular strands in the Winter 2014 undergraduate course: experiencing the middle school COOL OST curriculum as participants, becoming reflective practitioners by keeping a science notebook, and understanding the next generation science standards (NGSS, 2013) as they related to the design of the COOL curriculum. The mentors explored the COOL OST curriculum as participants and also with an eye towards facilitating the activities with youth in the spring.

### Contexts

The program served youth at two local middle schools with high populations of youth from non-dominant communities: Topaz & Marble. These middle schools were chosen for their high populations of youth from groups traditionally underrepresented in the sciences. COOL began working with Marble in 2011 and 2014 was the first year working at Topaz. Both schools had a rich tradition of youth programming in the OST space.

Our program collaborated with the existing OST schedule at the schools so as to leverage the existing infrastructure such as snack, venue, and transportation. This collaboration allowed us to reach students who might not have been able to participate in an offsite program where they or their families would be responsible for transportation to and from the program site. Topaz and Marble had dedicated staff who administered the OST and ran additional enrichment programming through the school's community learning centers. In the Spring OST time ran from 2:30- 4:30 daily from April through June 2014. During the four years COOL as has been working at Marble, we have built a strong relationship with the head of the science department. This relationship led to an academic collaboration in the 2013-2014 academic year. We planned lessons together, and piloted a new activity in her classroom during two three-day lesson enactments. This collaboration allowed mentors taking the Winter COOL class to participate in the iterative curriculum design process and visit a middle school classroom. The COOL program at Topaz met once a week for eight weeks and at Marble the program met twice a week for five weeks. These differences in delivery were in response to the needs of each school's OST program.

**Participants**

The mentors for this comparative case study were all participants in the fifth year of the COOL program from January through June 2014. They were a diverse bunch whose differences in experience led to salient comparisons based upon their backgrounds and orientation to broadening participation work. The mentors came from a variety of ethnic backgrounds Jilly self-identified as a Cambodian woman, Avril self-identified as a Caucasian woman (Scandinavian), and Steve self-identified as a Native Alaskan man. Steve, Jilly, and Avril were seniors all getting ready to graduate. Steve and Avril had STEM-backgrounds, while Jilly and Avril had youth development backgrounds. There were also differences across their educational background and STEM related experience. See Table 1 (below) for an overview of the mentor participants, their ethnic affiliations, educational backgrounds, and current positions. Steve worked with another mentor (whose experiences will be discussed in another paper) in the COOL OST program at Topaz. The program at Topaz met once a week for nine weeks culminating in a COOL carnival. Jilly and Avril worked together in the COOL OST program at Marble. The program at Marble met twice a week for five weeks culminating in a student organized conference and celebration.

Table 1. Description of 2014 COOL Program Mentors.

| **Mentor** | **Ethnic Affiliations** | **Educational Background** | **Current Position** |
|---|---|---|---|
| Steve | Native Alaskan | Senior fisheries major | Gap year- working with youth doing ocean education at a local beach |
| Jilly | Cambodian | Senior early childhood major | Preschool teacher incorporating STEM content into curriculum in a school serving immigrant children |
| Avril | Caucasian & Scandinavian | Senior animal behavior major | Training manager at a pet day care, applicant to graduate school & NSF fellowship |

The term participant observer would typically be used to describe my role in this type of study as a researcher and participant however the textbook definition does not encompass the work of a design-based researcher (Merriam, 2009). Design-based research entails designing and studying learning environments based upon best practices and insights from the literature (Bell, 2004; Design-Based Research Collective, 2003). In the case of project COOL we focused on youth identity development, engagement with contemporary STEM practices, identification with

STEM disciplines, and building relationships between youth and non-parental adults i.e. mentors and scientists as ways to broaden participation in STEM for youth from non-dominant communities. The design work entailed developing the undergraduate and middle school curriculum in partnership with scientists from our collaborating geosciences laboratory. This design work is highly iterative in nature and is constantly responsive to the changing needs of all the participants and contexts involved.

Beyond the roles of researcher and designer, I took on multiple roles in relationship to the mentors in program. Within the undergraduate preparatory course, I was typically the lead instructor but my team and I traded off leading course components. In my role as program coordinator, I took care of logistics and built relationships with school staff, the OST coordinators, and science teachers to facilitate the addition of the program to the OST roster. I also served as a liaison between youth, their families and the middle school sites.

In my role as professor I co-designed and taught the two-quarter undergraduate class. This work entailed serving as a coach for the mentors as they were learning how to facilitate the COOL curriculum and develop relationships with youth in the OST sites. Within OST program, I worked alongside the mentors to plan and facilitate activities. We also came together to reflect upon mentors' experiences in the OST program using video to capture and analyze their teaching practices. These multiple roles gave me the opportunity to fully understand and interrogate the experiences of the mentors in the program. The relationships I developed with the mentors were multidimensional, as student and teacher, as researcher and participant, as colleagues, and as co-designers of the OST learning environment.

**Data Collection and Analysis Strategy**

Data chosen for this analysis were collected as part of a six-year design-based research study with the goal of building a STEM broadening participation program for youth from non-dominant communities (see Table 2. below).

Table 2. Amount and Types of Data Collected During COOL 2014

| | **COOL 2014** |
|---|---|
| **Fieldwork Duration** | 20 weeks |
| **Field sites** | Marble & Topaz middle schools |
| **Video and Audio of OST Program Meetings** | 16- 20 sessions (~ 32- 40 hours) |
| **Video and Audio recordings of Undergraduate Course Meetings** | 20 sessions (~ 40 hours) |
| **Interviews** | 6 total, 3 adults interviewed twice |
| **Mentor Generated Artifacts** | Science notebooks, mentor curriculum modifications, undergraduate course written assignments |

This comparative case study focused on mentors in the fifth year of COOL and includes data from semi-structured interviews conducted at the beginning and end of the program, mentor generated artifacts (journals, reflections, surveys, cognitive maps, and curriculum modifications), and observations from the undergraduate classes and OST sites (field notes, audio, and video recordings). Table 2 above shows the amount and types of data collected during COOL program from January through June 2014.

**Cognitive Maps.** Concept maps were one way to visually represent the ways that individuals made sense of their experiences or filled concepts with meaning. Kearney and Kaplan (1997) used cognitive maps to capture ways that community members were making sense of environmental problems. They defined cognitive maps as “hypothesized knowledge structures embodying people’s assumptions, beliefs, “facts”, and misconceptions about the world” (p. 580). They argued that these knowledge structures determined future behavior and could provide a means of understanding how participants were making sense of complex problems and connecting ideas.

The mentors in the COOL program completed three Conceptual Cognitive Concept Maps of mentorship during their participation in the program (Kearney & Kaplan, 1997). The following questions were used to prompt the creation of the maps: (a) What words come to mind for you when someone says the word mentor?; (b) Can you think of a person in your life who was a mentor to you?; (c) What were some characteristics this person had?; (d) What are some characteristics that you would like in a mentor?; (e) What words come to mind when you think of yourself as a mentor (in any capacity)?

Each time the mentors completed a cognitive map, they were given the same materials and prompts. Mentors had post-it notes, a legal size (11 1/2 X 17”) sheet of paper, and a writing implement. They were instructed to place one concept or idea on each post it note and that they could use as many post it notes as they wanted to write their responses to the prompts. Once the mentors were satisfied with their collection of ideas, they placed the concepts into groups, and named the groups (see Figure 2 below for an example of a completed cognitive map).

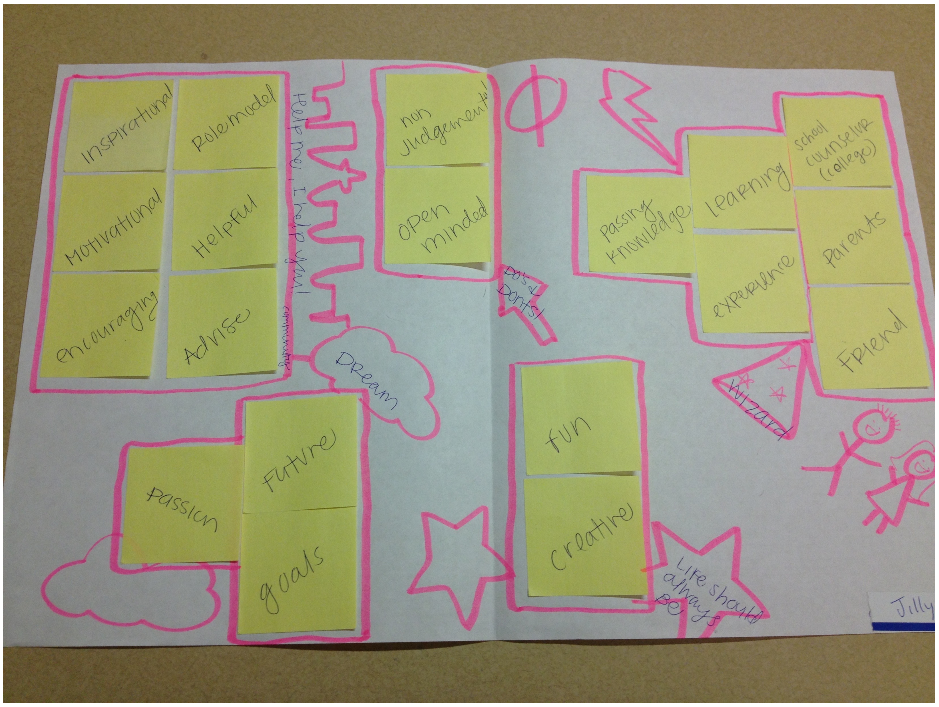


Figure 2. Jilly’s First Cognitive Map of Mentorship (01/07/2014)

Mentors completed the first map on the first day of the program in winter quarter, the second map in the spring quarter prior to starting their work with youth, and the third map during the follow up semi-structured interview. After each subsequent map, mentors were given an opportunity to reflect on the differences they saw between each map. Their comments were captured in interviews and audio recordings. This reflective tool was designed to allow the research team to capture the ways that mentors were thinking about the concept of mentorship during their time in the study. We can look at the entire data set as a way to think about the categories that all the mentors used to describe their concept of mentorship and how many concepts were nested under each category.

Given that cognitive maps were completed at three times that were directly relevant to mentor’s development of the concept of mentorship, (prior to taking the COOL winter class, before working with youth, and after working with youth in the spring) the maps comprise a self-report of each individual’s definition of mentorship at important moments during their participation in the study and reflect on their changing definitions of the term mentorship.

**Analysis**

Conceptual Cognitive Concept maps (Kearney & Kaplan, 1997) are a qualitative methodology that asks participants to create representations intended to make visible their concepts or ideas in response to a particular theme as well as the ways that they choose to categorize those concepts. A cognitive map is both a representation of the concepts and the unique ways each individual participant categorizes them. Participants in Kearney and Kaplan's study were given a set of concepts the researchers believed were related to the initial questions and asked to sort them into categories. I used a modified version of the cognitive mapping task in COOL that was much more open-ended. I asked mentors to create their own list of concepts rather than sorting a preselected set of concepts.

Semiotic cluster analysis takes responses to a single question and moves through three levels of meanings: competing, connotative, and institutional (Feldman, 1995). The competing meanings come from individual responses from participants that typically include disparate responses to the question. The next analytical step was to group the competing meanings into a set of superordinate categories based upon similarities called connotative meanings. Institutional meanings come from the literature that connects connotative meanings to the larger societal expectations or set of intended responses to the initial question.

Figure 3 (below) shows Steve's second cognitive map that had four competing meanings: "first word," "people," "characteristics," and "what I want" (04/24/14). Figure 3 below shows Steve's comments written on post-it notes in columns. These comments were considered the individual meanings he associated with the term mentor at the time he completed this cognitive map. He then grouped the concepts into categories, drew a boundary around the groups, and named each group. The names of the groups were taken as the competing meanings and are written in pen either above or below the column of post-it notes.

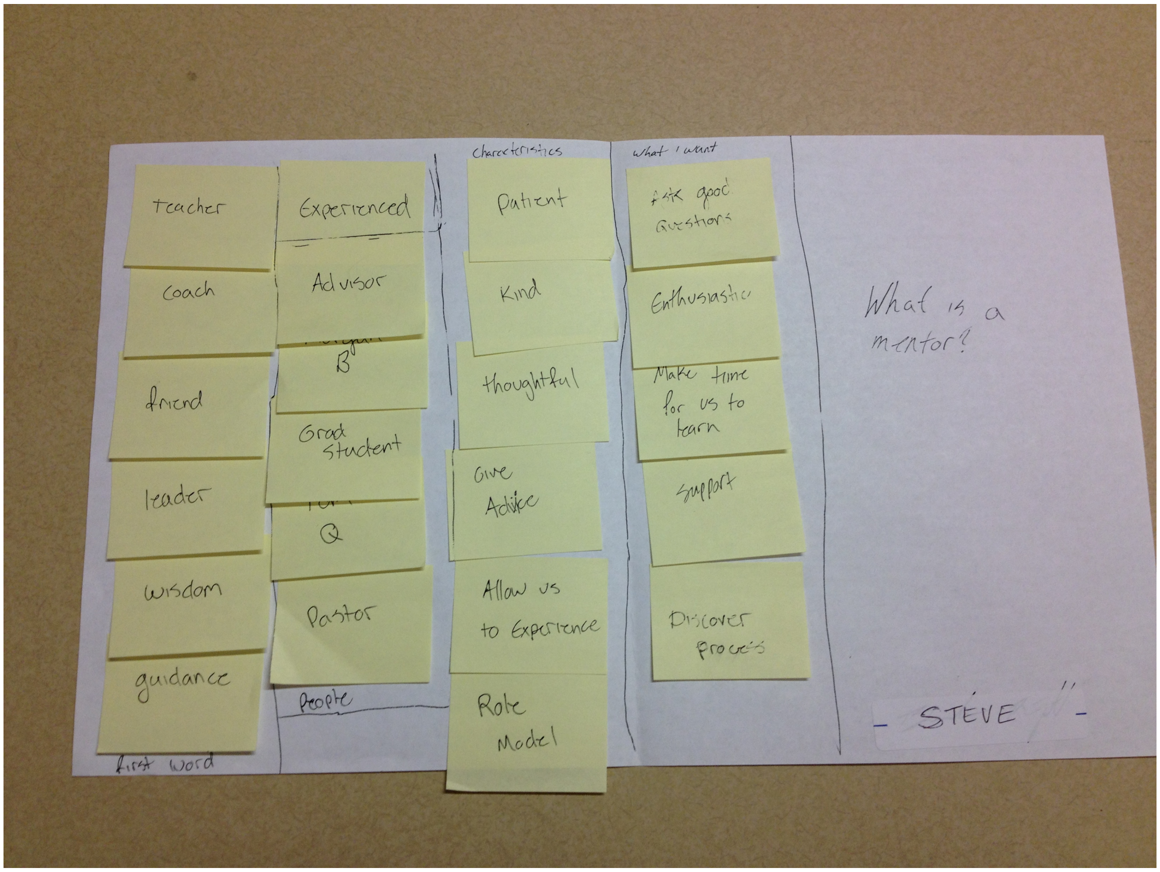


Figure 3. Steve’s Second Cognitive Map (04/24/14)

Typically the analysis of cognitive maps entails comparing the concepts that individuals choose and the unique categories they create. However, the modification that I made to Kearney & Kaplan’s procedure meant that few mentor maps had concepts in common, making it was difficult to compare from mentor to mentor. I drew upon semiotic cluster analysis to identify a set of themes associated with each of the mentors’ self-identified categories (Feldman, 1995).

Table 3. Examples of Individual, Competing, and Connotative Meanings

| **Individual Meanings** (Mentor generated comments) | **Competing Meanings** (Mentor generated categories) | **Connotative Meanings** (Analytical categories) |
|---|---|---|
| Sharing, teaching, | Describe Mentors | Mentor Role |
| Share passion of knowledge of subject, guided learning | Role of the mentor | |
| Confident, Energetic, patient, | Qualities that make a good mentor | Mentor Skills |
| Experienced, resource, knowledgeable. | Qualifications | |
| Balance of learning | Mutual role of mentor/mentee | |
| Set a high bar for standards, dependable, 1-on-1 connection | Type of commitment | Relationship |
| Partner, invested, give-and-take | Relationship | |

The above table helps to make the link between individual, competing, and connotative meanings. Mentors generated each individual meaning in response to the prompts. Then the mentors also generated the competing meanings. Then I took the analytical step to develop the connotative meanings using a grounded theory approach (Merriam, 2009). Semiotic cluster analysis was a strong match for this data set because it allowed me to begin with the individual mentor categories (competing meanings) and to explore the potential connections between the individual categories (connotative meanings) and to apply the empirical findings to the ways that mentorship is conceptualized in the literature.

I started by entering each of the individual concepts into an Excel spread sheet. Next I grouped each individual concept under the mentor's self-identified categories. Then I grouped the mentor self-identified categories into thematic superordinate categories. These superordinate categories are considered connotative meanings that related to each concept that mentors mentioned in the cognitive maps of mentorship.

Once all the mentor's individual concepts had been gathered into connotative meanings, I used Excel to sort the categories and counted instances of connotative meanings across the entire data set. I also looked within the three cognitive maps of mentorship for each mentor across time. The findings from this analysis served as a triangulation point for charting the mentor's development as I charted changes in the kinds of concepts they associated with mentorship as they deepened their participation in the COOL program.

## Findings

In the following section, begin with an exploration of the collected cognitive map findings. Next, I present three cases of mentor learning during their participation in the out-of-school time programming. I begin by sharing what we knew about the mentors when they began their work with COOL, move on to discuss their participation in the program, and finish with a discussion of where they ended up at the end of the program. I integrate mentor's cognitive map response as snapshots of their concept of mentorship. These snapshots demonstrate the connections between mentor's conceptual operationalization of the term "mentor" as it changed over time.

### Cognitive Maps of Mentorship

Cognitive maps functioned as snapshots that when taken together told a developmental story of mentor learning. Cognitive maps allowed me to contextualize other measures of mentor learning and development. Taken together they offered insight into the ideas that participants in the program associated with the concept of mentorship. Table 4 below shows the full set of connotative meanings and some examples from the 2014 data.

Table 4. Cognitive map Connotative Meanings and Examples

| Connotative Meaning | Definition | Examples |
|---|---|---|
| Mentor Role | Positions that mentors took in relationship to participants in order to facilitate learning | Passing knowledge, sharing, teaching, education |
| Mentor Characteristics | Attributes participants felt mentors ought to have | Wisdom, guidance, leader |
| Mentor Skills | Qualification that participants expected mentors to have | Leading, confident, patient |
| Mentor Actions | Things mentors can do to facilitate learning | Strengthen you, inspire you, helps you, guides you |
| Mentor Support | Ways that mentors provide emotional assistance | Shoulder to cry on, relax, allows me to be myself |
| Non-mentor Support | Additional things that provide emotional assistance | Stories, movies, random people |
| Participant Characteristics | Attributes participants felt they ought to have | Encouraging, motivational, inspirational |
| Participant Outlook | Ways that participants view the world | Future, passion, fun, creative |
| Participant Needs | Things that participants want to get from the people who mentor them | Make time for us to learn, ask good questions, support |
| Participant Actions | Things that participants would like to do in their own roles as mentors to youth | Not above you, ask questions, include into team |
| People | Individuals who were mentors to the participants | Pastor, advisor, senior graduate students, coaches |
| Relationship | The interactions between mentors and mentees | Balance of learning, dependable, 1-on-1 connection, invested |

All three mentors listed mentor characteristics, mentor skills, mentor roles, and people in at least one of their maps. Mentor characteristics referred to attributes participants felt mentors ought to have (e.g. wisdom, guidance, kind[ness], and thoughtful[ness]). Mentor skills referred to qualifications that participants expected mentors to possess (e.g. patience, excitement, and experience). Mentor role referred to the position that mentors took in relationship to participants in order to facilitate learning (e.g. guide learning and pass knowledge). Mentors listed many types of people in the category from specific individuals (e.g. their advisor, senior graduate students in their labs) and types of people (e.g. a pastor, a coach, or role model).

Each mentor's map contained a subset of these connotative meanings. Mentor's connotative meanings varied across their three maps. Steve for example, had four concepts in his first map (mentor role, mentor skills, participant actions, and people), three in his second (mentor characteristics, participant need, and people), and three in his third map (mentor characteristic, participant needs, and people). Looking at the full set of categories helps to illuminate the ideas that were on the minds of the mentors in the 2014 cohort as they thought about themselves as mentors and the people who had been mentors to them in the past.

In the next section of this article, I will weave the individual mentor's cognitive maps together with ethnographic accounts of their learning through their participation in the COOL program in order to deepen our understanding of the experiences of adult participants in broadening participation programing in out-of-school time contexts.

**Jilly: A case of a mentor as a learner**

When I met Jilly in January 2014, she was a senior early childhood studies major with extensive youth development experience. She was very comfortable working with youth in informal environments. She had been a coach for various sports, a dance teacher, a camp counselor, and a camp supervisor. She was training to become a preschool teacher and saw COOL as an opportunity to work with an older demographic as well as to develop science teaching skills. She recognized her preparation to work with youth in informal settings but that she had never interacted with youth in "classroom science." Of all the 2014 COOL participants, Jilly had the least background experiences in STEM classes or informal disciplinary practices.

She was concerned about her lack of formal science training but had a very expansive definition of science. Her nuanced picture of science and what it meant to be a scientist was grounded in an everyday science orientation (Bricker & Bell, 2014; Zimmerman, 2012; Warren, Ogonowski & Pothier, 2003). Jilly recognized that there were many disciplines of science and she felt underprepared to teach them. At the same time she saw science as something that everyone was capable of doing. She described herself as a scientist at the beginning of the program when she said, "yes, I am able to analyze many living things. Even observing a child is a way of being a scientist" (04/17/14).

Later in the same interview, she made a list of the practices she believed that youth could do that were like science in their everyday lives, "drawing conclusions, making observations, predictions, creating graphs and tables" (1/8/14). By her own definition she saw herself simultaneously as a scientist because she was able to analyze things, to observe children, and to use her observations to make decisions about youth learning and development. This translated into her orientation to science as a learner intending to master STEM content. Jilly may not have seen herself as someone with formal science training but her expansive picture of science and her stance as a learner influenced her orientation to working with youth in the program. She was motived to learn science and to be an advocate for youth as learners.

Jilly's motivation for becoming a teacher and advocating for young people from non-dominant backgrounds stemmed from her own difficult childhood. Within the first three meetings of the preparatory course, Jilly shared her history of childhood abuse with us. During the first few weeks of the program, Jilly shared the fact that a male family member molested her when she was a young child. She explained that she wanted to become an early childhood educator "to make a difference and help the students that struggle like me"(04/17/14). This history had lasting impacts on Jilly's experiences in educational settings as she struggled to navigate the public education system as an abuse survivor with undiagnosed learning disabilities, "school was a struggle through learning, comprehending, testing, and everything" (02/24/14). These experiences in middle and high school made her particularly sensitive to the experiences of other marginalized groups.

Jilly also had expansive understandings of what it meant to be a mentor. Within her cognitive maps, she had eleven unique connotative meanings associated with the term mentorship. Amongst the mentors she had the largest number of unique concepts from one cognitive map to the next. It was as if she approached each cognitive map as an opportunity to explore an entirely different meaning for the term mentor.

**Participation in the preparatory class**. During the COOL undergraduate winter class, Jilly consistently focused on the needs and experiences of youth. There were two interrelated characteristics that defined Jilly's participation in the COOL program: empathy and orientation as a learner. Jilly's empathy manifested as a focus on the needs of youth in all aspects of the program. During the COOL undergraduate class we routinely witnessed Jilly engaging in empathy in order to envision the experiences that youth would likely have with different program instruments or activities.

Her approach was evident as she looked at the half-page we had given youth to use as they completed the self-documentation task about places that health and beauty product residue might leave their homes. The page we had given youth contained a simple table that we had asked them to complete at home. Jilly's first comment shared her own experiences with school-based assignments and highlighted a flaw in our design, "if you'd given this to me as an assignment I wouldn't have done it because by the time I got home, I would have forgotten what I was supposed to do because there are no instructions on this sheet" (01/30/14). In this comment Jilly foregrounded her experiences as a learner and how they prepared her to orient to youth experiences in educational contexts. Jilly's critique was triggered by her own experiences as a young person navigating the school system with undiagnosed learning disabilities. Her experiences were the evidence she used to share her reason behind the need to redesign artifact so that it considered the needs of the learner.

Jilly's responses to the first cognitive mapping task showed her orientation to the role that she wanted to play in relationship to youth. Her first cognitive map (see Figure 2) parallels this focus on mentor characteristics (42%), mentor roles (32%), and participant outlook (26%). Jilly's map contained a new category coded as participant outlook, i.e., approaches that she wanted to take towards her own mentoring practice involving "passion, fun, creative" (01/01/14).

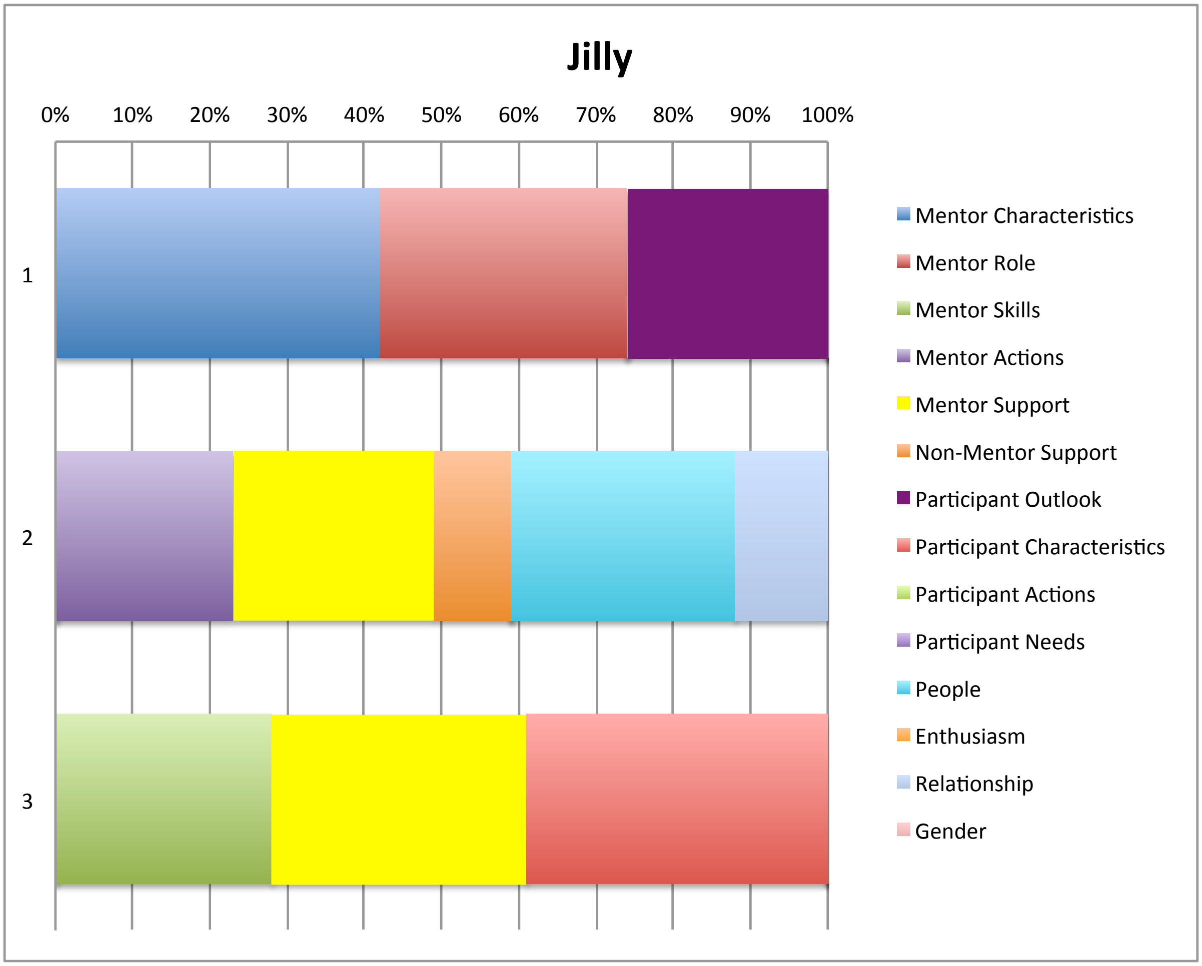


Figure 4. Jilly's Cognitive Maps Across Time in the Program

All three categories related to the ways that Jilly thought about her role as a mentor in the program with respect to youth participants. Taken together, 74% of her comments were related to mentor characteristics (42%) and mentor roles (32%). She also used attributes to describe mentor characteristics such as "inspirational, motivational, encouraging, nonjudgmental" and the roles she spoke about were a combination of types of people "school counselor, friend, parents" and roles they played "passing knowledge, learning, experience." Jilly used no personal pronouns at all in her first map and although her responses refer to her own experiences she did not locate herself within the map. Rather her vision of mentorship was focused on the ways she would work with youth in the future.

Jilly was also developing her sense of herself as a scientist during the program. In a reflection on one of the activities she wrote about the growing connection she saw between the activity and her experience fishing in Puget Sound: “I was able to map out and see what locations in the Puget Sound that causes the most effect on the fish. It is also a good connection for myself because my family goes fishing a lot and we return the female fishes (which is caught more than males) therefore I wonder if the female fishes we catch originally were females or if they change gender by the time we fish them out” (2/13/14). In this written response to a set of activities we engaged in to understand what was happening to fish in Puget Sound, Jilly connected her experiences of fishing in the Sound to her growing understanding of the concept of fish feminization. This moment marks a change in Jilly’s resources for reasoning with evidence about her lived experiences of scientific phenomenon. Jilly was able to draw upon her understanding of the fish feminization process in COOL to make sense of her own experiences fishing with her family.

**Participation in the COOL OST program at Marble**. The responses on Jilly’s second cognitive map showed a completely different perspective on the exercise. On this map, Jilly created a completely new set of categories: mentor actions (23%), mentor support (26%), non-mentor support (10%), people (29%), and relationship (12%). Taken together, 49% of her comments were mentor related, this time her comments were coded as mentor actions and mentor supports. Comments were coded as mentor actions if they were actions that Jilly wanted mentors in her life to do, e.g., “strengthen you, encourage you, inspire you, guide you, and helps you.” Jilly’s second cognitive map of mentorship read like a narrative and a list of things that she wanted to get from mentors in her own life. She identified people in her life, who “do these things” (mentor actions). These were coded as mentor actions because Jilly framed them this way, calling the category that contained these comments "do these things."

This new orientation may map onto what was happening for her during the beginning of the Spring quarter. She was applying for jobs and trying to figure out what her next steps would be once she graduated with her degree in early childhood development. Jilly came to the COOL program in order to learn how to facilitate STEM content with youth because she was trying to develop her skills as an educator. She was taking regular courses in education and family development and also student teaching in a preschool class. Her cooperating teacher appeared on this cognitive map in the category of mentor supports.

However, this did not change her approach to working with youth in the program. Jilly's approach to working with youth was based upon the stance of herself as a learner. She positioned herself as learning from the youth in the program thus setting them in the role of experts. Her approach to mentoring youth was influenced by both her expansive view of youth STEM participation and her background in informal education. She joked with the young people at Marble. She was the first person to do a silly walk down the hallway or ask youth about their day and school projects. She encouraged them to share their knowledge about conducting research on the Internet. She and they were together learning how to be scientists in informal settings but also how to engage with formal STEM projects such as those of COOL.

Jilly's approach mentoring by learning from youth included providing them with genuine opportunities to help her learn what they had been up to in the program. For example, towards the end of the program at Marble while students were conducting research, Jilly went over to check on one of the groups. She did not look over the students' shoulders to see what they were doing on the computer; instead she occupied her hands with something else and casually asked them about what they had discovered. She noted to them that she had "never thought about what water on other planets would be like." The youth jumped at the opportunity to "teach" her what they had just learned. In her pre-interview Jilly had argued that young children are born scientists because of the ways they make observations, measure things, and try to understand the natural world. Later in the same interview, she explained that youth needed to know that "science is not what we tell you; it's what you want to learn in more depth." By approaching students in this manner and placing value on what *they* had learned, showing her interest and providing her own listening ears, Jilly embodied her view of what science is—what you want to learn in more depth—in her interactions with youth at Marble.

**After the program.** Jilly's experiences in the COOL program left her feeling, "much more confident, inspired, and organized" (06/04/14). As a senior education major she was having many culminating experiences in the program, and thus we cannot claim that her experiences with us in COOL alone were the cause of the change she described. However, given that she came to COOL seeking an experience with science that would prepare her to engage in STEM work with youth, we can say that her experiences satisfied her goals for herself. Jilly's final map mirrored a greater sense of confidence in her skills and the characteristics she could bring to STEM work. In her final map, (see Figure XX) Jilly had three connotative meanings for mentorship: mentor skills (28%), participant characteristics (39%), and mentor support (33%). The category "mentor skills" was the only overlapping connotative meaning from her second map. The other two categories related to her ideas of her own characteristics that could help her students learn science, e.g., strong, confident, communicate, and inspirational (06/04/14). The second new category was related to the kinds of skills she felt she had developed as a mentor, e.g., communicating through experience, trust worthy, and helpful (06/04/14). Jilly described the characteristics and skills she could now employ as a mentor to help her students understand and connect to science learning.

Although Jilly initially thought she needed to be a scientist to engage in science work with youth, her experiences facilitating STEM projects in COOL empowered her to modify COOL lessons for use in her preschool class. Nearing the end of her participation in the program, Jilly was hired as a lead preschool teacher at an international school. She started her job there as a substitute and they invited her to take over as the lead teacher in mid June—two days after she graduated with her undergraduate degree in childhood studies. Jilly described her time in the COOL program as a major influence on her sense of how she could engage in science as a teacher, “science is everywhere. Harder science can be simplified into smaller meanings or understandings for all ages” (06/04/14). In this comment, we saw a new sense of self-efficacy for Jilly related to science. Whereas in her first interview she was worried that she had not learned enough to be an educator, now she was ready to step into leading instruction in her own classroom and to introduce science activities that she herself felt comfortable modifying for her own students.

Jilly’s orientation as a learner also meant that she was comfortable asking questions and making herself vulnerable as she did when presenting the science rich activity with our science liaison in the room. This approach to positioning herself as learner framed Jilly’s experience in the program. Jilly’s developmental trajectory included coming to see herself as a learning partner for youth (Barron et al., 2009; Tabak & Baumgartner, 2010). The interactions that Jilly had were in relationship with youth as a learner, she allowed the youth to teach her and thus positioned them as developing experts.

**Steve: A case of a mentor working on sharing disciplinary knowledge**

Steve vigorously pursued project COOL to develop “a better ability to teach to the public and be confident in [his] people skills” (01/07/14). He heard about COOL from one of the advisors in his degree program and sent multiple emails to me and other program staff to advocate for himself as a prospective student. Steve came to project COOL arguably with the most relevant disciplinary expertise as an aquatic and fisheries major. He was in his senior year and was interested in learning more about working with youth in an informal learning environment. Steve mentioned some prior experiences with youth through working with his mother, a second grade teacher. He volunteered in her class and enjoyed developing STEM related activities to facilitate in her classroom. He also co-developed some activities for youth when he was in high school. Steve self-identified as Native Alaskan and often spoke about the men in his family as fishermen. This was one of the things that motivated him to become an aquatic and fisheries major. He spoke of the importance of doing outreach and said that he did community engagement because the public is, “the future of science, whether it is parents or youth. People are genuinely curious” (01/07/14). Steve wanted to do outreach to satisfy people’s curiosity and because it brought him joy and because he,“ love [d] sharing knowledge” (01/07/14).

Steve’s responses to the first mapping task reflected an orientation towards the role he would take in relationship to the youth. While 61% of his comments were coded as mentor- related, these reflected attributes of mentors he felt were “sharing, understanding, leading, confident, and patient.” His map included a new category coded as participant actions (26%) or those things he wanted to do as a mentor. He used personal pronouns to describe what he wanted the youth to remember about his mentoring, i.e., that he was “not above you, not afraid to say [he was] …

wrong" (01/01/14). Steve's use of second person pronouns highlights the connections he wanted to build between himself and mentees in the future.

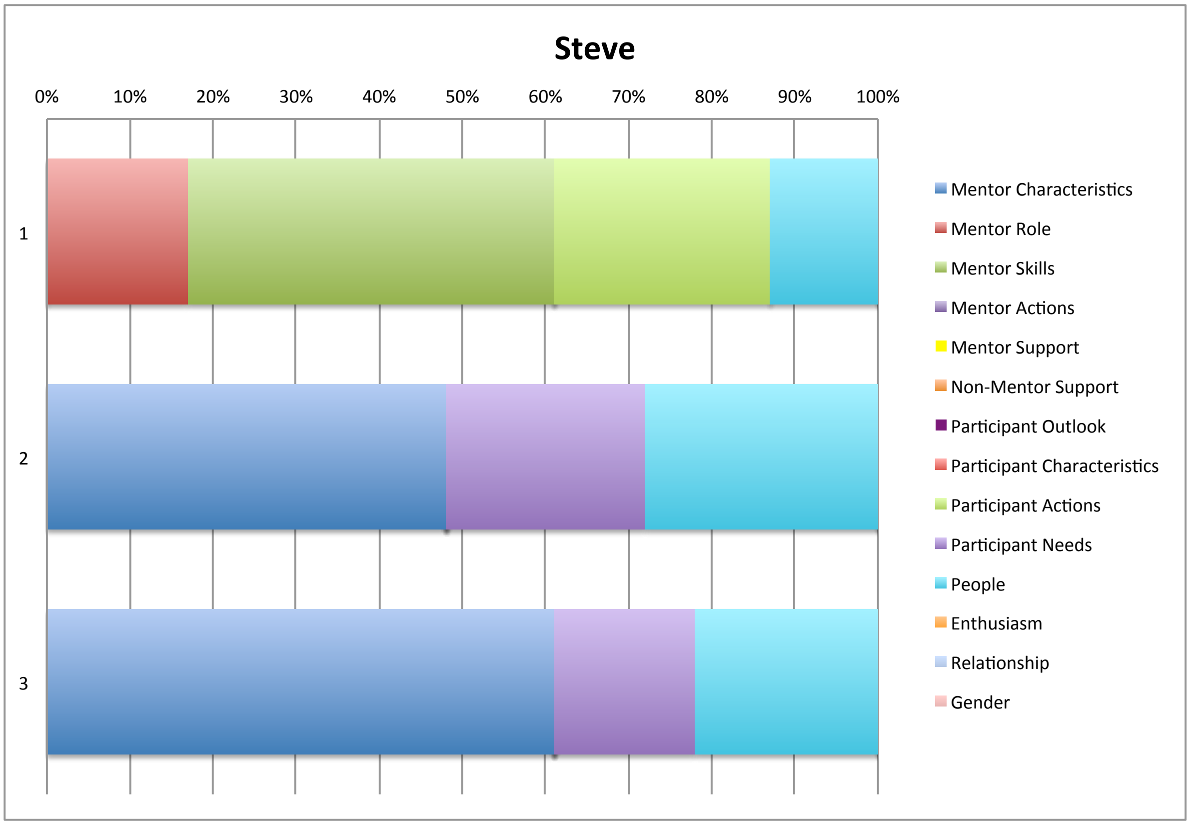


Figure 5. Steve's Cognitive Maps Across Time in the Program

**Participation in the COOL preparatory course.** Steve came between 20- 30 minutes early to each project COOL undergraduate course. He would routinely arrive while the research team was setting up the audio and visual recording equipment. He used this time to build relationships with the research team and often shared insights into his life or the ways he was wrestling with the course material. Steve's identity as a scientist was very important to him. He consistently drew upon examples from his experiences within science classes to shape his comments in the undergraduate preparatory course.

Steve's identity as a scientist was very important to him and he often described the lens he used to make sense of things as analytical and objective. For one of the assignments in the preparatory course we asked mentors to read an article about reflexivity by Kleinsasser (2000). Steve's response to the article in his notebook highlighted his stance on objectivity in science, "I don't know if I can write as eloquently as these authors. My background in writing is very scientific, there is no opinion, just cold, hard facts" (01/15/14). Here I want to highlight Steve's concept of science as cold, hard facts. He believed that there was no place for opinion in science and that it was free of any personal opinion. We made it our mission in COOL to present all the mentors in the program with some destabilizing experiences, many of these challenged Steve to re-conceptualize his ideas about science as an acultural and purely objective practice. Over the course of the preparatory program we had many conversations about the role of the researcher in determining valid questions, data collection, evidence, analysis, and ways to communicate findings.

One component of the COOL program entails taking a peer-reviewed article about fish feminization in Puget Sound and turning it into a series of activities geared towards middle school participation (Johnson et al., 2008). The Johnson et al. (2008) paper was full of disciplinary specific terminology, e.g., "Xenoestrogens, estruate sites, and abnormal vitellogenin" and dense visual representations (see Figure 6 below)

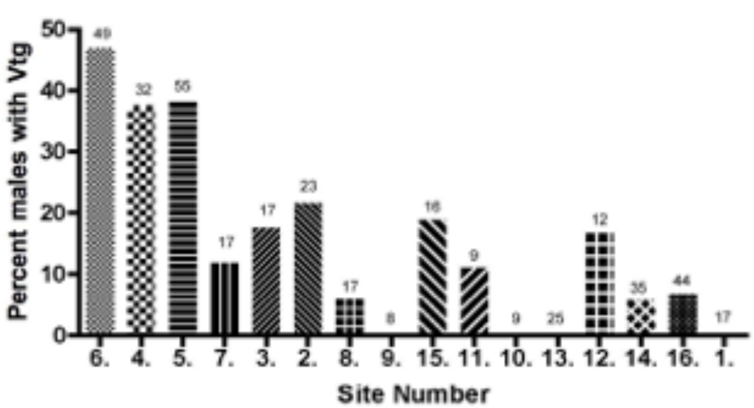


Figure 6. Graph Showing Percentages of Feminized Males by Site from Johnson et al. (2008)

The histogram shows the percentage of males at each estruate site that contained vitellogenin around the Puget Sound. These types of dense representations require a great degree of knowledge and understanding to unpack (Saul, 2004). Within the COOL program, as a designed strategy, we took this representation and turned it into a series of activities that youth could engage in so that they could reason in the same ways that scientists did with data. Youth worked with mentors to create their own representation. In the preparatory course, we asked mentors to read the article and come to class ready to discuss it and participate in the activities. As an aquatic and fisheries major, Steve was well prepared to read and understand the article as presented. He even commented that he was able to get the information out of the article in 35 minutes by skimming the opening sections and diving into the figures and discussion sections. In the passage taken from his science notebook, Steve wrote about his own realization that this was a privileged position. He contrasted the experience of reading the article and participating in the activities.

> If I were to compare and contrast the two experiences. I would say that both presented the facts in great ways. However, the method we went through in class gave the same knowledge but in a better visual fashion. We need to be able to show the information in a better visual representation for scientific papers. Just because I have been trained to find information in scientific papers, doesn't mean that everyone else has. I also don't want to seem like an arrogant, judgmental jacka** when giving knowledge I know to others" (01/24/14).

In the above reflection, Steve's words, "just because I have been trained to find information in scientific papers, doesn't mean that everyone else has," begin to add complexity to his understanding about the communicative power of science. Steve saw himself as someone with a specialized set of skills that allowed him to understand scientific material when it was presented in one way. He wanted to make sure that others could also understand the material. This aligns with his ideas about outreach work a as necessary part of doing science. He saw himself as someone who could translate for others. Steve took up this practice in his work as a mentor with youth in the OST program.

**Participation in the COOL OST program at Topaz**. The responses on Steve's second cognitive map show a smaller set of categories: mentor characteristics (48%), participant needs (24%), and people (28%). Response like "teacher, friend, leader, patient, kind, and thoughtful" were all coded as mentor characteristics. He spoke about specific people who were helping him including his advisor, graduate students, and professors. Steve's final category contained comments like "ask good questions, enthusiastic, make time for us to learn, support" These responses were coded as participant needs due to his use of the world support and use of the pronoun "us." I took this as an indication that Steve was listing a set of needs that he wanted to have met as a learner.

This new, more focused set of responses aligns with what we saw Steve do in the OST space. In his responses to the pre-survey Steve had written, "teaching is hard" and "scientists may not be willing to make themselves vulnerable" (01/07/14) in response to questions about why scientists might not do more outreach. We also saw Steve make himself vulnerable while sharing his love of science with youth in the OST program. He began to make modifications to the COOL curriculum that were geared towards making his practices as a scientist visible to the youth in the program.

Steve introduced science notebooks to the youth at Topaz. Science notebooks were a central part of the COOL OST curriculum as they were a space where youth could make notes about the things they were learning and experiencing in the COOL program. They were intended to be a reflexive and hybrid space where youth could explore their developing scientific identities (Calabrese Barton, Tan & Rivet, 2008; Kleinsasser, 2000). Although personally Steve had been trained to think of a science notebook as a purely objective space for recording data, his engagement with youth in the program around notebooks showed a more expansive picture of practice.

When he introduced notebooks to youth in the OST space, he pulled out his scientific notebook and flipped through it describing the contents, “my thoughts, diagrams, questions, writing, drawings" (04/23/14). This represented an expanded picture of the purposes of a science notebook. Sharing his notebook with the youth showed some of his vulnerability and willingness to share his practices with youth. He talked about separating it into dates, which allowed him to remember what happened each day. He leafed through each page, showing the youth a model of what their notebook could look like.

Once the youth began to write in their own notebooks, Steve went one step further and created something he called the NET project. NET was an acronym for “Notice, Experience, and Take home.” Steve pitched NET as a way for youth to keep track of the things they did in COOL and what they wanted to learn from the experience. His reasons for using the term NET made it clear that he had taken up the practices of reflexive writing in his science notebook use. “I love fish, I love the ocean…so we’re going to come up with the NET project” (04/23/14).

In the quote above, Steve was blending a strong set of scientific practices: noticing, experiencing, and taking home with his own identity as someone who loves fish and the ocean. Sharing a scientific idea in combination with his personal identity was one way that Steve’s practice with youth may have been influenced by the way the program pushed him to be reflexive and to see identity as a resource for science teaching.

**After the program**. Steve's final cognitive map had two of the same categories as his second map: mentor characteristics (61%) and people (22%). However, there is a marked shift in third category from participant needs to participant characteristics (17%). This new category for Steve included the following comments: "enthusiastic, share excitement, and lead to discovery." These comments parallel actions that Steve took as a mentor in the COOL OST space and map onto the needs that he described as a learner in his second map. Mentor characteristics has grown substantially as a category, from 48% to 68% in his final map, potentially indicating that Steve's experiences in the COOL program expanded his concepts of what mentorship means.

Steve came to the program looking for an opportunity to learn how to work with people because he understood that teaching and communicating science or sharing knowledge with people is not an easy task. Steve's experience in the COOL program helped him to feel like a stronger science communicator. In his final interview, Steve said that now he could see himself doing, "public education, doing research. Anything with the ocean but where I can interact with people. I can see myself doing that now. For a year and then go [I will go] to grad school." He has since graduated with is degree and is currently working with "elementary school kids on the beach" (05/12/15). He has found a way to work with youth, do public education, and to continue to develop his science education skills. Steve's cognitive maps show that his understanding of mentorship shifted from teacher focused to an orientation towards learner needs.

**Avril: A case of a mentor helping youth see themselves as scientists**

I first met Avril in 2013 when she took the undergraduate class in the winter quarter but was not able to participate in the OST setting in the spring. She had to bow out of the program because she got the opportunity to design her own research study in collaboration with her advisor. I was surprised to get an e-mail from her in winter 2014 asking to participate in the class again. Rather than simply joining us in the spring to facilitate the OST, Avril opted to join us for the full two-quarter sequence. In 2014, Avril was a senior animal behavior major who studied dog memory and was working on her honors thesis project.

Avril realized she could be and become a scientist through her experiences as a young woman in Head, Heart, Hands, and Health (4-H). As a child, she had a Bichon puppy and her mother enrolled her in 4-H so that she would learn how to train her dog. Avril continued to participate in 4-H through high school and this led to her reaching out to work with an animal behavior professor at a local university to serve as a mentor to her while she completed her senior capstone project. This relationship became central to her science participation and her identification with the domain of science. Thanks to Avril's apprenticeship with the animal behavior professor in high school, she came to understand that the things she loved- taking care of her Bichon puppy, learning about animal behavior, and studying dog physiology were science. Similar to accounts of youth learning about biology through taking care of pets Avril learned that studying animals was a viable career option because of her deep engagement with her Bichon puppy (Zimmerman, 2012). Coming from an ethnographic approach of exploring "when is science?" in moments of everyday life, Avril's account is parallel to other instances of science rooted in everyday practice involving the care of pets and other animals (Zimmerman, 2012).

Once Avril realized that studying animals was a viable profession she decided to become an animal behavior major. The pathway into a science major felt natural to her. She came to the COOL program with the hope that she would learn more about developing a broader impacts program that could help youth who did not see themselves as scientists find their way into

STEM. Practically, she was also interested in developing her expertise in order to shape the broader impacts section of her NSF fellowship application to support her graduate schoolwork

Avril is an interesting case because she brought a focus on STEM, youth development, and informal education expertise to her engagement with the OST program based on her 4-H participation. She graduated from 4-H at the end of high school. Since then, she has returned to serve as a mentor to youth in the program and as the leader of 4-H at the local county fair. She likened the time spent working as the 4-H superintendent at the local fair to organizing a camp and felt that she could leverage this experience in her work with youth in the COOL program.

Avril's responses to the first cognitive mapping task reflected her experiences with mentoring since 86% of her comments related to roles that mentors could play and characteristics that she felt described effective mentors. Avril's responses fell into four categories: relationship (7%), mentor characteristics (57%), people (7%), and mentor role (29%). Comments like "older, helpful, influential, experienced" were coded as mentor characteristics. She also reflected from her prior experiences the view that good mentors "share passion of knowledge of subject, let me go through trial and error with guidance, watch the "ah ha" moments occur." These comments were all coded as mentor role. She mentioned her animal behavior advisor as allowing a "balance of learning" in their joint work, which was coded as relationship. Avril entered the program with a refined sense of the roles and characteristics that make a good mentor based upon her own experiences.

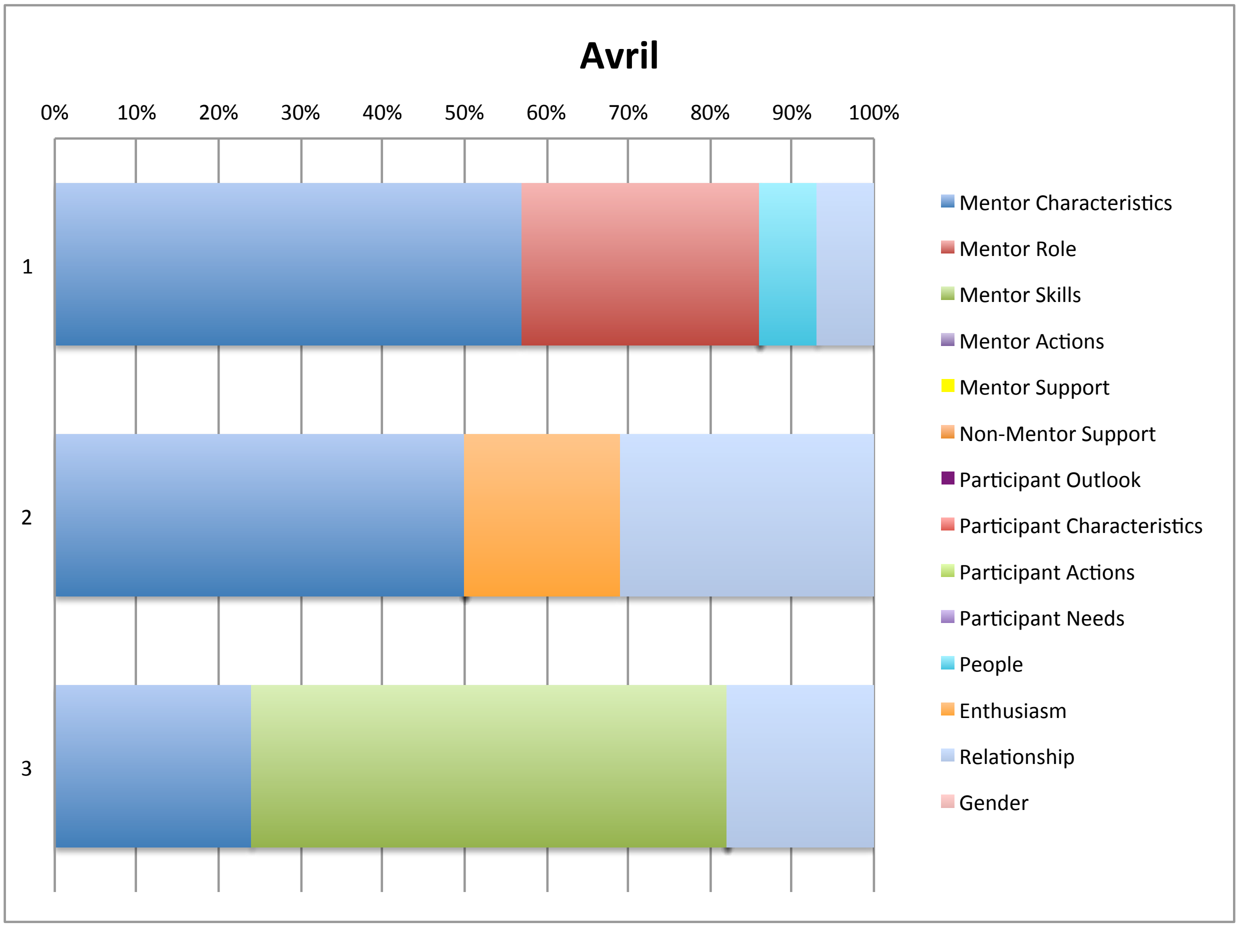


Figure 7. Avril's Cognitive Maps Across Time in the Program

**Participation in the COOL preparatory course. Sharing the Practices of Science.** Avril's approach to working with youth leveraged her own experiences becoming a scientist. She helped them see how the things they were already doing related to the practices of science by leveraging media and pop culture representations. When she found out that COOL was going to teach youth about the gas chromatography mass spectrometer (GCMS) she began searching for ways to contextualize it for them. Avril knew that the concepts were going to be difficult for youth to grasp because she had participated in a three-day middle school class the research team facilitated in partnership with one of the 8th grade science teachers at Marble. Avril watched the

COOL research team facilitate the activities and decided to try to bring some real world applications to the activities for the youth. She researched television shows that used GCMS machines to evaluate the chemical composition of mystery substances and chose a set of videos to share with youth. Avril was working to think about the best ways to connect youth to her own love of science. Avril crystallized these ideas in the philosophy of education statement that she wrote at the end of the preparatory course, "I feel that it is the teachers's job to make learning fun and relevant to the students" (04/12/14). She went on to articulate her goals as a teacher and mentor, "one of the other driving forces behind my desire to teach is to broaden the entrance point to the "STEM pipeline" so that students realize that they can get on the path even later in life and that is not an isolated foreign discipline" (04/12/14).

In the above quote, Avril's approach mirrors that of scholars seeking to help youth recognize the science in their elective pursuits and see how they could build bridges between their interests and disciplinary expertise development (Bell et al., 2012c; Clegg & Kolodner, 2014; Luehmann, 2009; Nasir, 2002).

**Participation in the COOL OST program at Marble.** Avril's approach to working with youth shows how making an emotional identification with science shaped her mentoring practice. Avril came to the COOL program with the goal of developing programs that could help youth who did not see themselves as scientists find their way into STEM. Avril's second concept map had three categories: mentor characteristics (50%), enthusiasm (1%), and relationship (31%). Mentor characteristics were comments like, "leader, role model, older, expert, warm, friendly, relatable, and understanding." Comments like, "set a high bar for standards, dependable, 1-on-1 connection" were all coded as relationship because they described relationships between mentors and mentees. She introduced a new category—enthusiasm,

“enthusiasm is contagious, encouraging, passionate about subject”(04/24/14). When Avril looked at her first and second concept maps, she described her second map as, “way more detailed and specific” (04/24/14).

Towards the end of the program, the young people asked her to help them carry out a series of experiments that ranged from trying out two different models of underwater volcanoes to testing health and beauty products for micro-plastics. Avril brought in a poster from Mythbusters, a popular science TV show (see Figure 6 below), to contextualize the need to keep notes while doing any experiment. I suspect that Avril and Steve talked about this because he also used the same quote to talk with the youth at Topaz to motivate them to take notes.

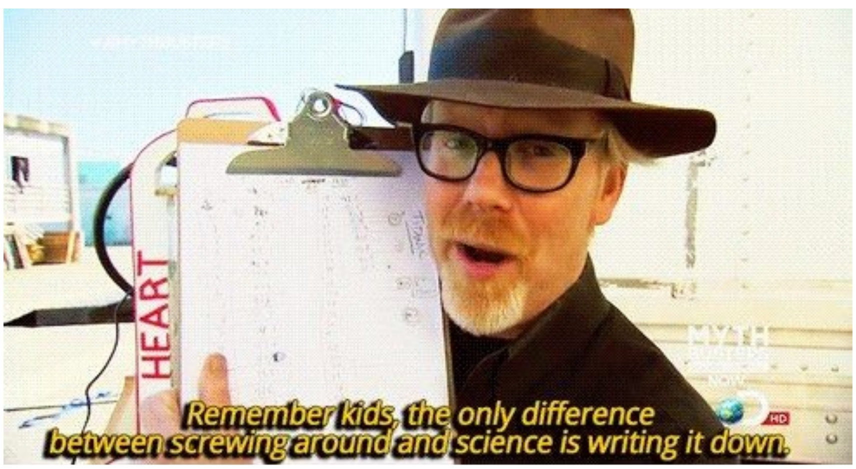


Figure 8. *Mythbusters* Meme that Avril Brought to Marble to Share with Youth

This meme was another way that Avril brought pop-culture into the COOL program to connect youth to science through things they already knew. She came to science through joy and wanted to translate this to the youth she worked with in COOL.

Avril also brought her science expertise into the COOL OST space. One of the activities in the program calls for youth to create a filtration rig and try to get a sample of water as clean as possible. However, the sample was spiked with ammonia, a chemical hidden there to make the point that cleaning water takes more than just physical measures. At the end of the exercise youth tested their samples with ammonia test strips. The strips all turned blue demonstrating that each group's sample still contained ammonia. Avril created the physical artifact below to make it possible for the entire group to compare and contrast their samples:

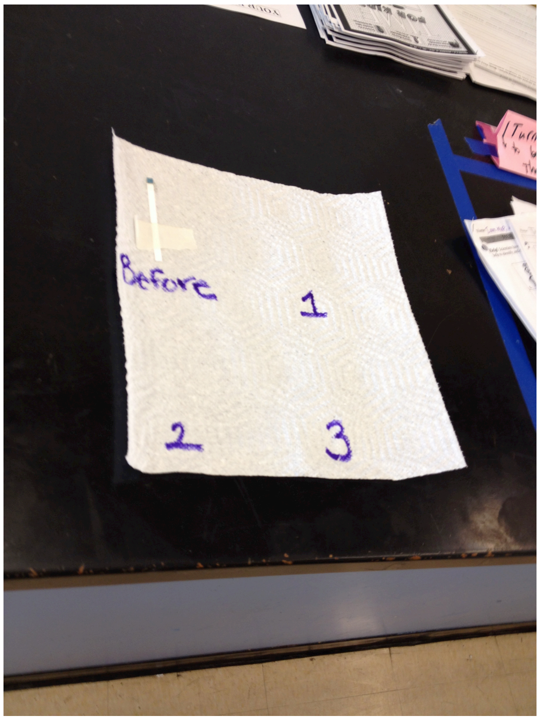


Figure 9. Physical Artifact that Avril Created to Compare and Contrast their Test Strips

When we asked, Avril said that she came up with the idea because she wanted the youth to easily be able to compare and contrast. She was also thinking about the fact that when comparing colored samples in laboratory her professors always makes them compare the colors against a white background. This may seem like a simple modification but I see it as an example of Avril looking for ways to build bridges between her knowledge of scientific practice and youth's everyday experiences.

**After the program.** Avril graduated in June 2014 and went on to work as the training manager of a pet daycare. Avril saw this work as a directly useful application of her science degree, “part of my role as an applied animal behaviorist is also to bring the cutting edge science knowledge to my clients so that they too can understand the science behind the training they are doing with their pet” (06/05/14). In this reflection, I want to draw attention to fact that Avril described herself as an “applied animal behaviorist.” It may seem that she was trying to elevate her position working at a pet day care but I think that she was again bridging the gap between the experiences of her clients and their dogs to her scientific training. Avril recognized that she had access to experiences and scientific evidence about animal behavior that prepared her to reason with evidence about problems that were happening with her clients.

Avril’s final concept map had three categories: mentor characteristics (24%), mentor skills (58%), and relationship (18%). Mentor characteristics were similar to her second map and included comments like: “friendly, helpful, supporting, and encouraging.” The following comments were coded as relationship, “partner, invested, and give-and-take.” She introduced a new category—mentor skills that dominated her cognitive map. Comments in the mentor skills were even more specific than her last cognitive map. I placed comments like, “resource, experienced, knowledgeable, holds you accountable, raises your standards, role model, and leadership” (06/05/14) in the mentor skills category.

While she participated in COOL, Avril applied for two rounds of National Science Foundation graduate funding. She was accepted into the animal behavior PhD program at her undergraduate university to continue her work with the man who had been her advisor since she began the program. Unfortunately even though there was a place for her research and scholarship, there was not enough funding unless she was able to fund herself. Her application essays for the doctoral fellowship highlight many of the things she learned through her participation in project COOL. Avril wrote that, “one of my educational goals is to create an after school program that allows students of all ages to become an animal behaviorist for the duration of the program hoping to inspire a scientific curiosity in the students using the Hamilton Search as the topic of investigation" (11/07/14). In the above statement, I want to draw attention to a few important pieces of Avril's stance towards doing broadening participation work (a) she wanted youth to engage in contemporary scientific practices—the Hamilton Search is the technique that she used in her senior thesis project; and (b) she wanted to inspire curiosity.

Avril's design intentions for her own afterschool program aligned with the project COOL design principles and had the potential to offer youth opportunities to engage in contemporary practices along side scientists. These design principles connect to what we know about ways that youth learn science and also come to identify with the domain (Bell et al., 2006; 2012a; Bricker & Bell, 2008; 2014; Polman & Hope, 2014; Stromholt & Bell, in preparation: Van Horne & Bell, 2014). I consider this a positive learning outcome of her experiences in COOL and an indication that our efforts to broaden participation for adult participants in COOL may have been successful in her case. Avril's participation in COOL helped to build social capital that she hoped to use to further her professional STEM goals. Although she did not get the scholarship, her experiences in COOL helped her to get the lead trainer position at the pet day care where she currently works. Avril leverages her animal behavior expertise to work with pets and her pedagogical expertise to train her colleagues and the pet parents.

**Discussion**

This study suggests the potential for OST Broadening Participation programs to serve as sites for adult participant learning and broadening participation in STEM or education contexts. While mentoring is typically viewed as something one learns from prior person experiences with successful mentoring, it is also a complex endeavor that can be learned in practice (Grossman et al., 2009). In the following section, I will discuss cognitive maps as a methodology for tracing learning across time, COOL as a Deep Hanging experience, my reasoning for referring to adult participants as mentors, and suggest a typography of mentor roles in the COOL program.

**Mapping Learning and Cognitive Development**

Cognitive maps played an important role in tracing mentor's learning and development over time. At the outset of this study, I was invested in developing a rich understanding of mentor's developmental trajectories in order to examine how and what mentors learn through their participation in an out-of-school setting. The goal was to develop a series of deep accounts of learning for adult participants in out-of-school settings to parallel the robust accounts of youth learning in practice and in informal spaces (Azevedo, 2011; Barab & Hay, 2001; Bell et al., 2006; 2012a; 2012b; Bricker & Bell, 2014; Birmingham & Calabrese Barton, 2014; Kirschner, 2008; Nasir, 2002, Polman & Miller, 2010; Polman & Hope, 2014, Zimmerman, 2012). These rich accounts of learning and development chart the experiences of youth in informal learning spaces. My argument was that little was known about the experiences of adult facilitators of the kinds of environments that designers and educators hope will provide opportunities for transformative experiences for youth.

Teacher education literature is an exemplary of what I hope to continue to build which offers rich accounts of adults as learners as they practice. Lave & Wenger's Legitimate Peripheral Participation (LPP) is an excellent model of adult learning in practice and offered many connections to the notion of learning through practice that I advance here—Deep Hanging. This study adds to a growing literature focused on the experiences of adult learners who serve as mentors in informal STEM environments (Barron et al., 2014; Cole et al., 2006; Hsu, Roth & Mazumder, 2009).

A recent study of the digital youth network (DNY) detailed the training program developed to prepare practicing artists to work with youth as mentors (Barron et al., 2014). In the book-length exploration of the DYN learning ecology, mentor learning is foregrounded. The discussion of mentor learning begins by admitting that initially the program did not consider the learning needs of practicing artists learning to mentor youth in informal environments. The same was true of the COOL program when we began in 2010. Although youth in the first year of the program worked alongside scientists in the SoundCitizen laboratory, we did not focus on tracking the scientists' developing pedagogical or mentoring expertise. Rather, we focused on youth developmental trajectories. Exploring youth learning trajectories in broadening participation programming is a central component of learning sciences research and this study seeks to push for the inclusion of adults as learners in these spaces.

Cole et al. (2006) studied undergraduates as mentors across multiple Fifth Dimension afterschool spaces and offered findings from a pre and post survey to track the undergraduate's development of the concept of learning. Their findings demonstrated a process similar to the progression I saw in the COOL mentor's development of the concept of mentorship through their participation in the out-of-school learning environment. As Fifth Dimension undergraduates spent more time in the designed learning environment and in their child development classes they progressed from thinking about learning as a teacher-focused activity to a learner-focused activity. This trajectory parallels Steve's experiences in the COOL program.

Rather than survey measures, I used cognitive maps as a way to document mentor's changing understanding of the term mentorship over time. Coupled with ethnographic field notes, interviews, examination of mentor generated artifacts, and video interaction analysis of mentor's participation in the out-of-school time learning sites, cognitive maps allowed me to capture snapshots along mentor's cultural learning pathways into the development of new sociomaterial practices (Bell et al., 2012a; 2012b).

**Afterschool Science as a Deep Hanging Experience**

Deep Hanging offers a way to consider mentor learning in practice in informal environments. Deep Hanging (Scipio, in preparation) is a theoretical construct that refers to the ways that people learn to participate in complex, disciplinary practice through informal learning. Eva, one of the mentors in the 2011 COOL program, described the phenomenon when asked a question about the ways that she learned she could be and become a scientist. She said, "part of it is the Deep Hanging that you do" This quotation led to an analysis and exploration of the Eva's experiences and three other mentors in the program. The mentors in the 2011 cohort were all graduate students in STEM fields and their Deep Hanging experiences emerged through reconstructive history interviews. Though a grounded theory analysis of their experiences I developed Deep Hanging as an explanatory theory of learning.

COOL was the Deep Hanging context for mentors who participated in the 2014 program where they learned they could become STEM educators. As the case studies above indicate, each mentor came to the program with a different set of expertise and learned new things through their participation. Steve and Avril both came to the program with science expertise while Jilly felt she was lacking in this arena. Avril and Jilly both had youth development and informal mentoring expertise while Steve felt he was lacking in this regard. Avril was the only mentor with both sets of expertise and even she wanted to gain something from the program—the experience of participating in a hybrid academic and youth development context with the support of learning scientists. Each mentor wanted to learn different things from their experiences in the informal learning environment, and Deep Hanging offered them a flexible learning environment.

This provides useful comparative traction for analysis across the cases.

Deep Hanging entails (a) having an authentic role in a rich learning context; (b) accessing and taking up opportunities to engage in novel practices; (c) relationships that facilitate increased participation; and (d) envisioning new ways of being. As the mentors worked with us, they had authentic and complex roles in the OST settings. They were positioned as mentors and knowledge holders in the OST contexts. This meant that they were front and center as the facilitators and co-designers of curriculum. While they took this to mean different things based upon their individual personalities and prior experiences, the salient point here is that they had an authentic role as facilitators in COOL and knew they were expected to work in collaboration with youth.

Secondly, we provided access for the mentors and they were able to make agentive decisions about what they wanted to take up. Over the course of the COOL program, mentors had the opportunity to communicate with our resident scientist in class and via e-mail, to visit a middle school classroom during regular school hours, participate in a curriculum adaptation, to join us for recruitment activities, and to accompany the youth on a field trip visit to the collaborating geoscience lab at the university. Mentors then made choices about how they were going to take up these opportunities. Avril participated in all the learning contexts that COOL made available to her. She joined us for the middle school work and was the only mentor whose schedule allowed her to participate in the field trip to the university laboratory. Jilly took the opportunity to learn from the scientist via e-mail and challenged herself to explain a difficult scientific concept while our scientist liaison was in the room. Jilly viewed this as an opportunity to get feedback from the source of the knowledge. Steve took up the opportunity to practice curriculum adaptation. He modified activities and tried them out on his peers in the undergraduate course and then on youth in the OST program. Each mentor took up the opportunities in ways that were personally relevant. Theoretically speaking, Deep Hanging offers an agentive perspective on learning in practice. Within the 2014 cohort, choosing when and how to participate in the network of learning opportunities was the space for agentive decision making for the undergraduate participants.

Thirdly, relationships facilitated mentor's participation and helped to shift their identifications with the domains of STEM and education. As the mentors built relationships with each other and the research team as facilitators of the COOL program during the winter quarter, they were learning to participate in a professional learning community. We positioned them as experts who were encouraged to share their prior knowledge and bring themselves into the teaching and learning environment as equals. We created opportunities for them to experience the middle school curriculum as participants and facilitators and then as designers. In the beginning of the spring quarter, they practiced teaching lessons and facilitating activities as a means of preparing them to work with youth in the OST settings.

While studying mentors in earlier iterations of the program helped me to develop the theoretical construct of Deep Hanging by analyzing their retrospective history interviews mentors in the 2014 cohort helped to extend the theory. The mentor cases presented in the findings show multiple ways that Deep Hanging might have played into their individual broadening participation narratives.

**Undergraduates as Youth Mentors**

The COOL program broadened participation for multiple layers of participants: middle school participants, undergraduate students, and science professionals. Part of the work of broadening participation for all participants included working with undergraduates as mentors.

Traditionally mentors in workplace contexts are expected to be experts in the field or show evidence of deep familiarity with the domain or material prior to serving as guides and facilitators to novice participants, mentors can also focus exclusively on the development of socio-emotional expertise for youth considered to be at risk (DuBois et al., 2002).

These pictures of mentorship frame the role of a mentor in an academic or disciplinary context in terms of content expertise. Leading to the idea that only experts can serve as mentors. However, the above case studies show the mentors as complex individuals with rich backgrounds to share with youth. They also had relevant navigational expertise to share with youth in the COOL program. Mentors wore college memorabilia and shared their own journeys into college with youth. COOL asked mentors in the program to work in a hybrid socio-emotional and academic space. However, the COOL program has had a variety of mentors work with youth, in 2011 the mentors were all STEM graduate students but in 2013 and 2014 all the mentors were undergraduate students. Working with undergraduates taught us that they had much to offer as facilitators of OST programming and as mentors to middle school youth.

Duration is another important distinction between mentorship in COOL and the way that mentorship it is typically conceived. A meta-analysis of the impacts of socio-emotional mentoring relationships on youth development explored the interaction between length of mentoring relationships as related to positive outcomes for youth determined that duration is an important aspect of strong mentoring relationships (DuBois et al, 2002). In 2014, youth and mentors in the COOL program only worked together for eight or ten weeks. While this relationship did not have the duration of typical socio-emotional mentorship or the expertise typical of academic mentoring context, calling the undergraduates mentors activated different aspects of themselves as educators. It was a deliberate pedagogical and design strategy to position the mentors in relationship to youth in the program.

**Typology of Mentor's new Sociomaterial Practices**

This work also suggests a typology of mentor roles in relationship to youth learning in the OST setting. Similar to the typology of adult learning partner roles described by Barron et al. (2009)—when parents were serving as learning partners for their children in Silicon valley homes as young people developed fluency with technology. While that analysis was most interested in the role of adults in relationship to the work they did with youth, this analysis nests the work adult mentors did with youth within their own learning pathways and trajectories. Barron et al. (2009) describe a set of roles that adults can take in relationship to youth as they learn. In later work on the digital youth network Barron and colleagues speak about moves that mentors can make to facilitate learning for youth participants. Taken together roles and moves offer an interesting framework for thinking about the mentors in the COOL program.

**Mentor as co-learner.** As a mentor, Jilly positioned herself as co-learner with respect to the youth participants in the program (Barron et al., 2009; Brown & Campione, 1994; Tabak & Baumgartner, 2010). She approached the process of doing science by positioning herself as someone who was learning along with the young people in the program. The youth in Barron et al.'s 2009 study described the learner role as the parents who asked them for help learning how to use technology. This positions youth as experts and upends the typical parent/child dynamic. I argue that by positioning herself as a learner, Jilly was able to accomplish a similar reframing of the youth in the COOL program. Youth in the program explained things to Jilly in doing so they were able to practice science communication and reasoning from evidence. Jilly was the co-learner- she built relationships with youth and together they tackled STEM disciplinary projects.

**Mentor as resource provider.** Steve on the other hand, positioned himself as a resource provider. He provided the resource of information. Given that he also brought his experience as a scientist to the table, he may also be considered a teacher. Steve's approach to bringing the youth into the practices of science was mediated by the identity he framed for himself as an objective scientist. Yet through his engagement with youth over time, he began to ask questions and create experiences that allowed the youth to learn how to reason with evidence.

**Mentor as translator.** Avril was the translator, she saw herself as someone with experiences in STEM disciplinary contexts and her role as a translator between youths' everyday experiences and STEM practices. She did this by using pop-culture to share her science experiences and joy in science. Steve was a case of a mentor sharing disciplinary knowledge. Avril's approach to learning can be linked to the notion of values in education and their connection to leveraging the resources of youth into disciplinary expertise development (Bell et al., 2012 a; Emdin, 2011; Moll et al., 1992, Penuel et al., 2014).

Each mentor came into the program with a set of concepts and specific practices that shaped their initial approach to working with youth. This manifested in the ways that they positioned themselves in relationship to the content and to the youth in the OST settings. However, through their Deep Hanging experiences in the program they each developed new practices for working with youth, engaging in scientific work, or developing as STEM educators. This work has the potential to broaden definitions of who counts as a learner in informal environments to include adult participants as learners. Paying attention to the learning and development of adult participants in informal environments has the potential to create more sustainable outcomes for youth. An orientation towards understanding adult participation and learning in informal environments can lead to more sustainable learning environments for youth from non-dominant backgrounds as they develop personally relevant science identities.

# Chapter 5. CONCLUSION

Deep Hanging: Design principles for facilitating adult learning in STEM broadening participation programming

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# Deep Hanging: Design principles for adults as participants in broadening participation programming

This dissertation focused on the development of an out-of-school time (OST) Science Technology Engineering and Mathematics (STEM) broadening participation program and the mentors who facilitated the programming. Through design-based research over a period of four-years, the Chemical Oceanography Outside the Lab (COOL) program developed as a STEM learning environment for youth and adult participants that leveraged contemporary science practices, expert involvement, mentorship, and agentive learning. In COOL, I chose to position both professional scientists and undergraduates as mentors in order to surface their own experiences with mentorship in their lives, foreground relational pedagogies, and to prompt them to position youth as collaborators. The use of the term mentor was a deliberate pedagogical choice that shaped the participation and development of the adult participants in the COOL program.

In the following sections, I will summarize the entire dissertation by highlighting findings from each empirical article. Then I will share a set of design principles related to adult mentor learning. Finally, I will discuss future work and new areas of research that arose during these analyses.

## Summary and High-level Findings

The dissertation was divided into five chapters: an introduction, three empirical articles, and this—the conclusion. The first empirical article focused on lessons learned from four years of design-based research (Bell, 2004). Data included ethnographic field notes, participant-generated artifacts, semi-structured interviews and video recordings of program sessions. A framework for understanding the interconnected characteristics of designed broadening participation environments emerged from analysis of this data. Participants across four years and three iterations of the COOL program reported experiences related to Acting, Authoring, and Authenticating as central components of their broadening participation experience. I was able to link changes in youth and mentors' participation in performance spaces to the designed elements of COOL that allowed them to act, author, and authenticate within STEM learning contexts.

The next two empirical articles introduced and expanded upon Deep Hanging as a theory of learning in practice. Deep Hanging is the main theoretical contribution I make in this dissertation. Studying Deep Hanging allowed me to understand many phenomena in this study. Understanding Deep Hanging helped me: (a) understand the experiences of individuals from non-dominant communities coming to know that they could be and become scientists; (b) see parallels between scientists' Deep Hanging experiences and their approaches to mentoring youth; (c) and understand the experiences of undergraduates learning to be STEM educators and mentors while facilitating broadening participation programming for youth.

Article two centered upon on the experiences of Eva, Angelica, and Jesse—three women from non-dominant communities learning they could be and become scientists. The article leveraged data from semi-structured interviews, video and audio recordings of program sessions, and participant-generated artifacts to construct case studies of Eva, Angelica and Jesse's experiences. This analysis led me to characterize Deep Hanging as: (a) authentic tasks in rich contexts; (b) direct access and engagement with novel practices; (c) leveraging interpersonal relationships to facilitate learning; and (d) interpersonal relationships that encourage deepening identification with the STEM disciplines. Findings from this analysis also surfaced parallels between the three participants experiences learning they could be scientists and they ways that they then worked as mentors to broaden participation in STEM for youth in COOL.

In article three, I reported on the experiences of Jilly, Steve, and Avril—three undergraduates learning to be STEM mentors and educators in practice during their participation in the COOL program. The paper used ethnographic methods, cognitive mapping, and semiotic cluster analysis to build comparative case studies of mentor learning (Feldman, 1995; Heath, Street & Mills, 2008; Kearney & Kaplan, 1997; Merriam, 2009). The cognitive maps were snapshots of mentor's developing concepts of what it meant to be a mentor and taken together with ethnographic field notes and analysis of video and audio data helped me build cases of their learning during their participation in the program. The semiotic cluster analysis of the undergraduates' initial perceptions of the concept of mentorship showed that the term surfaced many relational qualities (e.g. encouraging, motivational, leading, guidance, sharing). During their participation in the study undergraduate's cognitive maps demonstrated a shift towards relational pedagogy as they continued to participate in the program.

## Mentor Learning Design Principles

My dissertation work has led me to develop Deep Hanging, a theory of adult learning in practice. I used Deep Hanging as an analytical lens to explore mentor learning and development. The design-based nature of my dissertation work also lends itself to the development of design principles and insights for the field related to implementation. These principles are meant as a guide for designers, policy makers, and educators but they should not be taken in isolation. Taken together they can help to inform an approach to building learning contexts for adults in out-of-school (OST) programming.

These principles pertain to adults learning to mentor youth in broadening participation programming. These principles are an attempt to highlight lessons learned from four years of supporting mentors while they worked with youth in OST STEM broadening participation programming. They will hopefully be useful for designers, educators, scientists, community members, and policy makers seeking to build designed learning environments that offer sustainable broadening participation programing in OST settings. I presented a set of design principles at the end of the first empirical article related to findings about design and implementation of the design-based research. In the following section, I present a parallel set of design principles related to findings about mentorship.

*Specific Design Principle: Understanding scientists' Deep Hanging experiences can help designers and educators to see parallels between scientist's experiences learning they could become scientists and their approaches to working with youth.*

Each of the professional scientists in the program had sets of Deep Hanging experiences. These Deep Hanging experiences helped them understand they could be and become scientists and shaped their relationships to science as a discipline. These different Deep Hanging experiences broadened the scope of possibilities for each mentor's participation in STEM careers. Each mentor described a cultural learning pathway full of places, positions, and actions that shaped their developing sociomaterial practices (Bell et al., 2012). These sociomaterial practices were related to: (a) disciplinary practices (e.g. engaging in lab practices, conducting experiments, analyzing data); (b) navigational practices (e.g. making sense of bad advisors, understanding their rights as students); and (c) socio-emotional practices (e.g. relationships that created novel participation opportunities). Mentors in the program leveraged sets practices in their work with youth that paralleled the ways they learned they could be and become scientists. As designers of learning environments for youth and adult participants, developing these understandings of the mentor's prior knowledge can help shape the development of training and debrief programming designed to create sustainable and supportive programs for all participants.

*Specific Design Principle: Broadening participation programming geared towards youth can provide learning contexts for adult participants by offering them opportunities to engage in Deep Hanging and develop skills as mentors in situated practice.*

The COOL OST program was a Deep Hanging context in which undergraduates could learn to be STEM mentors. Their experiences within COOL were designed to allow them to learn from complex practice. During the preparatory course our approach aligned with practice-based approaches to teacher education (Grossman et al., 2009). Undergraduates were positioned in authentic roles as mentors within the complex OST setting. They were given direct access to the OST contexts where they could engage in novel practices e.g. curriculum modifications, lesson planning, and facilitating activities with youth. They were also given various opportunities to learn from their experiences through reflective pedagogies. This design principle aligns with work done to train Digital Youth Network mentors (Barron et al., 2014) and Fifth Dimension facilitators (Cole et al., 2006). Studying the ways that performing artists and undergraduates learn through their participation in youth programming can offer additional insights into building robust supportive programming for adult participants in broadening participation learning environments.

*Specific Design Principle: When mentors have opportunities to engage in activities as learners, they are well-positioned to make learner-focused curricular modifications. The experience of participating in activities as learners positions undergraduates to consider the experiences of youth as learners when they shift their roles to mentorship and facilitation.*

As designers of learning environments that seek to foster multi-level learning, it is important to hold as a central focus the understanding that persons develop in structures of social practice

(Bell et al., 2012, Dreier, 2009). Considering ways that participants are positioned and resourced in relationship to practices and pedagogy are important considerations for designers of learning environments (Azevedo, 2011; Penuel, Lee & Bevan, 2014). During the COOL undergraduate class, mentors participated in the out-of-school time curriculum as learners and then unpacked their experiences with COOL researchers in order to help them to see the connections to the overarching elements of the COOL curriculum design. We saw mentors' reactions to these experiences described in their science notebooks and play out as mentors authored new activities.

*Specific Design Principle: Navigation stories emerge when mentors have opportunities to share their personal research, life experiences, and educational pathways with youth as a designed-component of the program.*

Creating opportunities for youth and adult participants to share their own experiences formally through presentations, panel discussions, or sharing their research or informally through impromptu conversations all can help shape youth's perception of themselves as scientists. Scientists from non-dominant communities who serve as mentors are in a unique position to share their navigation stories with youth from non-dominant communities. As persons developing in intersections of identities, community, and disciplinary memberships mentors were positioned to share their navigational expertise with youth. Within the COOL OST contexts we saw this play out in the ways that mentors' in the 2011 Cohort shared their research projects with youth via PowerPoint presentations and also shared pieces of themselves as members of multiple ethnic communities. Navigation stories allowed youth to explicitly come to understand the ways that personal interests and motivation shaped mentors' experiences of in finding their ways into new practices. Navigational practice entails finding ways to help youth directly engaging with new practices in personally consequential ways that are also disciplinarily rigorous. These navigation stories can make explicit codes of power that may be hidden in other educational contexts (Delpit, 1995). Youth across the iterations of the program spoke about coming to understand how they could take agentive moves that positioned them with relationship to science through their participation in COOL. Youth's developing understandings of the role that could play with regards to their own learning can be traced back to their deepening knowledge of science as a discipline and of the scientists they worked with as individual learners with their own complex relationships to science.

## Future Directions

The above design principles offer insights from lessons learned in chapters two and three of this dissertation. Findings were focused on the experiences of professional scientists and undergraduates in OST broadening participation programming aimed at youth from non-dominant communities. Bringing together these two learner populations helps to shed light on adult participants as learners in broadening participation programming. With this dissertation, I have aimed to offer insight into the design of broadening participation efforts. The adult participant learning through their engagement in out-of-school time programming aimed at broadening participation for youth from non-dominant communities. Definitions of broadening participation in STEM have historically involved underrepresentation narratives when framing participation for non-dominant youth and communities. Taken by itself this framing has the potential to lead to assimilationist models of broadening participation. Especially if the goals of designers of learning environments are mainly geared towards adding more people from non-dominant groups who are not currently participating in STEM to existing western scientific schema. My personal definition of broadening participation involves getting youth at a vantage point from which they can make decisions about their own continued participation in STEM fields. I agree with arguments from within the critical scholar community that we must move beyond assimilationist narratives of STEM participation to reframe STEM disciplines (Bang & Medin, 2010; Warren, Ogonowski & Pothier, 2003). I am particularly interested in exploring the tensions in STEM identity development, identification with STEM domains, and the need to foreground different epistemological perspectives on learning (Rosebery, Warren, Conant, 1992). There is work to be done to redefine what it means to do science to include the robust STEM activities of groups and individuals from non-dominant communities (Hanson, 2007; Medin & Bang, 2014; Kawagley, 2006).

Groups and individuals from non-dominant communities have been engaging in complex STEM and ways of knowing and gathering information (Bang & Medin, 2010; Bell et al., 2008; Brayboy & Maughan, 2009; Bricker & Bell, 2014; Hanson, 2007; Hudicourt Barnes, 2003; Kawagley, 2006; Nasir & Hand, 2008). My work seeks to better understand the diverse pathways that professionals from historically non-dominant communities forged in order to gain entry into STEM-related careers. At the most recent International Conference of the Learning Sciences, Jean Lave encouraged the crowd of Learning Scientists to go beyond problem frames to explore complex learning as it is happening in communities and contexts. This is the kind of work that I would like to do and I view this research project as an opportunity to contribute information about what is working to support non-dominant scientists joining and persisting in their fields.

I am interested in research around four main foci: (1) reconstructive histories of the experiences of STEM professionals from non-dominant communities, i.e., cultural learning pathways (Bell et al., 2012); (2) understanding the role of "Deep Hanging" and the relationship to STEM broadening participation efforts for non-dominant communities; (3) learning about activities and mentoring frameworks that exist within non-dominant community serving organizations like SACNAS, NSBE, etc.; and (4) exploring the link between mentor's own experiences learning they could be and become scientists and the ways they want to work with youth.

In future work, I will continue to focus on adult learners who work to help educate youth. This focus will help me develop an understanding of the developmental pathways of the kinds of adults who are often seen as our best resource for helping youth from non-dominant communities navigate into STEM-related careers (Bang & Medin, 2010). I am interested in studying STEM professionals from non-dominant communities in order to better understand their own journeys into STEM-related careers. I also want to understand how they position themselves in relationship to mentoring youth and early career professionals. I am particularly interested in understanding the ways that Deep Hanging narratives play out in the lives of non-dominant STEM professionals. Deep Hanging allows me to look at the agentive moves of participants and to track the ways that their experiences travel from one community of STEM practice into another.

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**CHAPTER 2**

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**CONCLUSION**

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# APPENDIX A

Table 1. Project COOL youth participants

| **Sites/ Year** | **Participants** | **Grade level** | **Ethinc Affiliation** | **Gender** |
|---|---|---|---|---|
| Sound Citizen Lab, 2010 | Sarah | 9th | African American | Female |
| | Hannah | 10th | Burmese | Female |
| | Joy | 12th | African American | Female |
| | Alma | 8th | Somali | Female |
| | Nick | 9th | African American | Male |
| | Ronnie | 9th | Latino | Male |
| | Joseph | 12th | African American | Male |
| | Mikey | 9th | African American | Male |
| | | | | |
| Marble, 2011 | Mika | 6th | Filipino | Female |
| | Sage | 6th | White | Female |
| | Cynthia | 6th | Chinese | Female |
| | Lauren | 6th | White | Female |
| | Francine | 6th | African American | Female |
| | Maria | 6th | Latina | Female |
| | | | | |
| | Jackie | 8th | African American | Female |
| | Keisha | 8th | African American | Female |
| | Hadya | 8th | Somali | Female |
| | Elena | 8th | Latina | Female |
| | Mercedes | 8th | African American | Female |
| | Natalie | 8th | African American | Female |
| | Sharon | 8th | African American | Female |

Table 1. continued

| **Site/Year** | **Participants** | **Grade Level** | **Ethnic Affiliation** | **Gender** |
|---|---|---|---|---|
| Marble, 2013 | Maria* | 8th | Latina | Female |
| Agate, 2013 | Tammy | 8th | African American | Female |
| | Ayana | 8th | African American | Female |
| | | | | |
| Topaz, 2014 | Amir | 6th | Somali | Male |
| | Crystal | 8th | Chinese | Female |
| | Elizabeth | 8th | Chinese | Female |
| | Ingrid | 8th | Pacific Islander | Female |
| | Jamal | 6th | African American | Male |
| Marble, 2014 | Madeline | 6th | French African | Female |
| | Jonas | 8th | Filipino | Male |
| | Isaac | 7th | Latino | Male |
| | Kassandra | 7th | African American | Female |
| | Jack | 6th | White | Male |

Table 2. Project COOL Adult Mentor Participants

| | **Participants** | **Year in School** | **Ethinc Affiliation** | **Gender** | **Educational Background** |
|---|---|---|---|---|---|
| Marble, 2011 | Eva | MS | Latina/German mixed race | Female | MS Aquatic & Fisheries Sciences |
| | Jesse | Graduate | Dine, Hopi | Female | MS Genetics |
| | Angelica | Graduate | Latina | Female | MS Botany, MA |
| | Andre | Post-bac | Native American | Male | |
| | | | | | |
| Agate, 2013 | Avril | Junior | White | Female | Animal behavior |
| | Huck | Junior | Chinese | Male | Biology |
| | Anderson | Post-bac | White | Male | Biology |
| | Emily | Senior | Korean & Vietnamese | Female | Childhood studies |
| Marble, 2013 | Taylor | Sophomore | White | Female | Biology |
| | Annabella | Senior | White | Female | Math |
| | Magdalena | Junior | Mexican | Female | Environmental studies |
| | | | | | |
| Marble, 2014 | Jilly | Senior | Cambodian | Female | Childhood studies |
| Marble, 2014 | Avril* | Senior | White | Female | Behavioral sciences |
| Topaz, 2014 | Jasmine | PhD | Chinese | Female | Economics & Forestry Resource Management |
| Topaz, 2014 | Steve | Senior | Native Alaskan | Male | Aquatic & Fisheries Sciences |

# VITA

Dr. Déana Aeolani Scipio is a woman of Afro Caribbean descent whose research interests include: mentorship, Deep Hanging, broadening participation, and non-dominant group member participation in STEM fields. Her work includes studying the relationship between formal and informal STEM learning environments; creating spaces for youth to demonstrate or create expertise; architecting community-university partnerships to facilitate STEM learning; and helping scientists build pedagogical capacity. She has a B.A. in English Literature with a minor in Biology from the University of San Francisco, a certificate in Education, Environment, and Community from IslandWood, and an M.Ed. in curriculum and teaching from the University of Washington.