Learning Beyond the Lab:
Designing for Identity Development and Relational Equity for Youth and Scientists

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Abstract

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This dissertation provides insights on how graduate-level scientists navigated developing their skills and identities as educators, across two different research contexts. Using a Design-Based Research lens, the design of a two-year scientist-youth mentoring program was investigated to understand how relational equity, or symmetrical power relations, can be fostered between participants. Mentoring scientists' identity development was also studied through a case study approach, to highlight the differential identity pathways that both motivated and were impacted by their developing practice in youth engagement. Finally, a graduate seminar on education research for scientists provided a counter-context to the mentoring program, that elucidated how identity development was also salient as scientists learned about evidence-based teaching practices. The studies are united by sociocultural perspectives on identity development and learning, collection and analysis of ethnographic, reflective, and quantitative data, and a focus on

how the design of learning environments impacted collective outcomes. Implications of this work span across disciplines, by situating graduate student identity development as a complex phenomenon rather than a narrow trajectory of socialization, and providing design principles and exemplars that can be leveraged in other contexts for youth to interact with scientists and scientists to learn how to teach.

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DEDICATION

For Eliora, Baby L, and all future science learners.

Chapter 1. Introduction

Research Rationale

Despite the fact that many scientists teach during graduate school and often aim for post-doctoral careers that involve some level of teaching (Austin, 2002; Connolly, Savoy, Lee, & Hill, 2016; Sauermann & Roach, 2012), graduate training primarily focuses on preparing students with research-related skills (e.g., Anderson et al., 2011; Golde & Dore, 2001). Doctoral candidates are often urged to minimize the time and energy they spend on teaching and commonly receive little (if any) training or systematic support for developing their practices as educators (Austin et al., 2009; Golde & Dore, 2001). This is especially true at research-intensive universities, from which the majority of science PhD's in the United States graduate, but who then go on to work, and likely teach, at a variety of institution types (National Science Foundation, National Center for Science and Engineering Statistics, 2017). Their positions range from the dwindling number of traditional university research and teaching positions (Cyranoski, Gilbert, Ledford, Nayar, & Yahia, 2011), to adjunct lecturer jobs, to K-12 education and outreach organizations: experiences for which their graduate training typically does not prepare them. Beyond these implications for graduate students' professional trajectories, this phenomenon also ultimately has negative impacts on undergraduates' science learning, given that instructors of their foundational courses are not well-versed in research-based teaching practices (Henderson, Beach, & Finkelstein, 2011; Marbach-Ad, Egan, & Thompson, 2015).

Graduate students who are interested in developing their teaching practice, then, often seek out opportunities to do so outside of their normal course of study. For scientists, there are a wealth of opportunities to engage in K-12 educational outreach (Dolan, 2008). Although scientists' participation is often limited in scope and duration (e.g., judging a science fair, presenting to a class about their career path), other opportunities provide sustained engagement and support for graduate students to expand their repertoire of pedagogical practices (e.g., the National Science Foundation GK-12 program, which, until 2011, funded STEM graduate students to collaborate in a sustained way with K-12 teachers to design lessons and co-teach). Other settings for graduate students focused on learning how to teach include professional development workshops, ongoing teaching support programs, and seminars focused on educational research. However, these are not consistently offered across institutions or science departments, despite evidence of their positive impacts for graduate students' professional trajectories (Connolly et al., 2016).

In this dissertation, I leverage a social practice perspective to consider how the division between developing skills in teaching and research in graduate school is integrally involved with graduate students' professional identity development. Other studies have demonstrated the long-standing relational hierarchy that exists between research and teaching in graduate school, with activities and professional goals related to research privileged above teaching (Austin, 2002; Connolly, 2010; Connolly et al., 2016; Fuhrmann, Halme, O'sullivan, & Lindstaedt, 2011). Individuals who choose to pursue teaching during and after graduate school, then, put their nascent professional identity at risk (Brownell & Tanner, 2012), in addition to possibly losing access to tangible resources such as funding or opportunities to collaborate with faculty. Other research demonstrates how this is a particularly salient process for scientists from under-represented and minoritized backgrounds, such that they may be "over-represented" in teaching and educational outreach activities (Ko, Kachchaf, Hodari, & Ong, 2014; Thiry, Laursen, & Liston, 2007). I build on these previous findings to emphasize how preparing graduate students for career pathways involving teaching has the capacity to truly broaden participation in the sciences, by supporting scientists from minoritized backgrounds and with diverse life experiences in redefining what counts as scientific activities and being a successful scientist in our society. Specifically, in the three empirical studies that comprise this dissertation, I ask: How can graduate students in the sciences develop their identities as educators?

Theoretical and Methodological Approach

In the empirical chapters that follow, I leverage socio-cultural theories of learning to attend to the ways in which PhD students' learning during graduate school is directly intertwined with their ongoing processes of identity development (reviewed in Hand & Gresalfi, 2015). As a learning scientist, I anchor my work in learning sciences literature related to how individuals develop their identities (or, in recognition of this active and dialogic view of identity, engage in identity work) as they interact with others and undertake social practices in particular contexts (e.g., Bell, Tzou, Bricker, & Baines, 2012; Holland, Skinner, Lachicotte, Jr, & Cain, 2001; Lave & Wenger, 1991; Nasir & Hand, 2008). I provide evidence to show how graduate students' learning how to teach entails figuring out how to be or become an education-interested scientist. Moreover, undertaking this complex process has implications for how one is perceived and positioned by others, especially those in positions of power (e.g., graduate advisors and dissertation committee members), such that engaging in activities to improve one's teaching practice may determine if an individual moves towards the center of their graduate school community of practice or is marginalized to the periphery (Lave & Wenger, 1991; Nasir & Cooks, 2009).

By taking up these socio-cultural approaches to identity, I conceive of individuals' identity work as deeply contextual, evolving over time, subject to internal and external conflicts, and evident through everyday practices (e.g., Holland & Lave, 2009). Methodologically, doing so foregrounds the importance of attempting to understand the multiple contexts and timescales through which research participants move (Banks, 2007; Wortham, 2008), a challenge to which ethnographic methods are well suited. Although the studies described below are not ethnographies, I used ethnographic methods throughout the research. In addition to observational field notes (Emerson, Fretz, & Shaw, 2011) and collection of artifacts, I employed surveys, interviews, and focus groups to triangulate between what people say upon reflection and what they do in everyday practice, and to get a sense of individuals' self-identification (Erickson, 1986; Heath & Street, 2008; Wolcott, 1997). These accounts were crucial in order to understand participants' identity-related experiences within the research settings from their own points of view, as well as to understand the contextual elements that contributed to those experiences.

Throughout the dissertation, I explore how the design of learning environments supported participants' identity work as educators, in order to articulate principles that can guide the design of other experiences for graduate students to learn how to teach and work with youth. In so doing, I draw on the Design-Based Research tradition within the learning sciences (Brown, 1992; Cobb, Confrey, Lehrer, & Schauble, 2003; The Design-Based Research Collective, 2003). My research findings have direct significance for scholars involved in designing, implementing, and studying teaching development experiences for scientists— whether in the fields of the learning sciences or Discipline-Based Educational Research (DBER; Singer, Nielsen, & Schweingruber, 2012).

Through my approach to the dissertation research, I align with Blomberg and colleagues (1993) in linking the ethnographic and design undertakings of "*understanding* human behavior as it is reflected in the lifeways of diverse communities of people [with] *designing* artifacts that will support the activities of these communities" (p. 123, emphasis in original). By illuminating the identity-related dimensions of graduate students' learning how to teach, my work conceptualizes how to design environments that foster development of teaching identities for graduate students and explicitly surface the teaching skills that participants may not even realize they are acquiring (e.g., Nasir & Cooks, 2009).

Research Contexts and Structure of the Dissertation

Against this conceptual backdrop, I investigated how graduate students from across the disciplinary sciences at a large, research-intensive university developed their identities as educators as they participated in two different education-related experiences: the STEM OUT Science Mentoring Program and the Biology Education Research Seminar.

STEM OUT: A High School Science Mentoring Program

For the first research context, I designed, implemented, and studied a two-year science mentoring program in partnership with a STEM-focused public high school, and with funding from the American Association for the Advancement of Science (AAAS). Over two years, the STEM OUT program brought together 18 graduate student scientists with groups of two to three high school students for hour-long mentoring sessions every other week during the school year. STEM OUT was designed to broaden participation in the sciences by directly connecting youth with scientists in mentoring relationships. Formally, mentors supported youths' science research projects (that were academic requirements at the school), while also providing opportunities for youth to make connections between their own research and the practices of university scientists, and envision multiple trajectories to college and STEM careers. As in other educational outreach programs, STEM OUT also supported mentors' development of pedagogical and science communication skills in informal learning contexts (Scipio, 2015), which many graduate students participate in as ways to get teaching experience outside of graduate school.

As a design-based research project that underwent two year-long cycles of design, implementation, and iteration, the STEM OUT program allowed me to test design conjectures related to learning processes and outcomes for both participating scientists and youth. In Chapter Two of this dissertation, I detail this iterative design process and the resulting outcomes. I focus primarily on how youth-scientist interactions can be structured to facilitate symmetrical interactions, or relational equity (DiGiacomo & Gutiérrez, 2016) between participants, in order to counteract deficit models of youth that undergirds traditional mentoring configurations (Kafai et al., 2008) and scientist-youth interactions (Rahm, 2007; Woods-Townsend et al., 2016). I specifically focus on the powered dynamics as evidenced by patterns in mentor-youth discourse, as well as participant structures (e.g., Cornelius & Herrenkohl, 2004; Goodwin & Heritage, 1990). Analysis of these patterns over the two years of the program, in conjunction with conjecture maps (Sandoval, 2013), demonstrate how designed features that facilitated distributing expertise and building relationships within mentoring groups enabled more talk about students' project work, and ultimately had positive impacts for the youth related to their participation in the program. The findings have implications for the design of other scientist-youth partnerships, in which scientists are often positioned as experts relative to youth, and the work of building relationships is secondary to undertaking disciplinary science practices.

In Chapter Three, I present a deeper dive on the identity work that mentors undertook as they worked with youth in STEM OUT. I focus on three mentors who represent different identity pathways as scientists, educators, and graduate students, as well as varied trajectories of participation in STEM OUT. My analysis demonstrates how crossing the boundaries (Akkerman & Bakker, 2011) between science and educational outreach can be a process of integration for graduate students, as they forged new identities as education-interested scientists or teaching scientists. Additionally, the focal mentors' case studies show how participating in educational outreach can provide opportunities for scientists to try out alternative skills and identity work, relative to their experience in graduate school. They can concurrently resolve conflicted identity narratives as scientists and find professional trajectories that align with their values, which may differ from those promoted in their department (Thiry et al., 2007).

Biology Education Research Seminar for Scientists

I also explored issues of graduate students' identity work as educators in a graduate-level seminar offered through the Biology department at the focal university. The course was designed by a Principal Lecturer in Biology to introduce students to undergraduate STEM education research, mainly drawing from literature in DBER and cognitive psychology. Participants discussed readings in a journal club format that is standard in the disciplinary sciences, often focusing on how to incorporate findings into their own teaching practice. As ways to further consider how to translate research into practice, they also observed a class in the Biology department and, towards the end of the course, wrote teaching philosophy statements.

The seminar provided an interesting contrast to STEM OUT, by enabling me to explore a different learning environment (a formal class that took place on campus) and set of participants, who were actively navigating their identity work and skill development as educators. Both learning environments were focused on very similar pedagogical goals for graduate students in the sciences, and were optional experiences requiring a relatively small commitment of time and energy. However, the seminar presented a more familiar context for graduate students to engage in practices related to improving their pedagogy and concurrently "try on" identities as educators, while the STEM OUT program more dramatically took them out of their comfort zone.

In Chapter Four of the dissertation, I show how one enactment of the seminar supported graduate students' identity work as educators. I followed connections between themes of participants' motivations to take the class, interactions during the seminar, and outcomes after its conclusion to demonstrate how issues related to identity were integral to all three of these dimensions, including increases in participants' teaching self-efficacy. I describe features of the seminar that contributed to participants' engagement during the class, and provided supports for their development of practice-linked identities (Nasir & Cooks, 2009; Nasir & Hand, 2008) as education-interested scientists. This set of findings has implications for how similar types of experiences— which are being recommended for broader implementation to prepare graduate students how to teach (Connolly et al., 2016; Schussler, Read, Marbach-ad, Miller, & Ferzli, 2015)—can be designed to productively leverage graduate students' developing professional identities. This research also likely has implications for "second career" STEM professionals who decide to become classroom teachers at the K-12 or post-secondary level—since these individuals are engaged in similar identity development work as they learn about teaching practice.

Collaborative Design & My Positionality

My motivations to undertake this research are grounded in my history as a former graduate student in Biology with an interest in teaching and learning. Collaborating with other learning scientists on multiple research and design projects (e.g., Educurious, Project COOL, STEM+C) as a graduate student at the UW Institute for Science & Math Education also directly informed my approach, through creating and studying science learning environments that bridged between university scientists and K-12 youth. For my dissertation studies, it was crucial to collaborate with others in designing the research and, in the case of STEM OUT, the context for the research, in order for this work and its implications to meet the needs and visions of various audiences. For example, administrators, teachers, and youth from the STEM OUT partner high school, as well as leaders of graduate student organizations were involved in the design of the mentoring program and accompanying measures of success. Similarly, the instructor of the education research seminar participated in developing the research tools used in Chapter Three. Focal participants, such as the graduate student mentors described in Chapter Two, provided feedback on my claims on their identity trajectories via member check interviews (Creswell & Miller, 2010).

The input and reflections from partners and participants ultimately allowed for a more complex analysis of how their experiences unfolded. Additionally, working with a variety of people through the research process enabled me to integrate the diversity of participants' priorities and ideas, as well as check my own assumptions and interpretations underlying the work, as is especially salient to the process of engaging in ethnographic research methods (Erickson, 2006). With the concurrent identities of learning scientist, STEM OUT program designer/facilitator, former biology graduate student, and white, cisgender, queer woman, I occupied a complex positioning in my research contexts that transcended a continuum model of participant/observer (Emerson & Pollner, 2001). Especially with a research focus involving other people's identity work, as well as participants that included scientists and youth from minoritized backgrounds, I was committed to not overlooking or making assumptions about participants' experiences, or to only attend to aspects that corresponded to my own.

Through collaboration and reflective practice, I aspired in this work to respond to the charge put forth by Nespor (2006) to "[look] at the world as percolating out of multiple processes that need to be understood in terms of specific cultural, historical, and geographical conjunctures" (p. 297), and strive to incorporate multiple layers of meaning and experience over time. Indeed, navigating one's own identity work in a research setting can actually help to capture more complex data, since evidence comes from a researcher's own multiple perspectives (Barab, Thomas, Dodge, Squire, & Newell, 2004). Throughout my dissertation research, I was committed to the ethical obligations inherent in reflexive awareness and practices, through all stages of a project (Kleinsasser, 2000). This was crucial in order to continually interrogate my own positionality, move past static notions of subjectivity/objectivity (Madison, 2005), and attempt to not speak for others (Alcoff, 1991) in my contribution of a novel perspective on graduate student education.

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Chapter 2. Distributing Expertise and Building Relationships: Designing for Relational Equity in Youth-Scientist Mentoring Interactions

Opportunities for youth and scientists to directly interact have shown to be powerful ways for youth to develop conceptual knowledge and experience disciplinary science practices, along a number of dimensions (Linn, Songer, & Eylon, 1996; Pea, 1993; T. D. Sadler, Burgin, McKinney, & Ponjuan, 2010). Working with scientists directly on data collection and/or analysis enables students to "participate directly in ongoing practices of a [scientific] community," rather than the often abstract activities undertaken in science classrooms (Barab & Hay, 2001, p. 75). Other research demonstrates how structured field research experiences can create safe opportunities for youth to try out science-related identity work, even at the boundaries of their previous comfort zones (Carlone et al., 2015).

Studies of youth-scientist interactions often highlight the social aspects of the science learning experience, often through the lens of how they relate to the processes of disciplinary identification for the participating students (e.g., Van Horne & Bell, 2017). Youths' science-related identity work can be integral for their continued interest and engagement (P. Bell, Lewenstein, Shouse, & Feder, 2009; P. Bell, Tzou, Bricker, & Baines, 2012), as well as contribute to efforts to broaden participation in the sciences (e.g., Aschbacher, Li, & Roth, 2010). However, the emphasis of many youth-scientist partnerships on bringing youth into disciplinary science practices is limiting, because it minimizes the expertise and ideas that youth bring to the interactions and reinforces hierarchical power dynamics between youth and adults.

In this paper, I build on arguments for moving beyond a framework in which scientist-youth interactions are structured to highlight only the expertise that scientists have to pass on to students, and the ways in which youth, as novices, are inculcated to the disciplinary practices of the scientists (Jrène Rahm, 2007; Woods-Townsend et al., 2016). I focus here on two particular limits: 1) A one-way transmission model of expertise does not meaningfully recognize or take up youths' knowledge, interests, or ideas (e.g., Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). Surfacing these and incorporating students' vantage point into interactions about science can make youths' encounters with scientists consequential for their science-related identity work (Carlone et al., 2015; Tzou & Bell, 2012). Additionally, intentionally recognizing how expertise is distributed among participants fosters mutual learning processes (A. L. Brown et al., 1993), such that co-creating experiences and sharing ideas are prioritized over scientists' knowledge of content or practices (Klein, 2016). 2) Relationship building is an important, and often overlooked, dimension of youth-scientist interactions—although broad relationships are known to be central to learning in the science classroom (Philip Bell, Tzou, et al., 2012). Social interactions that extend beyond scientific content can help participants find connections across their life-wide experiences (Banks, 2007) and enable both youth and scientists to bring more of their full selves to these interactions. These relationships can also change both youths' and scientists' ideas about what counts as science. For example, scientists can learn from youth about how they see scientific ideas as relevant to their everyday lives, enabling the scientists to improve their communication with broader audiences by connecting their work to students' lived experiences (Fitzallen & Brown, 2016; Hinko & Finkelstein, 2012). As scientists, in turn, share more of who they are beyond their activities and identities as a scientist, youth can develop an expansive sense of what it means to be a scientist (Rahm, 2007; Stromholt & Bell, 2017; Woods-Townsend et al., 2016). While preparing youth for possible educational or career trajectories in the sciences is one possible outcome, a broadened sense of who undertakes science can empower youth to draw from scientific practices and ideas to utilize for their own aims (Basu & Calabrese Barton, 2007). Rahm (2007) frames this idea by posing an essential question for designers of scientist-youth partnership programs:

> What would it take for youth to come to see science as a source of inspiration, as something intriguing and valuable, and as a world including them as active agents and legitimate members irrespective of who they are or who they want to become? (p. 517)

By purposefully designing contexts for scientists and youth to share expertise and build relationships, partnership programs can broaden participation in the sciences by shifting who gets to participate *and* expanding ideas of what counts as science. Although there is support for the integral role that relationship-building plays in science teaching and learning (P. Bell et al., 2012; Lemke, 2001), more empirical accounts are needed of how to promote an emphasis on developing relationships in science learning contexts, especially when bringing youth and scientists together. This can be accomplished, in part, by developing and leveraging principles of design for scientist-youth partnership programs that are rooted in sociocultural theories of learning and foreground the important roles of distributing expertise and building relationships.

Accordingly, in this paper, I take a design perspective to consider these issues, focusing on the development and outcomes of a science mentoring program called STEM OUT, which brought together graduate-level scientists and high school-aged youth in small mentoring groups. The study follows the program across two cycles of enactment, with analysis of interactive and reflective discourse data from mentors and youth to root overarching claims and design conjectures. Below, I first situate the study in broader literature on sociocultural approaches to science learning. I then describe the research context and methods of analysis and design, followed by findings tracing how the design of STEM OUT related to distributed expertise and building relationships within mentoring groups. In the final section, I consider broader implications of the designed elements and resulting outcomes from STEM OUT for other scientist-youth partnership programs.

Conceptual Framework

Understanding how Learning Environments are Organized through Discourse

As a learning scientist, I employ perspectives on teaching and learning in this study that foreground how students' processes and outcomes of learning are intertwined with the socio-cultural aspects of their learning environment (e.g., Lave, 1996; Lemke, 2001; Nasir, Rosebery, Warren, & Lee, 2006; Vygotsky, 1978). Moreover, for an individual learner, pathways to developing expertise are determined by the opportunities to demonstrate expertise and be recognized as having expertise, with implications for who one can be in a particular learning environment (i.e., their identity as a learner, P. Bell et al., 2012; Holland, Skinner, Lachicotte, Jr, & Cain, 2001; Lee, 2017; Wortham, 2008). This means that there are opportunities and limitations on what a person can learn and, therefore, their learning identity, based on the social organization of that context (Brickhouse, 2001; O'Connor & Allen, 2010).

Discourse is one way to understand these learning opportunities and limitations. Within a learning environment, every discursive interaction between individuals impacts how and if participants can demonstrate their expertise (A. L. Brown et al., 1993), as well as make connections, to each other and to the topics being discussed. Additionally, talk provides a way to understand how a context is structured, both by the participants within it and more intentionally through designed tools and activities (Tabak & Baumgartner, 2004). Discourse is particularly salient for understanding these elements of the science mentoring program that is the context for this study, given that the primary activity involved adults and youth talking with each other. As such, patterns in their discourse and participant structures ("the roles, rights, and responsibilities regarding who can say what, to whom, and when in the course of classroom activity," Lehrer & Palincsar, 2004, p. 389) can be used to characterize the range of learning opportunities for youth, and how they changed over time as the program was modified to intentionally promote certain kinds and modes of interaction.

Science Learning Impacts and Involves Social Positioning

Contexts for engaging about the sciences involve their history as exclusionary disciplines, with specific types of expertise (e.g., objective stances derived from empirical study) and modes of discourse (e.g., prioritizing "the right answer") privileged over others (reviewed in Carlone, 2004). Calabrese Barton and Yang (2000) describe how practices of teaching and learning in science classrooms often present "a fact-oriented science which appears decontextualized, objective, rational, and mechanistic" (p. 875), prioritizing "scientific concepts over scientific contexts—those stories which shape concepts and give them deeper, complicated, and connected meanings" (p. 876). By situating scientific knowledge as acultural and exclusive of other ways of understanding the world, science learning experiences have the potential to marginalize other forms of expertise and affective experiences (Bang, Warren, Rosebery, & Medin, 2012; Brickhouse, 2001; Lemke, 2001; Rosebery, Ogonowski, DiSchino, & Warren, 2010). This has strong implications for youths' learning, by impacting their *positioning* in science learning environments (reviewed in Carlone, Johnson, & Eisenhart, 2014). Davies and Harré (1990) describe how social positioning is an ongoing, contextual process:

> An individual emerges through the processes of social interaction, not as a relatively fixed end product but as one who is constituted and reconstituted through the various discursive practices in which they participate. Accordingly, who one is always an open question with a shifting answer depending upon the positions made available within one's own and

> others' discursive practices and within those practices, the stories through which we make sense of our own and others' lives. (p. 46)

In terms of learning, positioning determines how youth orient to the norms of what counts as scientific expertise and are recognized by others as successful (P. Bell, Tzou, Bricker, & Baines, 2012; Brown & Spang, 2008; Carlone & Johnson, 2007). Further, this process of interactive positioning can provide access for youth to reflexively position themselves— to identify either as a part of or be excluded from a particular discipline or community (Bricker & Bell, 2012b; Harré, Moghaddam, Cairnie, Rothbart, & Sabat, 2009; Holland et al., 2001). Additionally, as emphasized in the quote above, positioning—by its very definition as a temporally dynamic phenomena—is not static over time, but changes from moment to moment and across contexts, depending on who is present during an interaction and how that interaction is structured (Calabrese Barton et al., 2013; Carlone, Scott, & Lowder, 2014; Lemke, 2000; Wortham, 2006).

For example, youth may be oriented differently towards science in the classroom as compared to at home, depending on their access to identity resources, social positioning, and the socio-material arrangements of those two settings (P. Bell, Tzou, et al., 2012; Bricker & Bell, 2013). In general, informal learning environments, such as the science mentoring program described in this study, provide specific affordances by socially organizing a learning environment that is not bound to the constraints often found in classroom settings, with the potential to expand what discourse, expertise, and identities "count" as scientific (P. Bell et al., 2009; National Research Council, 2015). Although it is possible for science classes to include similar structures (Rosebery et al., 2010; Tabak & Baumgartner, 2004; Van Horne & Bell, 2017), discursive interactions in informal learning environments that (re)position youth as successful in science can involve: 1) eliciting and valuing youths' ideas; 2) providing opportunities for youth to make connections between their scientific ideas and everyday experiences; and 3) situating science as embedded in socially relevant pursuits, as defined by youth (National Research Council, 2015).

In this study, I focus on the positioning of the youth within mentoring groups, and how interactions with scientists and peers provided or constrained opportunities to showcase their expertise. As such, my analysis of talk between youth and mentors employs a broadened sense of *participant structures* to encompass how conversational moves demonstrate and have implications for participants' social positioning and power, relative to each other (Goodwin & Heritage, 1990) and to the larger discipline being discussed (Cornelius & Herrenkohl, 2004).

Structuring Mentoring Relationships to Disrupt Traditional Models of Expertise

Research from the learning sciences on mentoring programs demonstrates how their intentional design can disrupt hierarchical and problematic relations between adult and youth participants, which, in turn, impacts their subsequent social positioning. For example, mentors who undertook reflective practices developed more symmetrical power dynamics in their interactions with youth, or what DiGiacomo and Gutiérrez (2016) term, "relational equity." By doing so, participants have opportunities to view and position each other, as well as themselves, differently than traditional configurations of adult-youth interactions— for example, Kafai and colleagues (2008) found that mentors working with youth in a technology-focused out-of-school context positioned themselves as learners, observers, and co-constructors rather than strictly as teachers or facilitators. Further, upon reflection, many mentors cited changes in their perceptions of their mentoring roles, "gaining an understanding that being a learner is an equally important facet of [their own] critical learning" (p. 201).

Non-traditional mentoring arrangements foster stronger relationships between participants, which also have affordances for youth (Rhodes & Dubois, 2008). Working with an adult mentor that youth respect and value helps to orient towards being positively positioned as part of a broader network and community (Barron, Gomez, Pinkard, & Martin, 2014; Ching, Santo, Hoadley, & Peppler, 2016), especially if they are collaborating towards a shared goal or product (Chávez & Soep, 2005; Halpern, 2005; Heath, 2012). The outcomes from building relationships are particularly salient for students who may feel marginalized from their school communities or disciplinary focus of a particular mentoring program, and/or for whom seeking connections from adults is challenging (Ching, Santo, Hoadley, & Peppler, 2015). As such, in this study, I seek out the structures that supported participants' relationship-building activities within their mentoring groups, and how developing relationships related to broader patterns of discursive interactions, youth engagement, and positioning.

Foregrounding Youth Expertise during Interactions with Scientists

For the scientific disciplines, experiences that enable youth to interact directly with scientists provide an opportunity for them to be positioned as successful in the sciences (Rahm, 2007; Woods-Townsend et al., 2016), in ways that may differ from their classroom experiences. However, scientist-youth partnership programs, as described in the research literature, often take up a cognitive apprenticeship model (A. Collins, Brown, & Holum, 1991), in that scientists are generally positioned as the sole expert, with youth positioned as novices (Rahm, Miller, Hartley, & Moore, 2003). They learn the vocabulary, practices, and norms of a scientific field as they are led by scientists through a strategic scaffolding process of participating in disciplinary practices. These types of experiences can be valuable for youth to cultivate narratives of themselves in a scientific discipline by undertaking activities deemed scientifically authentic (Barab & Hay, 2001; R. L. Bell, Blair, Crawford, & Lederman, 2003; T. D. Sadler et al., 2010; Thiry, Laursen, & Hunter, 2011; Tinker, 1997).

In contrast, interactions with scientists that foreground youths' research and expertise provide an opportunity to develop relational equity and complicate unidirectional expert-novice dynamics. For example, Rahm (2007) organized an experience for youth to design and undertake interviews with scientists, as a way to "learn about science as a system of social practices and about the 'human element'" of doing science (p. 540). Interviewing scientists about a variety of topics not only expanded youths' notions of science and scientists, but, importantly, the discursive and youth-led nature of the experience "erased status differences between youth and scientists temporarily… No one voice was privileged over another" (p. 542). Given mentoring programs' emphasis on social interactions and relationships, science mentoring opportunities between youth and scientists provide an ideal context to expand upon these types of findings, especially if they are structured in non-traditional arrangements as described above.

Science mentoring programs that also bring together young people at various stages of their academic careers can be valuable for both sets of participants. Tenenbaum and colleagues (2014) describe a tiered "near peer" mentoring program in which undergraduate and post-baccalaureate students were guided by university faculty as they worked with middle and high school youth in a structured research experience. As in other mentoring experiences described above that brought together young adults with youth (Kafai et al., 2008), mentors cited how they learned more about themselves as scientists by working with students, with youth characterizing their mentors as "guides for learning" (p. 382). Undertaking peer or near-peer science mentoring provides an opportunity for young scientists to highlight their developing expertise and how they can leverage it in working with youth, and, further, are brought into a model that encourages integration of their personal interests with scientific research, teaching, and mentoring (Tenenbaum et al., 2014).

This exemplifies a social practice approach to science mentoring (William R. Penuel, 2016), by "foregrounding persons and practices' mutual constitution… [rather than a] focus on how persons apprentice to practices that are positioned as stable and decontextualized" (p. 92). Employing such an approach enables participants to relate between their practices across both everyday and professional pursuits, which they come to see as relevant through social interactions. In turn, making these connections can bring both youth and scientists into a broadened image of what counts as scientific practices (Rouse), impacting their future "scopes of possibility" in the sciences and beyond (P. Bell et al., 2012, p. 277).

Designing for Relational Equity in Scientist-Youth Mentoring Interactions

Through the design of informal science learning environments that leverage the above ideas, the processes of expertise development, positioning, and relational equity can be impacted in specific ways. Facilitating mentoring programs as partnerships is a crucial way to counteract deficit models of youth that undergirds traditional mentoring configurations (DiGiacomo & Gutiérrez, 2016; Kafai et al., 2008). As described above, programs that enable direct interactions between scientists and youth (or teachers) have the potential to re-position youths' orientations towards science, as well as shift scientists' orientation to K-12 education (Tanner, 2000; Woods-Townsend et al., 2016). Additionally, accounting for the experiences of all participants and stakeholders through intentional design of science partnerships between universities and schools is crucial to equitable engagement and, ultimately, outcomes for those involved (Falloon, 2013; Miranda & Hermann, 2010; K. Sadler, Eilam, Bigger, & Barry, 2016; Wormstead, Becker, & Congalton, 2002). By incorporating these ideas into the design of STEM OUT, I sought to understand how to cultivate a learning environment in which scientists and youth developed relational equity in their mentoring interactions, with implications for broadening participation in the sciences.

Over time, a particular context is constituted by the modes of participation within it, as people undertake specific practices together (Holland & Lave, 2009; Holland et al., 2001), which are in turn informed by their endeavors in other contexts (Dreier, 2009). As such, the mentoring program was a socially constituted space that offered opportunities for scientists and youth to reconfigure how they interacted relative to other contexts for science learning. The social norms for doing so were both externally imposed through intentional design features and internally developed as the mentoring groups interacted over time. Accordingly, I use a Design-Based Research framework (Cobb, Confrey, Lehrer, & Schauble, 2003; The Design-Based Research Collective, 2003) to attend to these processes, specifically on how expertise was distributed and relationships were built within mentoring groups. Further, through an iterative design process that spanned over two years, my collaborators and I sought to complicate the one-way expertise transmission model and privileging of scientific content that are prevalent in scientist-youth programs, by emphasizing opportunities for youth to signify their expertise and all participants to develop relationships during mentoring interactions.

Research Question

Against the backdrop of this conceptual framework, I investigated the following question in this study: What design features promoted participation structures to support relational equity between scientists and youth as they interacted in a science mentoring program?

Research Context & Methods

Analytic Approach

Recognizing that external structures directly impact what happens within a particular learning context, I studied the design as well as the processes of participating in the STEM OUT program. In the analysis described below, I identified what features facilitated the development of relational equity within mentoring groups, and the effects of doing so. In line with sociocultural approaches to educational research, I attended to how outcomes for participants "came about," rather than assessing against a set of benchmarks or expectations (e.g., Lave, 1996). For the mentoring interaction data, I consider the powered dynamics of science learning contexts by analyzing patterns in the structures of participation in the mentoring groups (Cornelius & Herrenkohl, 2004; Goodwin & Heritage, 1990). I utilized conjecture maps (Sandoval, 2013) in conjunction with analysis of mentoring interactions and reflections to understand how iterative design changes had differential impacts between the two years of the program. This analytic process then provided evidence to articulate broader principles to inform the design of other contexts for scientist-youth interactions.

With this approach, I take a critical design ethnographic stance (Barab, Thomas, Dodge, Squire, & Newell, 2004), to understand how the design of the STEM OUT context mediated the social interactions that ensued. Through a process of "participatory design and co-evolution that is never quite complete," (Barab et al., 2004, p. 259), this tandem research and design work is intended to inform broader conversations on how scientist-youth partnership programs can support participants' development of expansive views of the sciences.

Research Context & Participants

The STEM OUT mentoring program was a Design-Based Research project that went through two school-year cycles of design, implementation, and iteration. STEM OUT was funded by the AAAS STEM Volunteer Program and represented a collaboration between a large university in an urban center in the western United States and a small, STEM-focused public school, located 25 miles from the university. In the program, university scientists—mainly graduate students, representing a range of scientific fields (see Table 2.1)—met for hour-long mentoring sessions every other week with groups of two to three high school students at Regional Technology Academy (pseudonym; RTA). RTA aimed to empower students from under-represented backgrounds in the STEM fields; this mission is reflected in the school's demographics (Table 2.2), as well as the inter-disciplinary, problem-based learning instructional approach leveraged in RTA classes.

The STEM OUT program directly connected youth with scientists in mentoring relationships. Formally, mentors supported youths' science research projects: seniors designed and implemented an individual year-long research and community engagement project as the culmination of their high school experience, while non-seniors completed a project for the school-wide science and engineering fair. Through collaborative design of STEM OUT with partners from RTA and the university (see below), we conjectured that young, graduate-level scientists would be able to readily connect back to their high school and college experiences, given their relatively recent occurrence. Participating mentors varied in terms of their previous experience working with youth, with all identifying as having some amount of experience, although not necessarily with high schoolers (Table 2.1). Before each school-year iteration, mentors took part in a two-hour orientation workshop, in which they learned more about RTA and current systemic approaches to science education, discussed issues and experiences related to science and minoritized communities, and shared their own skills and ideas about mentoring.

Table 2.1. STEM OUT Mentor Demographic Data

Program Year(s)	Pseudonym	Status & Field	Age	Gender	Race/Ethnicity	Previous Experiences Working with Youth
1	Amy Schumer	5th year PhD, Chemistry	28	Female	Caucasian	Tutor, International High School Teacher, Graduate Teaching Assistant (GTA)
1	John Watson	2nd year PhD, Microbiology	26	Male	Caucasian	Children's Hospital Volunteer, Camp Counselor, Rowing Coach
1	Len Chui	2nd year MSc, Quantitative Ecology	24	Male	Chinese	Tutor
1	Mike Davidson	Graduated, AB Economics/Chemistry	28	Male	White	Chess Coach, SAT teacher
1	Pita Costanza	2nd year PhD, Chemistry	23	Female	Caucasian	Science Fairs & Festivals, GTA
1	Sasha Fierce	Post-baccalaureate Research Fellow, Microbiology	24	Female	Hispanic	Tutoring, Peer Mentor
1, 2	A.J. Princeton	3rd year PhD, Chemistry	25	N/A	Caucasian	Science Fairs & Festivals, GTA
1, 2	Dave Keuning	2nd year PhD, Chemistry	24	Male	Caucasian	Boy Scouts, GTA
1, 2	Percival Dittmeyer	1st year PhD, Biology	23	Male	White	International Youth Outreach, Tutor, GTA
1,2	Denard Robinson	4th year PhD, Microbiology	25	Male	White/Latino	Science Fairs & Festivals
2	Claire Tanner	2nd year PhD, Biological Oceanography	31	Female	White	High School Science Student Teacher, Science Tutor, GTA
2	Evan Kennedy	2nd year PhD, Electrical Engineering	33	Male	White	Middle School Mentor on Physics Outreach Project
2	Leah Klomsky	Postdoctoral Scholar, Neuroscience	29	Female	White	Camp Counselor, Science Museum Volunteer
2	Lennis Carmacho	3rd year PhD, Chemical Engineering	27	Female	Hispanic (Puerto Rico)	Mentor to Undergraduate Research Assistants, Summer Camp Tutor
2	Maya Ayman	Post-baccalaureate Research Fellow, Microbiology	22	Female	Middle Eastern	Tutor, Undergraduate Teaching Assistant

*All demographic data were self-identified by participants on their program application.

Table 2.2. Regional Technology Academy Student Demographic Data, 2016

Gender	
Male	51%
Female	49%
Race/Ethnicity	
White	31%
Hispanic	22%
Black	18%
Asian	15%
Other (Pacific Islander, Native, Multi-Racial)	14%
Other	
Free/Reduced-price Meals	51%
Special Education	8%
Graduate On Time	95%

Collaborative Design and Reflection to Address Positionality

In this study, I acted in the multiple roles of STEM OUT program coordinator, designer, and researcher— a complicated positioning in the work that transcends a continuum model of participant/observer (Emerson & Pollner, 2001). As such, I supported the graduate students in developing their mentoring practice, helped to facilitate the ongoing program activities with youth, and communicated with all participants on their reflections and experiences, including the RTA administrators. In order for the program to meet the needs and visions of the various participants, I collaborated with RTA administrators and leaders in university graduate student organizations on the funding, design, and implementation of STEM OUT. As recommended by Barab and colleagues (2004), collaborators followed from my previous relationships with these partners on other projects. We had design meetings before each iteration of the program, as well as debrief meetings at the end of each iteration to collectively reflect on the outcomes. Throughout each year of implementation, I met informally with the RTA principal and the staff/faculty members who helped to facilitate the program: in Year One the dean of students, Laura, and in Year Two the Extended STEM Research class teacher, Dana. As research data, these reflections from design partners, in conjunction with the feedback from the participating graduate students and youth (as detailed below), allowed for a more complex analysis of how STEM OUT unfolded. By incorporating mixed method analysis of data from multiple viewpoints over a two-year time span, this study responds to the charge put forth by Nespor (2006) to "[look] at the world as percolating out of multiple processes that need to be understood in terms of specific cultural, historical, and geographical conjunctures" (p. 297).

Tracing Outcomes to Design through Conjecture Maps

To aid in tracking our collective design thinking over time, I employed conjecture maps (Sandoval, 2013) as a tool to assess if the outcomes for which we originally designed STEM OUT were supported by participants' observable interactions, reflections, and artifacts. By spanning across two design cycles, findings from Year One directly informed the design of the program in Year Two. Additionally, after the conclusion of the program and data analysis, I created retrospective conjecture maps to trace what emerged through participants' mentoring interactions as a result of the constructs of distributed expertise and building relationships. This exercise helped to produce the design principles presented in the conclusion of this paper, to inform the design of scientist-youth partnership programs in other contexts.

Data Collection, Sampling, & Unit of Analysis

Data for this study comes from two years of mentoring sessions between 15 mentors and 53 students (Table 2.3). I took ethnographic field notes on the high level of topics and patterns of mentoring groups' interactions, as well as the talk between mentors in our drives together between the university and RTA (Emerson, Fretz, & Shaw, 2011). Mentoring groups' hour-long sessions were also recorded using audio and/or video. Focus groups were conducted with youth participants at the end of each school year, in order to understand their perspectives on the program. In collaboration with school administration, students were also given a reflective survey in the middle of Year One and an expanded pre/post survey in Year Two. Finally, I conducted semi-structured interviews with mentors at the end of each school year to elicit their reflections.

The reflective data (focus groups with youth and interviews with mentors) were transcribed for a fine-grained depiction of participants' experiences of STEM OUT. As a way to understand broad themes across the program and changes that took place within and between the two cycles of design, I sampled across the interaction data, selecting two sessions (one early, one late) from each mentor in each year. Each of these hour-long sessions was content logged (Derry et al., 2010), tracking the content and direction of conversational turns as participants interacted. Since I was present for the majority of the mentoring sessions when they took place, I compared the logs of sampled sessions with my field notes to ensure that they were representative of typical mentoring interactions for a given group (Erickson, 1986).

Table 2.3. Data for STEM OUT Design Study

Aspect of Program	**Participants (*N*)**	**Data Used in Analysis**
Mentoring Sessions	Mentors (15) & Youth (53)	38 hours audio/video Observational field notes from 25 sessions Mentors' Notes & Artifacts from 25 sessions E-mails between Mentors & Youth
Car Ride Reflections	Mentors (15)	25 hours audio from 25 session days
Focus Groups	Youth (44)	3 hours audio/video Posters with anonymous student responses (Year 1)
Mid-Year Survey (Year 1)	Youth (12)	Open-ended and rating response data from 12 students
Pre/Post Survey (Year 2)	Youth (34)	Open-ended and rating response data from 14 students (Pre-Survey); 20 students (Post-Survey)
Semi-Structured Post-Interviews	Mentors (13)	17.5 hours audio/video

This study is concerned with how relational equity developed between youth and mentoring scientists, by analyzing participation structures during their interactions and how they were impacted by the design of STEM OUT. Therefore, the unit of analysis is each year of the program itself, with a focus on the connections between themes of mentoring talk, participants' reflections, and the program design.

Coding & Analysis

The content logs of mentoring sessions were then coded using Dedoose v.8.0.33 using tools of discourse analysis (Gee, 2011). For each conversational turn, I coded the direction of interaction (e.g., "student to mentor" or "non-senior to senior student"), type of talk (e.g., "brainstorming," "asking questions"; see Appendix A), topic of discussion (e.g., "student's project work"; see Table 2.4), and source of expertise for that topic (mentor, youth, or mutual; Table 2.4). In addition to these emergent codes, I employed theoretical constructs of interest as parent codes, with emergent themes being identified as sub-codes. For example, I attended to how conversational moves by the mentors that positioned youth or themselves in certain ways (Harré et al., 2009), with the data directing me to the ways that they were positioned, such as: "youth as expert" or "mentor as learner". I also coded when participants specifically referred to or used designed elements of the program, such as tools or activity structures. For reflective and survey data from mentors and youth, I then open coded themes found across participants, in order to triangulate their experiences with the analyses of the mentoring sessions.

Analytically, coding was a first step to index the interaction data, in order to identify the participation structures that undergirded mentoring sessions. By subsequently analyzing coded data across mentoring sessions, I identified prevalent content themes and the modes and directions of interaction. Themes foregrounded conversational aspects such as: who is afforded and takes opportunities to speak, how the framing and topic of questions frames the speaker's expectation of the respondent's expertise, and how uses of designed elements either enabled or constrained participants' talk.

Qualitative analysis of these themes, in conjunction with the conjecture maps described above and descriptive statistics of mentoring groups' trends in discourse (Heath & Street, 2008),

Table 2.4. Most Common STEM OUT Mentoring Discussion Topics

Year 1												
Source of Expertise	Youth	Mentor	Mutual	Mutual	Youth	Youth	Mentor	Youth	Mentor	Mentor	Varied	
Topic	Project Work	College-General	Hobbies	Family	High School-General	High School-Systems & Culture	College Entry-Logistics	High School-Schoolwork	College Experience-Academic	Science	All Other Topics	**Total**
# of Talk Turns	126	81	81	59	53	50	49	46	45	41	358	989
% of Year 1 Total Dataset	12.7%	8.2%	8.2%	6.0%	5.4%	5.1%	5.0%	4.7%	4.6%	4.1%		

Year 2												
Source of Expertise	Youth	Youth	Mentor	Youth	Mutual	Youth	Mentor	Mutual	Mutal	Mutual	Varied	
Topic	Project Work	High School-General	College-General	High School-Systems & Culture	Family	High School-Schoolwork	College Entry-Logistics	Travel	Mental Health / Stress / Feelings	Pop Culture	All Other Topics	**Total**
# of Talk Turns	190	93	59	48	38	34	30	26	23	21	187	749
% of Year 2 Total Dataset	25.4%	12.4%	7.9%	6.4%	5.1%	4.5%	4.0%	3.5%	3.1%	2.8%		

allowed me to make higher level claims that: 1) highlight the ways that mentoring interactions created or constrained opportunities for distributed expertise and building relationships (Gee, 2011) and 2) connecting these findings to the structures of STEM OUT through analysis of design (Blomberg, Giacomi, Mosher, & Swenton-Hall, 1993). As such, I used a process of writing memos that triangulated between the data sources, seeking connections or disjunctions between design features, participants' interactions, and reflective data (Strauss & Corbin, 1990). These memos allowed me to make increasingly higher level claims as I abstracted up from the data (Erickson, 1986; Miles, Huberman, & Saldana, 2013), in order to connect to theoretical constructs and craft design principles (P. Bell, 2004; Gravemeijer & Cobb, 2006). In keeping with methods for ensuring validity of my findings (Erickson, 1986, p. 147), I worked with colleagues to check that my claims were representative of the breadth and depth of the dataset and grounded in sound interpretation of the evidence. In my search for disconfirming evidence, I note below when counter-examples were present in the data—which provided a rich area for subsequent theorizing (Erickson, 1986).

Findings

Below, I describe the iterative process of designing for relational equity in the STEM OUT program, along the dimensions of distributed expertise and building relationships. For each of these aspects, I describe the initial design at the outset of Year One, followed by the related outcomes based on evidence from participants' interactive and reflective data. I then detail how Year One findings informed the program co-design for Year Two, and the subsequent changes in Year Two mentoring group discourse, participant structures, and reflections.

By undertaking this design-based research approach to modify the programmatic components through closely attending to participants' experiences, STEM OUT was responsive to youths' and mentors' needs, which then directly impacted the types of discourse that ensued. Primarily, in terms of distributed expertise, there was an increase in talk between youth rather than between mentors and youth, and the amount of discussion focused on youths' sources of expertise increased in Year Two. When the program shifted to highlight developing social relationships in Year Two, there was more talk about youths' research project work, relative to Year One. The relationships between design, mediating processes, and outcomes for each year are illustrated in conjecture maps shown in Figures 2.1-2.3, while relevant conceptual connections and design principles are detailed in the Discussion section that follows.

Distributed Expertise Surfacing in the Mentoring Program

STEM OUT mentoring groups were structured to disrupt a traditional apprenticeship model of expertise and facilitate relational equity between youth, their peers, and adults. The section below depicts how youth were afforded opportunities to signify their expertise during mentoring interactions and the outcomes of doing so over the course of two years of the program (Figure 2.1). I highlight how these opportunities emerged through two specific pathways related to social positioning: 1) youth were positioned as mentors to their peers; and 2) mentors positioned students' project work as similar to their own research as graduate-level scientists.

Year one design: Collaborative design leading to structures for peer mentoring.

Peer mentoring was an integral component of the STEM OUT mentoring partnership model. However, the details for how to structure peer mentoring arose through the collaborative design process of the program being initially built. Before Year One, I met with leaders of university student organizations who partnered on the project. One leader, A.J., who was affiliated with Chemists for Social Justice and ultimately participated as a mentor in both years of the program, suggested having mentoring groups that consisted of youth from different

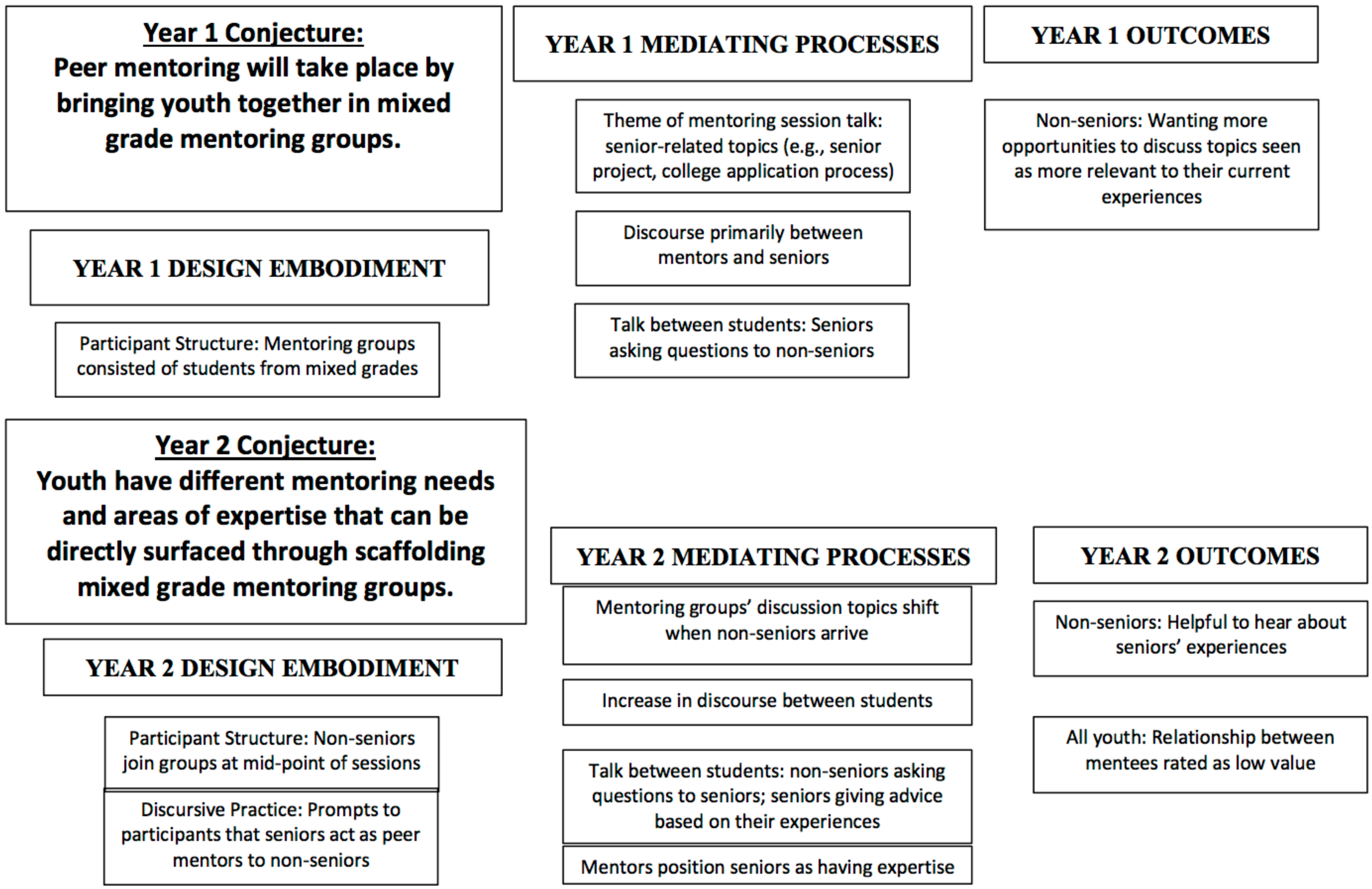

Figure 2.1. Distributed Expertise (Peer Mentoring) Conjecture Map

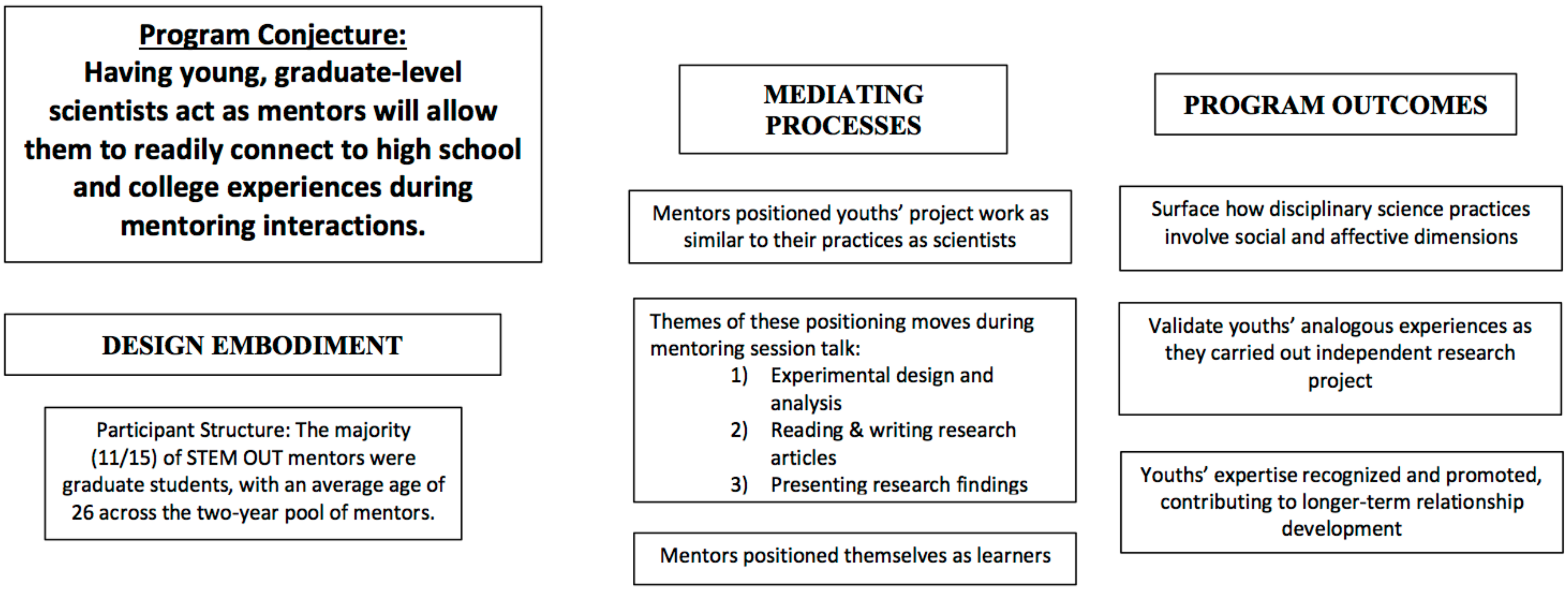

Figure 2.2. Distributed Expertise (Graduate Students as Mentors) Conjecture Map

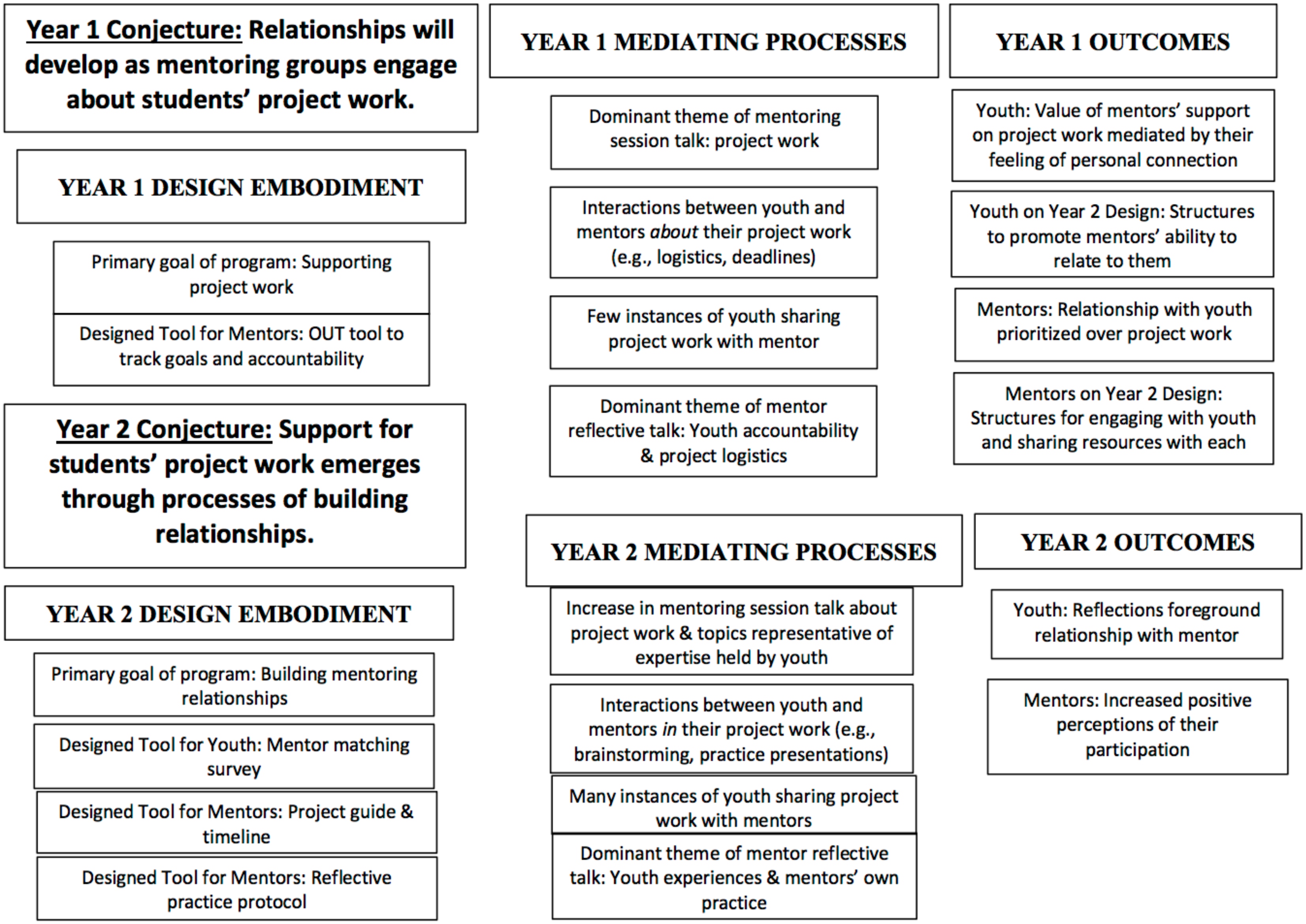

Figure 2.3. Building Social Relationships Conjecture Map

grades, so that older students could share experiences with the younger students. The RTA administrators enthusiastically agreed with this design decision, as it aligned with their institutional goal of encouraging connections between students across grade levels. As a result, mentoring groups consisted of one scientist, two high school seniors (such that the program then included the school's entire senior class of 20 students), and one to two non-senior students.

Year one outcomes: Mixed grade groups did not facilitate peer mentoring.

Over the course of the year, students expressed ambivalence about having mixed grade mentoring groups. Non-seniors reflected that it was generally helpful to hear about the process of undertaking the year-long senior research project and applying to colleges. However, some non-senior students disclosed to Laura, the dean of students who helped to facilitate Year One of STEM OUT, that sessions were often dominated by these senior-related topics and they did not always feel that they were getting the support that they wanted for their own project work. In line with this, the coded talk data from Year 1 showed that college was a dominant topic of conversation (17.8% of the dataset; Table 2.4). While conversations about college may ultimately be useful for younger students as they approached their senior year, some students may not have valued talking about college during their early high school career—especially since Year One non-seniors were mainly ninth and tenth graders.

Analysis of the interaction data from Year 1 also showed that the intention to foster peer mentoring through mixed grade mentoring groups was not borne out. Despite a few mentors' occasional attempts to directly position seniors as mentors to the younger students (three instances in the data corpus), talk between students was rare (Figure 2.4). When successful dialogue did occur between students, it was initiated only by seniors. For example, during an early session, Billie, a senior in Len's group, asked a ninth-grader about his project work and

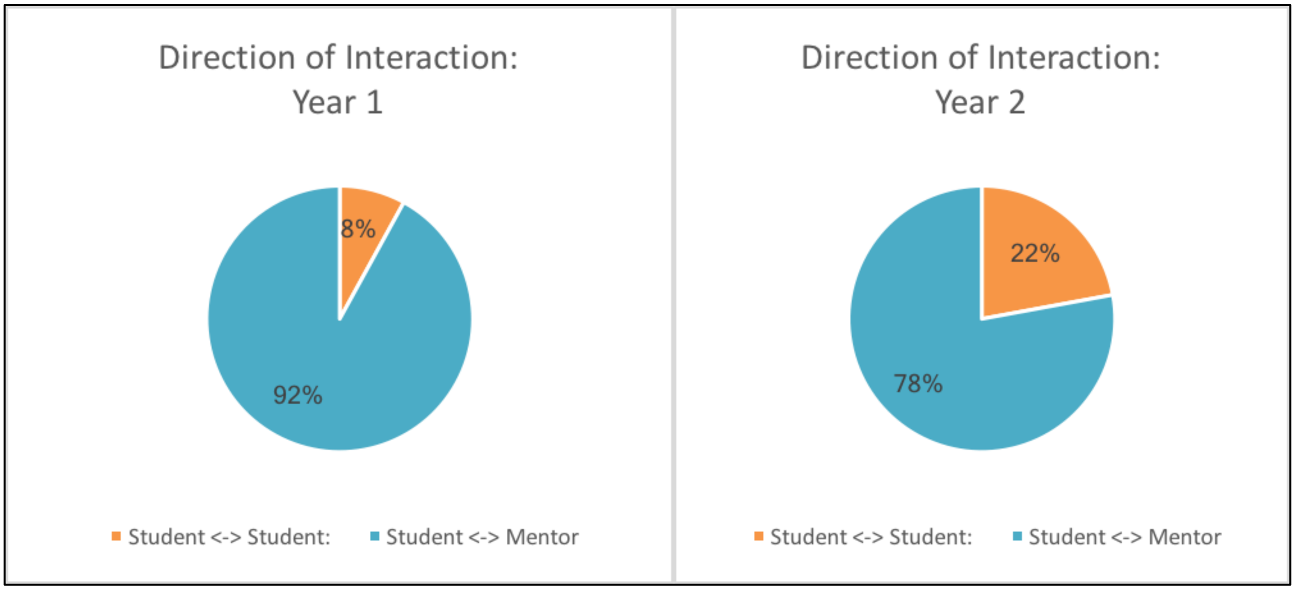

Figure 2.4. Direction of Discursive Interactions During STEM OUT

prompted him to share his life goals as part of an icebreaker activity. These individual exchanges helped to engage the non-senior in his group, an outcome that the program design had intended to promote more universally across mentoring groups (Figure 2.1).

Year two design: Rearranging social arrangements.

These findings led to two important design decisions for Year Two to more strategically encourage peer mentoring between youth participants (Figure 2.1): 1) having the non-seniors join their mentoring groups halfway through the session, so that seniors and mentors could first discuss the details of their independent project work and college-related topics; and 2) directly positioning the seniors as peer mentors to the non-seniors. This was mainly accomplished by Dana, the Year Two teacher collaborator. When non-seniors arrived around the mid-point of the sessions, she paused mentoring groups' conversations in order to shift their focus, prompting them to discuss science fair project deadlines or other topics that were relevant to the non-seniors, and reminding seniors that they were in a position to mentor other students. Over time, Year Two mentors began to intentionally change the focus of the conversation as soon as the non-seniors arrived.

Year two outcomes: Shifting patterns in discourse & youth positioning.

In Year Two, the intentional shifts in the format of STEM OUT directly impacted modes of interaction between participants during mentoring sessions. Analysis of the Year Two data showed a pattern of more discussion between students, in comparison to Year 1 (Figure 2.4). Additionally, rather than questions being directed only from seniors to non-seniors, there was an increase in non-seniors asking seniors questions, generally around school systems and senior project work. Both in response to younger students' questions and of their own accord, seniors also gave advice to the non-seniors, drawing from their own experiences at RTA. For example, in an early session, Jaden, a junior in Evan's mentoring group talked about trying to decide if he wanted to pursue a career path in engineering or psychology. He told the group that, "I'm leaning more towards psychology now, because I like breaking down how things work, but I think it'd be cooler to figure out how people work." One of the seniors, Andrew, responded:

> Andrew: I took a psychology class last year, pretty boring.
>
> Jaden: Really.
>
> Andrew: Yeah. You should sit in on one and see how you like it.
>
> Jaden: At [community college]?
>
> Andrew: Yeah dude.
>
> Jaden: That's what I was thinking.
>
> Andrew: Honestly, it was not much of a - I don't really- I jumped into it thinking the same, kinda the same thing. But it kind of depends, cuz I had no idea what I wanted to do. So you knowing that you want to do something in [psychology], that you have a path behind it, that'll help.

Through this exchange, Andrew encourages the other student to find out more about psychology by sitting in on a college-level class, acknowledging that the junior may be more invested than Andrew had been in “leaning more towards” psychology. He drew from his own experience as a student at the school and understanding of what opportunities were available to RTA students, which were beyond the scope of guidance that the scientist mentors could provide.

As seniors took these kinds of opportunities to listen to younger students and share their expertise in their mentoring groups, there was also a trend of Year Two mentors changing how they positioned students over the year. There were multiple instances, independently of being prompted by Dana, that the graduate students specifically positioned the seniors as mentors, in ways that did not occur during Year One sessions. As an illustration of this type of positioning move, Percival, a mentor who participated in both years of STEM OUT, elicited advice from seniors for the sophomore student:

> So I have a question for the two seniors. Was there anything when you were a sophomore that you wish you had known or done differently now that you guys are getting ready to graduate? Anything you felt like that would have been good to think about coming into this last month and a half, two months?

This led to a generative conversation between all three of the youth. The seniors shared advice based on their experiences as well as things they wish they had done, in relation to managing coursework, building relationships with teachers to support letters of recommendation for college applications, and getting involved in sports (which were not formally offered at RTA).

The emphasis on peer mentoring interactions in Year Two also resulted in some changes in themes of students’ reflections. On the post-survey, non-seniors reflected on how it was helpful to hear from seniors about “What to expect in senior year and being able to bounce ideas off them,” and “hearing the other seniors talk about their senior projects and what it's like to be a senior.” However, when students were asked to categorize the value of different aspects of the program, the relationship with peers was not highly ranked by either seniors or non-seniors, while "help with project work and the "mentor-mentee relationship" were rated as the most valuable aspects. This suggests that students saw their discussions with the mentors as the primary aim of STEM OUT, and that programs involving mentoring with peers in conjunction with adults should more intentionally highlight the affordances of sharing and hearing about experiences with peers/near-peers.

Years one and two: Youths' work as similar to graduate students' work.

While positioning seniors as mentors helped to encourage discourse between students, the initial design decision to recruit graduate student scientists as mentors led to another route for distributed expertise within mentoring groups: across both years of STEM OUT, mentors positioned youths' work on their projects as similar to their practices as scientists and graduate students (Figure 2.2). By bringing together youth and scientists in mentoring relationships around ambitious independent research project work, participants' discussion of these parallels in their respective work was an embedded goal of the program design (P. Bell, 2004; P. Bell et al., 2012; Bricker & Bell, 2012a). However, the pervasiveness of positioning moves across the dataset, and the specific ways in which mentors and youth found similarities in their projects emerged from the participants' dynamic interactions. There were three main categories of practices in which mentors identified connections between students' research and their own:

1. Undertaking experimental design and analysis of results;
2. Reading and writing research articles;
3. Presenting research findings to a broader audience.

The first two categories helped scientists to surface the underlying practices involved in the day-to-day activities of being a scientist, including how so much of scientific work involves failure. In response to Billie asking her mentor, Len, about major obstacles he navigated as a scientist, he talked about the emotional impact that failure in research can have:

> You can fail really hard and like things just won't go your way. And dealing with that is something that you have to confront, that it's okay to come up short. It's sometimes okay to get something you're not expecting. **When you're doing scientific research, you don't go in already knowing the answer, that's not interesting.** You go in, expect an answer, and you might work at something a lot and find, at the end of the day, that you don't get what you were expecting. That can hit you really hard depending on what the result is like.

Len went on to share an early experience from his graduate career when his research did not go as planned, and advised students that, "you shouldn't be discouraged by failure. Cuz it's a natural part of the research process."

The third category, in which participants were often relating about the stresses involved in giving presentations, was the most common across the dataset. This especially came up in mentoring sessions towards the end of the year, as seniors brought up their anxieties around the culminating public presentation for their projects. Mentors shared their own experiences feeling anxious about presenting on their work, reassuring them that students were not alone in those worries. For example, in Year Two, Scarlet discussed her concerns about sounding confident during her senior project presentation. Her mentor, A.J., commiserated and told Scarlet about tactics that they had found useful when presenting, like "power posing" and "finding an ally in the room." Beyond giving advice, though, A.J. leveraged a growth mindset approach (Dweck, 1999) that A.J. had learned about through working with Chemists for Social Justice, emphasizing that while Scarlet's anxiety about presenting might not go away, it would get easier with practice:

> Scarlet: Well, I've always not liked presenting, that's just the kind of person that I am, but I know I have to get over that eventually.

> A.J.: Yeah well, I think 'get over it' is always, we treat it like it's a binary. Either you're fine with presenting in front of people or you're not. I think the trick is to know and recognize that this is a thing that you will need in your life and that it's hard for you, and that's fine. And you'll collect tools that will make it easier for you. I don't think you're ever just going to get over it. If you're like me, you will always have stress about presenting in front of people. But just knowing that even though this is stressful, I can do it, is really useful knowledge. Because you're an outstanding sort of person.

By breaking down the “binary” of being good or bad at presentations and noting that Scarlet will “collect tools that will make it easier for you,” A.J. encouraged her to view presenting as a skill that can be developed, while acknowledging that Scarlet’s stresses involved in public presentations may never go away. A.J.’s claims and reassurances were bolstered by drawing from their own experience, rather than just giving abstract encouragement.

Additionally, many of the mentors across both years of STEM OUT continually positioned themselves as learners and non-experts. While they often did so in reference to specific aspects of the RTA school culture and activities, mentors also shared with students when they did not know something about students’ project work. This occurred especially when students’ project topics were outside of mentors’ disciplinary expertise and was a dominant theme in Year Two mentoring interactions, in which the majority of seniors undertook social science or technology-related projects. For example, in an early session in Percival’s group, Courtney, an 11th grader, described her project to develop an app that would improve systems for matching people recently released from incarceration to supportive housing, which built on her dad’s work as a pastor and community organizer. Percival asked a series of questions to understand more about the details of both the matching process and the app, and then declared to both Courtney and Tony, a senior, “That's cool. I don't know if someone thought I was really good at app development, but you guys are both developing apps, and I know nothing about it. But, hey, I'll take it! [he and students laugh].” Over the next year, Percival continued to position himself as a learner relative to students' projects by asking questions, but simultaneously supported youth by giving advice on non-technical aspects of their work and connecting to them to people he knew who had expertise in app development. Being honest about the limits of his expertise did not inhibit, and even contributed, to the development of relationships with youth as mentoring partners (e.g., Bransford, 2007). Indeed, Courtney and Tony continued to meet informally with Percival for years after they graduated from RTA and transitioned into local universities, demonstrating how fostering relational equity in mentoring groups was instrumental to building lasting social relationships, a theme that will be expanded upon in the next section.

Building Social Relationships to Sustain Engagement and Collaboration

In addition to distributed expertise, promoting relationship-building between mentors and students was an integral aspect of the STEM OUT program. The findings below show that when developing social relationships was emphasized as a leading focus of the program, there was an increase in mentoring groups' sustained engagement and collaboration on students' project work.

Year one design: Focus on project work by scaffolding interactions.

In the first iteration of STEM OUT, building relationships within mentoring groups was situated as a secondary aim of the program (Figure 2.3). Throughout the mentor recruitment process and the orientation workshop, mentors were positioned as primarily supporting students' project work. This was demonstrated through the materials and activities provided to mentors. For example, there were resources in mentors' binders on facilitating group conversational dynamics, and the entire group did ice breaker activities on the first day of the program. However, the focal tool provided to mentors in Year One was the OUT tool, which was intended to scaffold mentors' ongoing interactions with youth by helping them to set goals and hold students accountable to those goals. Using the OUT tool, mentors could record "Ovations, Updates, and To-Do's" from each group member for the next session. Mentors were encouraged, but not required, to use the tool.

Year one outcomes: Shallow engagement about project work.

Over their 13-15 hours together through the course of the school year, mentors and youth discussed other topics and ideas, but, in line with the program's initial framing, participants mainly focused on students' project work. This is evident from quantitative analysis of Year One mentoring interactions, which showed that students' project work was by far the dominant topic during mentoring sessions (12.7% of the dataset; Table 2.4). Talk about projects often took the form of mentors asking questions, one theme of which involved probing on details of project design. In this example from an early session, Denard used questioning to help a sophomore pragmatically narrow in on his idea of building a laser device to eradicate mosquitoes:

> I'm just trying to get an idea. So if you have this laser that's on a stand, like what kind of range is that going to have? I know lasers can go pretty far, but I can imagine, the closer you are to the source, the more effective you are. So are you trying to cut something that's within a one foot radius? Two feet?

Project logistics were another common theme of questions in Year One mentoring sessions (Figure 2.5), with mentors checking about progress towards project deadlines, or trying to unpack the specifics of what students needed to do for a particular part of the project. The below exchange between Sasha and one of the seniors in her group represents this theme:

> Sasha: So, goals for two weeks from now?
>
> Ben: Two weeks from now, I'm probably going to have my source analysis and literature review done for ten sources.
>
> Sasha: And ten sources?
>
> Ben: Yeah, ten sources- that's what we… [trails off]
>
> Sasha: Okay. Will they be due that week or the week before?

> Ben: Anywhere around that week, I don't think there's a specific deadline, but we're doing one a day, so we should be done by that time.
>
> Sasha: Okay. What format, like MLA?
>
> Ben: Not really a formal thing, more like an informal analysis of why the sources are useful to you.

Mentors' discussions in the car rides between the university and RTA also reflected their concern about project logistics, with student accountability and deadlines comprising a dominant theme of their talk. Similar to Sasha and Ben's discussion above, mentors tried to discern from each other the deadlines for students' project work, occasionally tempering this with concerns about building and maintaining relationships. For example, after an early session, Amy talked about how "students seem really stressed, but won't tell me when things are due." Percival discussed wanting to balance "being supportive, but also, [students] need to get this done."

This tension between accountability and building relationships was further exemplified by the use of the OUT tool. In Year One, only two mentors routinely utilized the OUT tool during their sessions, citing its utility for helping youth set goals, but also to keep track of what students had been up to since the previous session. The mentors who did not use the OUT tool were mindful of not wanting to be another adult in student's lives reminding them what to do. One mentor, Mike, characterized this as acting as an "ally" to students and not wanting to be "super prescriptive." In line with many of the other Year One mentors, he went on to describe what he saw as ideal mentorship from a student's perspective as,

> Being able to have this third person who isn't evaluating you, right, and who you don't have to be super walking on eggshells around or feeling like you can't unload or whatever you need to do. Having this extra voice there is super useful.

Overall, the above quotes and excerpts from mentoring interactions are representative of the discussions between mentors and with youth on students' project work in Year One.

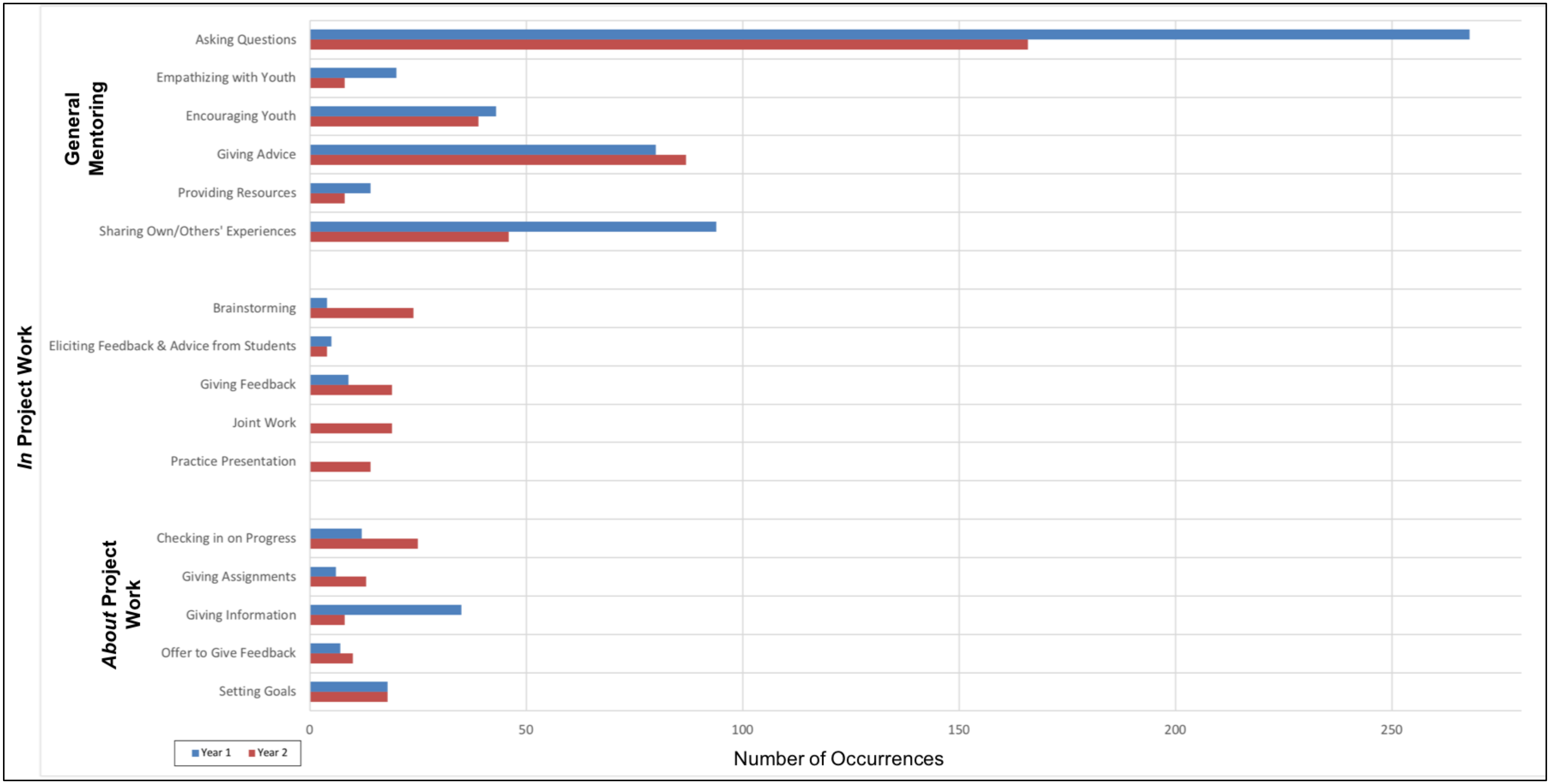

Figure 2.5. STEM OUT Mentoring Practices Across Program Years

Participants talked *about* projects on a surface level, but did not deeply engage *in* project work together— e.g., collaborative brainstorming, mentors giving feedback on writing, or youth practicing presentations of their work.

A counter-example to this claim demonstrates how being *in* project work together was mediated by the mentor-youth relationship, as found for youth outcomes of participating in mentoring programs more generally (Rhodes & Dubois, 2008). There were two exchanges in the Year One data corpus in which a mentor and youth directly interacted with artifacts or writing from student's project work; the following representative interaction took place during a session right before winter break. Mia, a senior, told Amy that she needed to "take more control of her project," and then initiated sharing her research proposal:

Mia: Can you check it, actually?

Amy: Yeah yeah yeah. I'd love to. Are you able to print it or do you want me to do it-

Mia [opening her laptop] Whatever's better for you.

Amy: Okay. Also, you can send it to me by e-mail. Because that way I can spend a little more time looking over it. Because it usually takes me a while to go through something. And then, you should also tell me, I remember last time we met you were like, 'Be mean, be brutal!'

Mia: Yeah.

Amy: But on this side of things, are you still thinking that?

Mia: Yeah. (Amy: Ah!) I need to get my shit together!

[They laugh together]

This excerpt highlights how Mia and Amy's established relationship informed Mia's decision to share her proposal during the session: she casually asks Amy to give feedback, Amy jokes about "being mean," in reference to a previous request from Mia, and they laugh together about Mia's declaration. Their bantering conversation continued on other topics, like watching Netflix and

Mia's job, as Mia opened the proposal file on her computer. Amy then gave detailed feedback on Mia's proposal, both during the session and on the version that Mia subsequently e-mailed her.

Feedback from both youth and mentors after Year One provided further evidence of the importance of developing relationships as a foundation for deeper engagement about project work. The youth focus groups revealed how students' favorite aspects of the program were getting to know their mentor and talking about topics outside of their projects. Youth participants reported that mentors were somewhat helpful with project work, but, as evidenced by Mia and Amy's exchange, this perception was mediated by their personal connection. One senior framed it as: "If you like the mentor, can be beneficial for senior project. Otherwise, cool to talk about what they do on campus, but can only go so far." Students' ideas for the design of Year Two of STEM OUT were concerned with the ability of their mentor to relate to them, which further supports how the mentoring relationship was integral to the youth participants' engagement.

In their post-program interviews, many of the mentors also discussed how developing rapport with youth led to more productive interactions about their projects. For example, A.J. reflected on prioritizing developing a connection with Miles, a senior who was behind on his project:

> I was just really wary of putting too much pressure on him, so I backed off of the senior projects a lot, not wanting to only focus on him for that and then just kind of trying to throw out where I'd be useful. And so it was pretty early on that I was just like, 'Mmmm, this is I think not what I need to be here for.'

Rather than compromise their mentoring relationship, A.J. decided to support Miles' project work by sending him articles he requested outside of sessions and spending their in-person time together talking about shared experiences. In so doing, A.J. prioritized social interactions with Miles, and facilitated connecting with him by recognizing what he needed. Finally, mentors' feedback for Year Two of STEM OUT centered on wanting more structures in place to support relationship building activities, both for working with youth and for learning from each other.

Year two design: Foregrounding mentoring relationships through multiple tools.

As a result of the cumulative findings from Year One, building relationships was highlighted as one of the primary goals for Year Two of STEM OUT (Figure 2.3). This occurred in part by returning adult and youth participants sharing their experiences and favorite aspects of the program during the mentor orientation workshop and when introducing the program to RTA students. Four mentors participated in both years, and the twelve youth participants who had been non-seniors in Year One participated again, working with the same mentor when possible. Returning participants had the advantage of building upon their previous established dynamics; however, all returning mentors worked with at least one student who was new to the program, such that processes of building new relationships were at play within all mentoring groups during Year Two.

To intentionally support relationship-building activities, three new tools were designed and leveraged in Year Two. Based on students' feedback from Year One about providing preferences during the mentor/youth matching process, Year Two youth participants were given a survey in which they described their project work as well as their conception of the characteristics of an ideal mentor (Appendix B). The Year Two partner teacher, Dana, and I then used these surveys when creating mentoring groups and shared with mentors before their first session with youth, so they had a sense of youths' goals and interests before meeting them. Simultaneously, we built a guide for mentors with details on students' project work, including a timeline (Appendix C) and project assessment rubrics, so that mentors could track what was needed for their projects without having to regularly ask mentees as they did in Year One. Finally, in collaboration with educational researcher colleagues, I developed a reflective practice tool to frame mentors' discussion of their sessions during the car rides between RTA and the university (Appendix D). The tool was intended to scaffold mentors' focus during their sessions, similar to supports for novice teachers' developing the ability to "notice" through reflection (Luehmann, 2007; van Es & Sherin, 2002). In response to mentors' desires to learn from each other, the protocol was designed for dialogue between two to three mentors. It emphasized understanding more about youth participants' experiences by asking questions such as: "What did you learn about students' experiences at school, home, or in their communities?"; "How did you relate to students?"; "What were students interested in today?" Although the OUT tool developed in Year One was also available to mentors in Year Two, it was offered as part of this suite of supports to assist mentors in building relationships with youth, rather than a primary tool.

Year two outcomes: Collaborative engagement *in* the project work.

Across Year Two mentoring groups, participants were supported by the tools described above to undertake diverse ways to get to know each other. These processes of building relationships, in turn, led to sustained engagement around youths' project work and discussions that drew on youths' expertise, with both youth and adult participants feeling more successful in the STEM OUT program than in Year One.

In early sessions, interactions were informed by mentors' initial understandings about youth from their pre-surveys. For example, a senior new to A.J.'s Year Two group identified himself as a "quiet person" on his survey, which then framed A.J.'s less talkative approach during their sessions. As the year progressed, specific practices of relationship building varied between groups, depending on the dynamics of participants. For example, after Leah's first session, she noted that her interactions with the three boys in her group were more one-on-one rather a whole group discussion. At the following session, she decided to foster a group dynamic by having each person talk about "something that brings you joy" as they ate pizza together. Over time, it became a ritualized norm for the group that the youth began to prompt themselves, and led to extended conversations about superhero movies and TV shows, topics that Leah and the youth participants discovered they were all deeply passionate about. Other mentoring groups found common ground by talking about upcoming holiday plans and family traditions, asking questions about the systems and culture of RTA, or sharing struggles with managing stress and anxiety (which were prevalent among both mentors and youth as they put pressure on themselves to be successful at their independent research endeavors).

However, Year Two mentoring interactions were not only centered on shared experiences and getting to know each other: in comparison to the Year One data corpus, there was ultimately more talk about student's project work (126 instances in Year One, 190 instances in Year Two; Table 2.4). Further, these conversations generally differed qualitatively from talk about projects in Year One (Figure 2.5). For example, there were fewer interactions about project logistics and deadlines, likely due to providing the project timeline to the mentors. In an early session, Leah used the provided rubric for the senior project literature review as she worked with the seniors in her group. The criteria from the rubric helped to mediate her feedback and structure their conversation on their project work, leading eventually to this constructive exchange with John about the purpose of a literature review:

> Leah [to other senior]: Okay, so it sounds like you have a really good grasp on outline, and in terms of fleshing out an outline from a series of facts to a composed document? Okay. We can go over that. And I feel like [to John, lays her hand on his printed proposal] this is almost the opposite, where you seem to have an idea of the flow of what you want to get, but need to get-
>
> John: I've connected everything, but I don't have my citations built out.

> Leah: Yes, and we need to like more rigorously build arguments instead of just describing them as well.
>
> John: That's what I was told a literature review was, instead of arguments or that kind of ordeal, you review all of the literature and add it all into one.
>
> Leah: Right. but you want to- in my experience, the idea of a literature review is you want to be able to walk away from that with a sense of where, where the field is currently and where the open questions are.
>
> John: Oh, okay.
>
> Leah: So you can do, you're relying heavily on other people's ideas but you also want... you want to have you own spin on it, because you want that to be able, you want to use your literature review to back up, to convince people that the questions that you're interested in answering are interesting. So the way that you show that is by saying like, ‘this is what everyone else has done and this is what we know, but here is the hole that I'm looking at.’

The conversation continued, with John asking Leah questions about how to structure literature reviews and format citations, opening his files on his computer for them to review together. As they did so, John declared that he had “a much better understanding of this now.”

Beyond this representative example, there were multiple other instances of joint work between mentors and youth in the Year Two data corpus, as well as increased interactions involving brainstorming and giving feedback compared to Year One (Figure 2.5). Additionally, there were also 14 occurrences of students giving practice presentations, which were not evident in the Year One data. This was exemplified in Maya’s group when the seniors presented talks on the connections between their senior project topic and their chosen career path, which they would give that night for an all-school exhibition. As soon as one of the seniors gave his introduction, Maya and Ellis, the other senior, shared their feedback on what else he should include. These kinds of talk activities demonstrate how, in Year Two, fostering relationships enabled mentoring groups to more substantially engage in youths’ project work together.

Besides project work, the topics discussed in mentoring groups in Year Two in comparison to Year One were more representative of expertise held by youth (e.g., high school, RTA systems and culture) or mutually between youth and mentors (e.g., hobbies, family, holiday plans), rather than solely mentors' expertise (e.g., college, graduate student experience, science). This is evident from Table 2.4, which shows the most common topics in mentoring discussions across both years of STEM OUT, while Figure 2.6 shows the sources of expertise for all discussion topics more broadly across the data set. Indeed, half of the topics discussed in Year Two were grounded in youths' expertise, as opposed to one-third of topics in Year One. Intentionally emphasizing developing relationships and structuring groups to facilitate peer mentoring (as described in the previous section), then, enabled participants to feel comfortable in eliciting and sharing on a range of topics that went beyond mentors' areas of expertise.

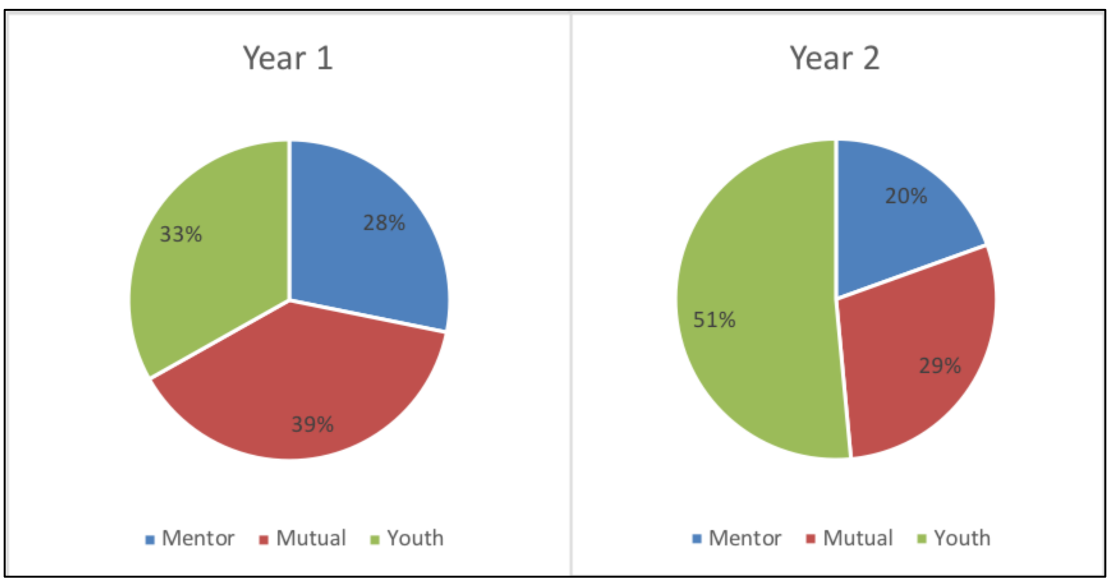

Figure 2.6. Sources of Expertise During STEM OUT Mentoring Interactions

Finally, the reflective practice protocol designed to prompt mentors' attending to student experience impacted their interactions with each other. For example, mentors talked significantly more about youth engagement (47 occurrences) in the car rides after mentoring sessions, in comparison to Year One (15 occurrences). Mentors discussed finding out more about youths' interests ("Leah said that they both watch the same animation- 'they started speaking anime, and I could no longer follow what was happening!'" - 10/29/15 Field Note), patterns of participation in their groups ("A.J. also talked about how there are some silences in the group before the non-senior gets there, A.J. is working on just being comfortable in those silences. " - 11/18/15 Field Note), as well as supporting students' progress in their project work ("Claire discussed the non-senior in her group and how he is still looking for a project topic and the challenges of trying to help him do that. Hard to sink in to things he might be interested in." - 1/6/16 Field Note). These latter two examples also show how the protocol influenced mentors' consideration of their practice, by reflecting on their role while interacting with students during sessions, rather than what youth could do differently.

Overall, reflections from the Year Two mentors on their participation in the program were more positive than Year One mentors. In contrast to themes in mentor post-interviews about student accountability and attendance in Year One, mentors shared what they had learned about students and the connections that they made through building relationships. Excerpts from interviews with Denard, who participated in both years of STEM OUT, illustrate this shift:

> Elaine: Can you think of a specific moment that you felt like you were really successful as a mentor?
>
> Denard: **I was trying to push the non-senior to look at some different [colleges]. And I was getting a little bit frustrated** because I'd tell him to please e-mail me something by Monday, and I'd send him a reminder about that on Monday, and then on Tuesday, and he never really responded. And the next time, I just brought some different, like five different schools that were pretty different from each other, and lists of what they cost, what the average class size was, what SAT scored you'd need, that kind of thing. And he had actually done a little bit of research, he was just very afraid of the number of schools, he couldn't pick from that kind of thing. **So, that was successful, I'd say, 'cuz he definitely put some effort into trying to figure out what some of his options were.**
>
> \- Year One Interview, 4/22/15

> Elaine: How do you feel like your mentoring approach potentially was different between last year and this year?
>
> Denard: **I knew there was going to be a lot of stuff that I couldn't do but there'd be some things that I could help them out with.** And I think that was actually really helpful and that, the.... so the seniors weren't the most accepting when it came to help with applications to college. That was something that I tried to keep bringing up to them, like I can see, I can read your essays, and they do have a lot of resources there for other people that read their essays. So I think they had already done that, like 'oh I don't need to show it to someone else.' **So I had a little different expectations** for not trying to say 'okay, I want to make sure both of these kids get into a 4-year university' and that kind of thing, **it's more like, where they are and what I can do to help them.** One of the seniors definitely had a lot of anxiety about college and about paying for it and the options, and I tried to let him know that he still has a lot of options, he'll go to community college, he can do well there, it will be cheaper and he can transfer to a bigger school.
>
> \- Year Two Interview, 6/6/16

Rather than concentrating on specific tasks that youth did (or did not) accomplish outside of their mentoring time together, Denard's second response shows how he is reflecting on his own practice, as well as his privilege and social position. He learned more about what the seniors in his group wanted and needed support for around applying for college and attempted to meet them where they were at rather than setting his own goals for their success that were based on his own experience.

A main theme of youth participants' reflections from Year Two also foregrounded the relationships they had built with their mentors. Eleanor, a non-senior, described how she would take forward "the advice and fun conversations I had with my mentor," while Kim, who discussed her immigration status with her mentor, shared how she felt "that I'm not alone" on her post-survey reflection. Additionally, in contrast to their Year One design recommendations on wanting more opportunities to build rapport with mentors, students' feedback centered on scheduling logistics and wanting more time to meet with mentors. This shift signifies how youth participants in Year Two were more satisfied with the mentoring dynamics and relationships that they had developed in their groups.

Discussion

In this study, I was interested in how a science mentoring program could be structured to promote relational equity between scientist and youth participants, and, further, how to articulate those structures as broader principles to inform the design of other scientist-youth partnership programs. The previous section outlined the main findings that address the first question, detailing how the distribution of expertise and prioritizing relationship-building fostered less hierarchal relations between participants within mentoring groups. Through documenting the iterative changes to the STEM OUT program design, I portrayed how designed features contributed to these outcomes. Below, I situate these findings in the broader conceptual framing presented previously, and then describe principles of design that can be adapted for any setting for scientist-youth interactions, even those of short-term duration. Finally, I address the broader implications of designing for relational equity between scientists and youth, in terms of expanding what counts as participation in the scientific fields.

Distributed Expertise and Building Relationships as Connected and Dialogic Processes

When mentoring groups were structured to promote expertise as distributed among all participants and building relationships as a focal enterprise, I found evidence of mentors and youth engaging more deeply with each other on youths' research projects and shifting from mentors' external monitoring of youths' project work to an internal collaborative dynamic. I characterize these changes as being *in* students' projects together rather than shallow engagement via talking *about* their work. My findings suggest that emphasizing the dimensions of mutual expertise and social relationships during scientist/youth interactions actually facilitated their collaboration in disciplinary practices, rather than conversely assuming (as we did at the outset of the program) that participants' focus on project-related activities will facilitate distributed expertise and relationship development.

Although situating distributed expertise and building relationships as two distinct dimensions served this analysis by disentangling the many processes that were occurring simultaneously, it is important to remember that they are directly linked, as illustrated by the following claims. As mentors and youth got to know each other over the course of one or two years, their developing relationship facilitated positioning moves that resulted in expertise being distributed more equitably among group members, as they discussed topics that encompassed youths' or mutually held expertise, rather than mentors' areas of expertise (Figure 2.6). Similarly, when mentors reflected on how it felt to "fail" at designing an experiment or commiserated about the anxieties involved in presenting research findings to an audience, they validated students' analogous experiences as they carried out an independent research project (which some students were undertaking for the first time). Relationship building, in turn, directly contributed to and built on expertise being distributed within mentoring groups, by mentors discussing on what they had in common with youth, or what students were up to outside of school, rather than privileging scientific content knowledge or their own experiences.

Mentoring to Highlight Social Practices as Authentic Scientific Practices

Participants in the STEM OUT program did not undertake "authentic" scientific practices together in the sense usually considered in the literature on scientist-youth interactions (e.g., doing scientist-led disciplinary activities in a lab or field setting; Barab & Hay, 2001). However, by surfacing and discussing the social and affective dimensions of being a scientist, they illuminated how "authentic" scientific practices are conjoined with social processes. Rahm and colleagues (2003) describe how an expansive notion of "authentic science" should be "best understood as grounded in the relations and negotiations among the worlds of teachers, students, and scientists as they collaborate in ecologically valid contexts" (p. 251). Authentic scientific practice, then, can be re-positioned during scientist-youth interactions to encompass the many layers of coordinating social practices, navigating identity work, collaborative sense-making, and evidence-based dissent, that take place in research contexts (Bang et al., 2012; Brickhouse, 2001; Latour, 1987; Latour & Woolgar, 1986; Nasir et al., 2006; Rouse, 1996). By doing so through sharing their own research and connecting with scientists as people in mentoring partnerships, youth begin to develop an understanding of how science and engineering *in practice* are rooted in social interactions and community work (National Research Council, 2012; Penuel, 2016). This is in contrast to how scientific practices can be situated by adults working with youth, as externalized and different than what people do when they build devices at home or design a community service project (Philip & Azevedo, 2017).

Specifically, the ways that mentors positioned students' work as similar to what they were doing in their own research helped youth participants to visualize how 'doing science' involves a complex suite of social practices, rather than just 'knowing science,' as a settled set of facts presented in science classrooms (Collins & Shapin, 1986; Latour, 1987). Additionally, making connections between their mutual endeavors positioned youth as undertaking the actual disciplinary practices of scientists, legitimating the multi-faceted tensions, struggles, and successes that students encountered as they navigated different stages of the research process. This privileged youths' conceptions of authentic scientific practices, rather than bringing them into static conceptions of the lab or field-based practices undergirding the graduate students' research (Penuel, 2016; Rahm et al., 2003; Rouse, 1999). If supported over time, these kinds of positioning moves could lead to more enduring identity work in the sciences (e.g., P. Bell et al., 2012), as youth come to recognize and identify with expansive ideas about what counts as ‘doing science.’

The relationships that youth developed with scientists also played a vital role in these potential processes of envisionment. Themes from students’ reflective data demonstrate how they connected what they learned from their mentors about the social practices involved in being a scientist to their own possible futures (e.g., Stromholt & Bell, 2017; Van Horne & Bell, 2017). An example came from a Year One senior, Felicity, who developed rapport with her mentor, Pita, through talking about their shared interests in “geeky” activities such as cosplay and ComicCon. After her participation, Felicity reflected how these interactions with Pita, a chemist, prompted her to reconsider her focus in college:

> It kind of opened my eyes, cuz now I want to do engineering, chemistry, and physics, like not all of them together, but just try to see which one fits. Because seeing her passion for chemistry was like, I want that passion for my learning and so I kinda wanted that in everything.

Similarly, Jaden, a tenth grader, characterized how “his favorite aspect” of the program was talking with his mentor about the social aspects of college: “And it kinda just alleviates some of the stress, cuz it's like 'ohh, it's relatable. I feel comfortable talking about this.’” Although it is beyond the scope of this study to ascertain the impacts of their STEM OUT participation as these students moved into college, the above reflections demonstrate how getting to know a scientist and adult through developing a mentoring relationship began to reframe and reassure their perceptions of future pathways through the academic and social dimensions of college.

More broadly, findings from the analysis of talk between youth and scientists during STEM OUT mentoring interactions illuminated how the social practices that contributed to distributed expertise and building relationships also enabled key affordances for learning in informal environments (Barron & Bell, 2015; Nasir, 2012). By developing relationships that were not solely rooted in scientific expertise, youth chose to share their work with mentors, such that the scientists could give feedback and make connections to how students' research process was similar to their own. This, in turn, allowed youth to develop a sense of science as a social process and one to which they belonged and were already undertaking through their own work—as illustrated by the feedback from youth after their participation. Finally, the positioning of seniors as mentors to younger students emphasized the multiple roles that they could take on, and the expertise they had to share, as opposed to being solely learners/novices, as often occurs during adult-youth interactions (DiGiacomo & Gutiérrez, 2016).

Designing to Counter Deficit Perspectives of Youth

Beyond creating a context for youth and scientists to develop relational equity and learn from each other as they interacted, I also sought to understand the specific contextual features that enabled them to do so. Hierarchical power relations can be much more easily reified in scientist-youth mentoring programs that "are built on an inherent knowledge differential between the mentor and mentee and thus often assume inadvertently a deficit perspective" (Kafai et al., 2008, p. 202). By incorporating structures to prompt participants' reflections and interactions that countered this "inherent knowledge differential," the STEM OUT program's activities demonstrate how design can intentionally disrupt these asymmetrical relations, and, as discussed in this paper's final section, ultimately contribute to broadening participation in the STEM fields.

Below are principles of design that follow from this study's findings, with accompanying suggestions for implementing or adapting for a particular context that involves scientist-youth interactions.

Design Principle 1: Develop structures to position all participants as having expertise.

The findings from this study build on previous research on the power of eliciting and invoking youths' expertise in science learning contexts (Bell, Bricker, Reeve, Zimmerman, & Tzou, 2012; Bell, Tzou, et al., 2012; Stromholt & Bell, 2017; Van Horne & Bell, 2017). The work here presents a particular version of how to foster participants' recognition of multiple sources of expertise, by facilitating peer mentoring and having young, graduate-level scientists interact with youth. Ways to design for expertise being distributed in other settings will depend on the specifics of the localized context and activities through which youth and scientists are coming together. Some examples include eliciting interests or connections that youth have to the activities at hand, or intentionally designing activities such that youth can develop and share expertise as they interact. One way to do so is to build a jigsaw structure into activities, in which individual or small groups of students become experts on a particular content area or technique and are then responsible for teaching others.

Additionally, the STEM OUT mentors' status as early-career scientists may have more readily enabled them to find the parallels between students' research projects and their own work, given their relative positioning in their respective fields as developing experts. Therefore, creating structures to elicit and distribute expertise when working with youth may be even more salient for scientists further along in their careers, who may be accustomed to being positioned as experts.

Design Principle 2: Promote developing rapport as an integral activity.

As demonstrated by the Year Two redesign of STEM OUT, ensuring that participants recognize the value of developing relationships and the social dimensions involved in scientist-youth interactions can result in increased engagement in the scientific or mentoring activities at hand. Although the nature of relationship-building will vary for a short-term interaction rather than a prolonged mentoring experience as described here, having an introductory "ice breaker" activity to mutually share about who participants are outside of being a scientist or student is one way to accomplish this. Scientists or facilitators can then strengthen these connections by connecting to outside interests and identities over the duration of their time together with youth. Another way to facilitate relationship-building is for scientists to connect back to their experiences and interests when they were at the age of the students they will be working with, in order to remember their particular experience of adolescence or childhood and the types of concerns and pursuits that they were interested in, which may or may not be related to science or school. Similarly, scientists should be prepared to share with youth about the repertoire of ways that they see science as relevant to their lives, either currently or at younger ages. Finally, program designers can additionally support participants' building rapport by providing materials to orient the scientists to the students' school or community (especially if the program takes place in the scientists' context), so that they can ask more questions or show a basic level of understanding about their community context when meeting with youth.

Design Principle 3: Design tools to scaffold participant structures for relational equity.

In developing materials and activities for scientist-youth interactions, attending to *how* participants will interact is a key finding that follows from this study. As demonstrated in the evolving set of tools that were designed to scaffold participation structures in STEM OUT mentoring groups, encouraging collaboration, discussion, or joint work between youth and scientists can be done through straightforward means—e.g., mentoring groups were prompted to talk about non-seniors' interest and expertise. For experiences involving collaborative scientific work, a way to foster relational equity between adult and youth participants is to facilitate moments of joint sense-making by pausing to discuss what they are doing together and what it means. For scientists working with groups of students, prompting them to attend to who is talking and how much is important. A think-pair-share strategy may work well to encourage discourse in large groups, for students to talk to each other as well as the facilitating scientists. Finally, if scientists are developing their own program or youth interaction experience, building in time and structures to elicit, share, and follow up on students' ideas are crucial ways to foster relational equity.

Implications for Broadening STEM Participation on Multiple Dimensions

In regards to expanding youths' conceptions about who participates in the STEM fields, STEM OUT mentors' demographic backgrounds (Table 2.1) demonstrated a higher degree of gender and racial/ethnic diversity relative to PhD students in STEM fields across the United States (National Science Foundation, 2016). As found in another study on scientists and youth from under-represented backgrounds working together in an informal science learning environment, mentors not only served as guides into their respective disciplines, but "embodied the notion that individuals [from diverse backgrounds] can successfully complete such degrees" (Polman & Miller, 2010, p. 912). This can be incredibly valuable for youth from minoritized demographic backgrounds, especially when mentors and students also directly discussed issues of under-representation in the STEM fields (Hazari et al., 2013), which occurred on multiple occasions during STEM OUT mentoring sessions.

Reports on broadening participation often emphasize these ideas of shifting *who* studies and works in the sciences, in order to better represent the demographic diversity of the United States (Gibbs & Marsteller, 2016; National Science Foundation, 2008). While this is a vital goal, youth-scientist partnership programs provide opportunities to also redefine *what counts* as science (e.g., McDermott & Webber, 1998; Stevens, 2013). Interactions between youth and scientists have the potential to reorganize broader cultural frames for all participants: for example, challenging stereotypes of who gets to be a scientist, but also unpacking what it means to be a scientist (Rahm, 2007; Woods-Townsend et al., 2016). In STEM OUT, the ways that youth were positioned as having expertise and getting to know their scientist mentors as full people enabled this second aspect of broadening participation. As described above, they had the opportunity to understand science as a multi-dimensional suite of social practices that connected to a variety of life experiences, not just being in the lab or field. 'Doing science,' then, involved passions and struggles and family experiences, similar to what the youth encountered in their project work, which leveraged their interests and ideas that transcended the repertoire of disciplinary practices as often presented in science classrooms or other types of scientist-youth interactions. For scientists, having opportunities to recognize the parallels between their research and youths' science learning can broaden their own sense of what counts as scientific practice, and shift their orientation to K-12 education and youth engagement. For example, interacting with youth can make scientists aware of their own limitations in communicating about their experiences as a scientist (Woods-Townsend et al., 2016), or recognize how they can learn from youth, disrupting hierarchical notions of novice/expert and teacher/learner dynamics (DiGiacomo & Gutiérrez, 2016; Kafai et al., 2008).

The outcomes of this study also demonstrate how acknowledging the emotional and affective experiences involved in undertaking scientific practices and incorporating these aspects into science learning experiences can have powerful outcomes for youth (e.g., Carlone et al., 2016). This can have implications for youth that may be marginalized from science or disinterested in the vision of the disciplines as presented in classrooms, by broadening their perspectives on what counts as science. Lemke (2001) frames the implications for this on students' science identities as needing to understand the "affective response of students to our teaching, and on what exactly is happening as so many students get put off by our approach to science at just the age when they begin to consolidate their adult identities." (p. 300) The design-based research approach employed here helped to elucidate "what exactly is happening" in a particular scientist-youth mentoring program, by surfacing the contextual features that promoted relational equity that, in turn, informed students' broader conceptions of the sciences. Beyond the implications for youth to pursue science in college, graduate school, or professionally, being positioned as already successful and engaged in scientific activities is crucial to young people's leveraging disciplinary knowledge and practices in pursuit of their own valued aims and futures (Basu & Calabrese Barton, 2007; O'Connor & Allen, 2010). This study contributes one example of how to move closer to this goal through fostering relational equity between scientists and youth; through intentional design, other opportunities for scientists-youth interactions can similarly have lasting impacts for all participants.

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Chapter 3. "Learning from them as they are learning from me": Science Graduate Students' Identity Development through a Youth Mentoring Program

Calls for scientists to undertake K-12 educational and public engagement opportunities[1] are prevalent throughout the educational research literature (Barab & Hay, 2001; Newstetter, Johri, & Wulf, 2008; Sadler, Burgin, McKinney, & Ponjuan, 2010), policy recommendations (Bell, Lewenstein, Shouse, & Feder, 2009; National Research Council, 2012), and scientific funding guidelines (American Association for the Advancement of Science, 2013; National Science Foundation, 2008). As novice scholars, graduate students in the sciences are frequently involved with community engagement endeavors. The nature of this involvement can vary (Dolan, 2008), from single events such as judging at school science fairs or presenting at science festivals to more sustained opportunities such as facilitating an after-school program (Scipio, 2015b) or collaborating with science teachers to design curriculum and co-teach (American Association for the Advancement of Science, 2013; Falloon, 2013).

Although youth engagement is often thought of as an avenue to broaden the impacts of scientific research and diversify who participates in sciences (Bell, et al., 2009; National Science Foundation, 2008), they also can serve as contexts for scientists to learn how to teach. For graduate students interested in teaching, working with youth or the public can help them to build their pedagogical skills by working directly in classroom settings (American Association for the Advancement of Science, 2013; Laursen, Thiry, & Liston, 2012), improve their science communication skills (Montano, 2012), and provide a space in which to affirm or promote their

[1] Although opportunities for direct engagement between scientists and youth or community members are often called "outreach," the mechanics and history of this term implies a hierarchy between participants that privileges the expertise of scientists and the institutions they represent expertise and experience over that of youth or community members (Bell et al., 2009). Hence, this term is used minimally throughout the paper.

identities and professional goals as educators (Christodoulou, Varelas, & Wenzel, 2009; Laursen et al., 2012; Wilk, 2016).

Opportunities for science graduate students to practice teaching are crucial, given that many doctoral programs do not adequately prepare graduate students as teachers, with the primary emphasis instead on undertaking and developing research skills (e.g., Fuhrmann, Halme, O'sullivan, & Lindstaedt, 2011; Golde & Dore, 2001; Tanner & Allen, 2006). The focus on research during graduate training continues to persist despite the fact that many individuals undertake a graduate-level degree within the scientific disciplines because they are inspired to teach (Austin, 2002; Sauermann & Roach, 2012). Further, the majority of science graduate students teach during graduate school (Golde & Dore, 2001) and/or ultimately work in vocations involving teaching (Connolly, Savoy, Lee, & Hill, 2016): experiences for which their graduate training does not adequately prepare them (e.g., Anderson et al., 2011; Tanner & Allen, 2006).

Prioritizing research during graduate school is pervasive and often intentional: studies of graduate education emphasize the hierarchy that prevails between research and teaching in academic departments, with the two often positioned dichotomously. Connolly (2010)notes that, in his interviews of graduate students and post-doctoral researchers, an interest in teaching is viewed as "a sign of a failed researcher" (p. 1). Austin (2002) also cites this internalized perception by graduate students, with an interviewee from zoology noting, "Teaching takes a back seat to research . . . research gets the glory" (p. 108). For graduate students in the sciences, these perceptions are derived in part from observations of their faculty advisors: for scientists working as university research professors, there is often a lack of institutional incentives to focus on developing their teaching practice (Anderson et al., 2011; Brownell & Tanner, 2012). On a broader scale, the past decade has seen a rise of federal funding structures and policies (e.g., Brewer & Smith, 2011) to support academic communities of scientists focused on improving their own and colleagues' pedagogical practice through undertaking Discipline-Based Education Research (DBER; Singer, Nielsen, & Schweingruber, 2012) or disseminating evidence-based teaching practices (e.g., Gehrke & Kezar, 2017). However, engaging in these endeavors is not the norm for scientists at research universities, as represented by reports that they receive hardly any preparation for their roles as teachers (likely only the scant guidance offered to graduate teaching assistants, plus at best only 5-12 days of faculty development workshops over 1-3 years; (Ebert-May et al., 2011; Tanner, 2011).

The institutional incentives that perpetuate graduate students being prepared only as academic researchers also have social consequences: as alluded to in the quotes above, being successful in graduate school becomes defined by engaging in what are valued as prestigious activities and practices, with research activities (e.g., devoting extra time to a professor's research project or receiving grant funding) privileged above those connected to teaching (e.g., thoughtfully preparing a syllabus or taking a workshop on improving pedagogy). By participating in activities related to teaching and/or research, individuals deliberately position themselves in specific ways towards what it means to be a graduate student. As in all experiences involving significant learning, undertaking practices related to teaching or research is not solely about attaining skills, but also deeply connects with individuals' identity development (Lave & Wenger, 1991); in this context, figuring out *who to be* as a graduate student and scientist (e.g., Brownell & Tanner, 2012; Connolly, 2010; Gazley et al., 2014; Kendall et al., 2013; Szelényi, Bresonis, & Mars, 2016; Thiry, Laursen, & Liston, 2007).

In this study, I use social practice frameworks (Holland & Lave, 2009; Holland, Skinner, Lachicotte, Jr, & Cain, 2001) to understand and situate these aspects of science graduate student identity development. I specifically utilize the Figured Worlds framework (Holland et al., 2001) to explore how graduate students in one youth engagement context interact with, resist, and/or re-constitute institutional structures through their individual experiences, and how their social practices relate to broader themes of powered relationships during graduate school. Holland and Lave (2009) discuss how social norms are often unwittingly reproduced through people's everyday interactions: "Local practice comes about in the encounters between people as they address and respond to each other while enacting cultural activities under conditions of political-economic and cultural-historical conjuncture" (p. 3). Localized practices also impact individuals' activities across settings (e.g., Dreier, 2009). For an example relevant to this study, a scientist who devalues teaching, in accordance with the norms in their department, may blatantly or inadvertently make this known to their students by their low level of enthusiasm while teaching, or the limited time that they make available to meet with students outside of class.

Given that youth engagement is an optional activity for graduate students, deciding to do so instead of, or even in addition to scientific research, is a socially value-laden decision (Thiry et al., 2007). Scientists who do so may be putting their reputation and perceived commitment to their discipline on the line, as well as risking access to material resources such as funding or opportunities to work more closely with their advisor. In this study, I demonstrate how choosing to focus on teaching or participating in youth engagement activities involves graduate students negotiating their still-developing professional identity (Brownell & Tanner, 2012; Wilk, 2016) and navigating how their decisions impact how they think of themselves as scientists, and, just as importantly, how they are seen by others (e.g., Alcoff, 1988; Carlone, 2012; Davies & Harré, 1990; Gee, 2000).

It is vital, then, to consider issues of identity, power, and social positioning when studying and designing pathways for graduate students as educators. Here, I present findings from one possible pathway: a youth science mentoring program that enabled graduate students to develop their teaching practice—and hence refine their professional identity by learning about teaching. STEM OUT was a two-year project in which graduate students from across scientific disciplines worked in mentoring relationships with high school students from cultural backgrounds under-represented in the sciences. I investigate three graduate students' trajectories through the program to show how mentoring interactions between scientists and youth were impacted by scientists' prior experiences, as well as their motivations and expectations for participating. By understanding why scientists decide to join a particular community engagement opportunity and how that impacts their subsequent interactions, program designers and facilitators can provide supportive structures that productively leverage scientists' identity-related experiences as resources when they work with youth. Doing so has the potential to improve outcomes for all participants, and to reconfigure the relationships between university science departments, community partner organizations, and schools. Additionally, studies on outcomes of scientist/youth programs generally rely on individuals' retrospective accounts, rather than the sustained, ethnographic approach used here (e.g., Erickson, 2006; Heath & Street, 2008) to elucidate how focal participants' cross-setting experiences unfold and link together over time.

Conceptual Framework

This study seeks to elucidate how scientists' interactions and construction of self in one context (graduate school in the sciences) mediates those same processes in a different context (a youth science mentoring program). Consequently, it is essential to employ a theoretical and analytical lens that accounts for the flexible, contextual nature of identity as people author themselves within and across settings. Here, I describe the affordances of social practice theory in general for studying participants' identity work, and then explicate the primary framework that I utilize in this research.

Social Practice Approaches to Theories of Identity

This study is guided by a social practice framing of identity, which is concerned with the tensions between individuals and their social worlds (Holland & Lave, 2009). Nasir & Hand (2008) describe the contextual nature of a person's sense of self in a social practice paradigm as: "[Identity] is locally and interactionally constructed and shifts in relation to the social setting and actors" (p. 147). With this conception, the process of graduate students in the disciplinary sciences navigating multiple identities (as characterized by more static notions of identity, such as Erikson, 1980) is more accurately portrayed as one of holding various, possibly conflicting identities-in-action simultaneously. In consideration of how to theoretically approach this complexity in this study, I use the term *identity work*, described aptly here by Calabrese-Barton and colleagues (2013):

> By identity work we refer to the actions that individuals take and the relationships they form (and the resources they leverage to do so) at any given moment and as constrained by the historically, culturally, and socially legitimized norms, rules, and expectations that operate within the spaces in which such work takes place. (p. 38)

Depicting a person's identity work entails a more active focus on identity creation through sociocultural processes (Bell, Tzou, Bricker, & Baines, 2012; Lee, 2017; Nasir & Cooks, 2009; Wortham, 2006) rather than an essentialized form of an identity that they carry into different settings. Within the context of this study, characterizing individuals' identity work in such a way allows me to attend to the complicated narratives that graduate students are telling about themselves through their interactions and reflections, rather than attempting to categorize their identities in more limited ways. Identity work also can account for the positioning dynamics that unfold within settings, in relation to prevailing storylines and kinds of “normative” or “celebrated” persons (Carlone, 2012).

Figured Worlds: Accounting for Contextual Structures & Individual Agency

In order to account for the complex social structures in which graduate students exist as they navigate identity work across settings, I draw on the Figured Worlds framework (Holland et al., 2001). According to this framework, a figured world is:

> a socially and culturally constructed realm of interpretation in which particular characters and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others….These collective ‘as-if’ worlds are socio-historic, contrived interpretations or imaginations that mediate behavior and so, from the perspective of heuristic development, inform participants’ outlooks. The ability to sense (see, hear, touch, taste, feel) the figured world becomes embodied over time, through continual participation. (p. 52)

Figured Worlds provide a frame of meaning in which individuals simultaneously negotiate actions and identity work through specific modes of participation in a social context (Holland et al., 2001, p. 57). To ground analyses of science graduate students’ unfolding identity work in STEM OUT and the relation of these processes to other relevant settings, I utilized the main elements of the Figured Worlds framework: practice, self-authorship, power and positioning, and agency and improvisation.

Developing through practice. Figured worlds and, more generally, social practice theory are both concerned with how people develop through practice. In his philosophical work on the nature of practice in the sciences, Rouse (1996) gives a nuanced sense of what this entails:

> Practices are not just patterns of action, but the meaningful configurations of the world within which actions can take place intelligibly, and thus practices incorporate the objects that they are enacted with and on and the settings in which they are enacted." (p. 135)

As discussed in the Introduction, Holland and Lave (2009) similarly postulate that by foregrounding individuals' mundane activities (e.g., how a science graduate student works with others to learn about teaching—or chooses not to), we can get a sense of how they are navigating broader sociocultural forces (e.g., political and corporate arguments for increased preparation of qualified candidates for the STEM workforce). With this framing, practices are the link between institutional structures and individual agency, revealing how the two realms intersect to impact (and are impacted by) everyday interactions. In this study, as the graduate students undertake specific practices related to mentoring youth, they simultaneously engage in identity work to embody those practices, using the language, symbols, and artifacts of those practices to make their position known to others in a specific moment and context (Holland & Lave, 2009).

Linguistic constructions of self-authorship. As a process of identity work, self-authorship addresses the dialogism inherent in constructing our selves through language; self-authorship is identity work accomplished through discourse. Bakhtin (1981, 1986) characterized how language acts as a culturally mediating force:

> For any individual consciousness…, language is not an abstract system of normative forms but rather a concrete heteroglot conception of the world….Each word tastes of the context

> and contexts in which it has lived its socially charged life; all words and forms are populated by intentions. (1981, p. 293)

He further postulates that moments in which individuals explicitly speak of themselves using "I" pro-nouns are indicative of the meaning individuals make of themselves in a specific moment, in relation to the others present at the time, and it is through these moments that they author themselves. Self-authorship, then, is a crucial empirical component of my approach to understanding scientists' identity work in this study. By seeking out reflexive "I" moments and subsequent identity-related actions across settings, time, and among different participants, I characterize their unfolding and connected conceptions of themselves as graduate students, scientists, and educators, as well as how they are able to locate youths' and colleagues' experiences in relation to their own.

Power and positioning through discursive and institutional forces. Through these processes of identity work, an individual utilizes their agency and capital to reflexively position themselves (Davies & Harré, 1990) within a figured world. Simultaneously, an individual is also constantly, interactionally positioned by others through discursive moves ranging from subtle to overt (Bakhtin, 1981; Davies & Harré, 1990), which has implications not only for one's identity work, but also for an individual's ability to socially navigate a given figured world (Alcoff, 1988; L. Bricker & Bell, 2012). As each of the above theorists articulate in various ways, structural forces—such as positioning due to age, race, class, gender, or ability— exist outside of a particular figured world, but are afforded differing significance, privilege, and power through symbolic capital (Bourdieu, 1984) within different figured worlds. These forces translate to a person's lived experiences through recognition (or lack thereof) of qualities deemed salient by others, who then position them through language and actions founded on assumptions based on those qualities (see Carlone & Johnson, 2007; Malone & Barabino, 2009 for examples specific to STEM graduate students). In this study, scientists' reflective and interactive talk provide evidence of their identity work and self-authorship, which in turn helps to situate how these processes enable or constrain their access to power and continued participation in the figured worlds of the sciences, graduate school, and/or K-12 education.

Agency and improvisation through boundary crossing. As Dreier (2009) reminds researchers interested in identity work, it is imperative to consider individuals within the diverse multiple contexts through which they move, recognizing people "as situated participants in structures of social practice" (p. 196), rather than embedded in one static setting. Conceiving of social contexts as figured worlds, then, requires an exploration of how these are socio-materially arranged, how they are "re-produced and changed by their participants and separated from and linked to other social contexts in a more comprehensive structural nexus of social practice" (Dreier, 2009, p. 196).

The notion of *boundary crossing* is useful to help theoretically characterize these links and articulate the structural nexus in which individuals are situated. For example, the boundaries between the disciplinary sciences and educational practice are ill-defined, in the sense that focusing on engaging youth about science does not automatically position a graduate student centrally in the figured world of educational practice. An individual may be positioned on the periphery of both figured worlds, in what Akkerman & Bakker (2011) deem "a nobody's land, belonging to *neither* one *nor* the other world" (p. 141, emphasis in original). Individuals in these ambiguous roles must improvise their way through their own sense of relevant practices and a novel process of self-authorship—the rules of a single figured world no longer apply.

This improvisational process between figured worlds can lead to *conflicted narratives* (Williams, Corbin, & McNamara, 2007) in terms of a person's identity work. Science graduate students who are interested in teaching and educational research, for example, may have to consider how much of this aspect of themselves to reveal to others in their department, given the relatively lower status positioning that revealing this may entail (Austin, 2002; Brownell & Tanner, 2012; Connolly, 2010).

Individuals may develop *boundary skills* through practice and identity work to make sense of their conflicted narratives; essentially, by strategically enacting and telling who they are across figured worlds: "[The ambiguous position at the boundary] requires people to have dialogues with the actors of different practices, but also to have inner dialogues between the different perspectives they are able to take on" (Akkerman & Bakker, 2011, p. 140). In this study, I highlight instances of these "conflicted narratives" for boundary-crossing scientists. What prompts the emergence of conflicted narratives during youth engagement experiences, and how do these narratives potentially mediate the scientists' ongoing identity work? Further, what factors influence when, how, and why scientists develop boundary skills—and to what effect?

Methods

Research Questions

For this study, I engaged in ethnographic methods (e.g., Erickson, 2006) with a focus on concepts from the Figured Worlds framework to understand three graduate students' identity work as they participated in the STEM OUT program. Specifically, I pursued the following research questions:

1. How did scientists' experiences and identity work (as scientists, teachers, and/or researchers) in the figured world of graduate school inform their motivations to participate in youth science mentoring?

2. How did scientists' identity-related experiences and processes of self-authorship surface through their mentoring practice?
3. After participating in STEM OUT, what kinds of professional identity pathways were available to scientists?

Research Context

The STEM OUT mentoring program was a design-based research project (Brown, 1992; Cobb, Confrey, Lehrer, & Schauble, 2003; The Design-Based Research Collective, 2003) that went through two school year cycles of design, implementation, and iteration. Adopting a DBR approach enabled the design team to adapt the program based on findings and feedback from each cohort of participants, making it responsive to the needs of youth, graduate students, and school administrators. STEM OUT was funded by the American Association for the Advancement of Science (AAAS) STEM Volunteer Program and represented a collaboration between a large university in an urban center in the western United States and a small, STEM-focused public school, located 25 miles from the university. In each year-long design cycle, graduate student scientists met for hour-long mentoring sessions every other week with groups of two to three high school students at Regional Technology Academy (pseudonym; RTA). RTA focused on empowering students from under-represented backgrounds in the STEM fields; this mission is reflected in the school's demographics (Table 2.2), as well as the inter-disciplinary, problem-based learning instructional approach leveraged in RTA classes.

The STEM OUT program was intended to broaden participation in the sciences by directly connecting youth with university scientists in mentoring relationships. Formally, mentors supported youths' science research projects: seniors designed and implemented an individual year-long research and community engagement project as the culmination of their high school experience, while non-seniors completed a project for the school-wide science and engineering fair. Beyond their project work, STEM OUT provided opportunities for youth to make connections between their own research and the practices of university scientists, and envision multiple trajectories to college and STEM careers. STEM OUT also supported mentors' development of pedagogical and science communication skills in informal learning contexts (Scipio, 2015a), through a two-hour orientation workshop and structured debriefs on the 30-minute car rides between the university and RTA.

Case Selection & Focal Participants

As a way of theoretically sampling (Corsaro, 1996) across the 18 STEM OUT mentors, I focus in this paper on three mentors who represented different pathways of identity work as scientists, educators, and graduate students, as well as varied patterns of participation in STEM OUT. This multiple case study comparative approach (Stake, 2005) allows me to make claims about the identity work that scientists navigated while undertaking K-12 education work, recognizing the diverse experiences that mediated graduate students' engagement, and outcomes for adult and youth participants. Each focal mentor's group usually consisted of two high school seniors and one non-senior, to facilitate peer mentoring interactions.

As shown in Table 3.1, the three mentors varied in their disciplines, years in graduate school, and previous experiences working with youth. Lennis[2] was a third-year PhD student in Chemical Engineering who was new to working with high school youth, but had previously mentored undergraduates. She self-identified as a Hispanic female and worked on developing better methods for integrating biological components into artificial devices. Amy was a fifth-year PhD student in Chemistry and planned to graduate the summer after her participation in STEM OUT. She self-identified as a Caucasian female and studied the structure and organization of

[2] All names used in this manuscript are pseudonyms selected by the participants.

Table 3.1. Demographic Information, Data, and Findings Summary for Focal Mentors

Participants & Data	**Demographic Information (Self-Identified)**	**Positioning in Graduate School**	**Motivation to Participate as Mentor**	**Professional Goals**	**Themes of Mentoring Practice**	**Outcomes of Participating**
Lennis Carmacho, 3rd year PhD student, Chemical Engineering **Data:** - Pre-survey - 7 hours audio/video of mentoring sessions - Participant notes from mentoring sessions & pre-program brainstorming activity - Field notes and audio from reflections while driving to site - E-mails with mentees - Post-program ethnographic interview - Youth reflections via survey - Member check interview	Age: 27 Gender: Female Race/Ethnicity: Hispanic (Puerto Rico)	Challenges of being only Hispanic female student in her department. Supported by strong mentors and collaborative nature of her research lab.	Be the mentor that she wished she'd had in high school; "tell my experience" to youth from under-represented backgrounds.	Academia, to contribute to diversifying the sciences and "reach to my community and help others".	Sharing own experience as scientist from under-represented background. Building relationships with mentees through discussion and feedback on their research projects.	Comfortable at working with youth. Took on leadership role in university initiatives focused on supporting students from under-represented backgrounds.

Participants & Data	Demographic Information (Self-Identified)	Positioning in Graduate School	Motivation to Participate as Mentor	Professional Goals	Themes of Mentoring Practice	Outcomes of Participating
Amy Schumer, 5th year PhD student, Chemistry **Data:** - Pre-survey - 7 hours audio/video of mentoring sessions - Participant notes from mentoring sessions & pre-program brainstorming activity - Field notes and audio from reflections while driving to site - E-mails with mentees - Post-program ethnographic interview - Youth reflections via focus group - Member Check E-mail	Age: 28 Gender: Female Race/Ethnicity: Caucasian	Feeling like an outsider to research-focused culture. Conflicted about commitments to teaching, "feel like I'm letting women [in science] down."	Be the mentor that she wished she'd had in graduate school; diversify STEM by "making science approachable and exciting to students."	Teaching position at PUI (Primarily Undergraduate-serving Institution)	Relating own experience to students' experiences through validation and empathy. Held students accountable to goals and deadlines.	Related students' anxieties about their future to her own experience as imminently graduating. Confirmed decision to pursue teaching career "in an environment where you have time with your students and you get to know them."

Participants & Data	Demographic Information (Self-Identified)	Positioning in Graduate School	Motivation to Participate as Mentor	Professional Goals	Themes of Mentoring Practice	Outcomes of Participating
Dave Keuning, 2nd year PhD student, Chemistry **Data:** **Year 1:** - Pre-survey - 7 hours audio/video of mentoring sessions - Participant notes from mentoring sessions - Field notes and audio from reflections while driving to site - Post-program interview - Youth reflections via focus group **Year 2:** - Returning mentor survey - 6 hours audio/video of mentoring sessions - Participant notes from mentoring sessions & pre-program brainstorming activity - Field notes and audio from reflections while driving to site - Post-program ethnographic interview - Youth reflections via survey - Member check interview	Age: 24 Gender: Male Race/Ethnicity: Caucasian	Supported in both his scientist and emerging teaching identities. Recognized his privilege as "middle-class Caucasian male" in his success as a scientist.	Diversify STEM as means to generate creative ideas to solve problems.	Start of Year 1: Academia or industry Start of Year 2: Community College Professor	Group brainstorming on students' project work. Trying out teaching techniques (e.g., growth mindset language).	Mentoring as having "biggest impact" on decision to focus on teaching and teaching philosophy that prioritized critical thinking. Projected future self as approachable & equitable science professor.

lipids in cell membranes. Amy had extensive previous experience teaching and working with youth, from teaching and tutoring in Chemistry to teaching English in China. Dave participated in STEM OUT during his second and third years of his PhD in Chemistry, and self-identified as a Caucasian male. He came from the same lab as Amy and did research on the physical properties of vacuole membranes in yeast cells. Dave had worked with older youth before coming to STEM OUT, through teaching in the Chemistry department and as a Boy Scout.

Data Collection

As a program in which scientists met with youth for a sustained period, STEM OUT provided a context in which to understand mentors' evolving identity work as well as the development of collaborative relationships between participants over time (see Chapter Two of this dissertation). Accordingly, data for this study comes from a variety of sources to capture both implementation and reflective data from adult and youth participants (Table 3.1). I took ethnographic field notes that focused on documenting the focal mentoring groups' interactions, as well as the talk between mentors as we commuted between the university and RTA (Emerson, Fretz, & Shaw, 2011). The majority of the focal mentors' hour-long sessions were also recorded using audio and/or video (Derry et al., 2010); when sessions were not recorded, it was due to logistical constraints of having multiple mentoring groups happening concurrently. Focus groups were conducted with youth at the end of each school year, to understand youths' perspectives on their participation in the program. In collaboration with school administration, students were also given a reflective survey in the middle of Year One and an expanded pre/post survey in Year Two. Mentors completed a pre-survey at the beginning of each program year. I also conducted semi-structured reflective interviews with all STEM OUT mentors at the end of each school year, and elicited focal participants' feedback on initial findings through member check interviews or e-mail interaction (Creswell & Miller, 2010).

The reflective data (focus groups with youth and interviews with mentors) were transcribed for a fine-grained depiction of participants' experiences of STEM OUT. Each of the mentoring sessions were content logged (Derry et al., 2010; Miles, Huberman, & Saldaña, 2014), tracking on a high level the content and conversational turns as participants interacted. Since I was present for the mentoring sessions, I compared the content of the sessions with my field notes to ensure that they were representative of typical mentoring interactions for a given group (Heath & Street, 2008).

Coding & Analysis

This study is concerned with the identity work that mentors engaged in before, during, and after their participation in the mentoring program. Therefore, the unit of analysis is the individual mentoring groups, with a focus on the connections between the focal mentors' identity-related experiences across contexts and over time (e.g., Bell et al., 2012; Polman & Miller, 2010; Wortham, 2006). I iteratively moved between the data and theoretical constructs of interest as I developed codes (Coffey & Atkinson, 1996), beginning with a pass through my field notes. This gave me a sense of what I had broadly considered to be "happening here," in STEM OUT, as advocated for by grounded theorists (Glaser & Strauss, 1967). From this review, I generated an initial set of codes focused on mentoring practice (e.g., giving advice, asking questions) and topics (e.g., college, pop culture). I simultaneously derived codes from theoretical constructs of interest related to mentors' identity work, such as "self-authorship as educator" and "positioning-self as different from student(s)". I used the Dedoose data analysis software to apply these codes to the content logs from the focal mentors' sessions to understand how these themes were enacted in their mentoring groups. I tracked these emergent ideas through analytical memos (Lofland & Lofland, 1995) and iteratively refined my codes accordingly. The primary coding categories that resulted from this process are listed in the table in Appendix E.

While the data sources outlined above provide a portrayal of what happened in STEM OUT over time, they also allowed me to analytically triangulate (Erickson, 1986; Walford, 2008) between what the mentors narrated about themselves as educators, scientists, and graduate students (from their surveys and interviews), how they embodied this in practice (from the audio and video data), and my own field-based observations through my lens of research inquiry (from the field notes). These methods of ethnographic inquiry enabled me to elucidate the social meanings, mundane practices, and relationship-building that occurred via discursive interactions within mentoring groups and how these mapped onto mentors' own developing self-conceptions. These triangulated accounts are crucial to understand participants' experiences of the program and to understand the figured world of STEM OUT in relation to their experiences and identity work.

Qualitative analysis of the coded data, through analytic memos tracking the connections or disjunctions between the focal mentors' identity-related experiences allowed me to make increasingly higher level claims as I abstracted up from the data (Erickson, 1986; Miles et al., 2014). In keeping with methods for ensuring validity of my findings (Erickson, 1986, p. 147), I worked with colleagues and the focal mentors (via member check interactions) to check that my claims were representative of the breadth and depth of the dataset, and grounded in sound interpretation of the evidence. This was especially relevant given my multiple roles as STEM OUT program coordinator, designer, and researcher— a complicated positioning in the work that transcended a continuum model of participant/observer (Emerson & Pollner, 2001).

Findings

Findings for each focal mentor are described below, with themes relating to their identity trajectories across time and contexts summarized in Table 3.1. Connections between the cases and to the Conceptual Framework are detailed in the Discussion section that follows.

Lennis Carmacho: Graduate School Mentoring as Supportive Pathway

As the only Hispanic female student in her department of chemical engineering and the only woman in her graduate cohort, Lennis felt challenged by her experiences in graduate school. However, she also talked about how it "has been one of the best experiences in my life" in terms of the collaborative nature of the work in her lab, and the opportunities to develop her skills in communication and problem-solving. Mentors were essential to Lennis's developing identity as a graduate student, particularly during a difficult time in her second year in which she was considering leaving the program. In particular, Lennis discussed the crucial role of a Hispanic female professor in her department, who had attended the same undergraduate university as Lennis. Their weekly meetings, in which they discussed everyday life topics as well as research, served to support Lennis to persist in graduate school:

> [T]he moment in which I wasn't even believing in myself, I had a person that trusted me and said you can do this and it was really important for me to have that person. I think that's why it is important to increase minorities and diversity because…you keep helping others, right, by having people that look like me or that speak the same language or that have been through the same experiences.

This type of mentoring, which Lennis did not have when she was in high school, motivated Lennis to join the STEM OUT program, to work with youth from minoritized populations and "tell my experience to others, that it's doable."

Lennis had previously mentored a group of undergraduates in her lab, and received an award for her leadership of the team in an entrepreneurship competition. However, she had not previously worked with high school-aged youth or formally taught undergraduates, so Lennis also wanted to participate in STEM OUT to develop her youth engagement skills.

Academic career to continue diversifying STEM. Lennis's identification as a scientist from an under-represented background and commitment to diversifying STEM informed her future career goal of attaining "a position that could help me reach to my community and help others to further [their] education." During the study period of her third year in graduate school, she was "considering academia" and discussed how "I am a woman and I'm a minority and I think that's the stuff that I can add to the department in terms of what people think about the department." As a chemical engineer, she also was considering a future career in industry, but discussed how even if she pursued that route, she would want to "establish some collaborations with a university or high schools to promote STEM and diversity."

Engaging with mentees about lived experiences of under-representation in STEM. Lennis's mentoring group consisted of four girls of color, which helped to frame her mentoring approach, in terms of her ability to speak to her intersectional experiences as a Hispanic female chemical engineer. In line with her motivation to be a STEM OUT mentor, Lennis engaged with her mentees as a "friend for the students to share my experiences and motivate them for the future."

Lennis built upon the youths' interests in under-representation in STEM to share about her own experiences. At the beginning of one session, Tiffany, one of the senior mentees, showed Lennis her presentation on discriminatory practices in hiring and retaining university faculty in the sciences; Lennis told her this is a “great” topic and that “I see this all the time.” She goes on to share the demographic make-up of her own department:

> Lennis: In my department, we have 22 faculty members, now we have four female professors.
>
> Tiffany (makes a surprised face): Wow!
>
> Lennis: And that's because we hired a new female this year, it was three out of 21 faculty members.
>
> Tiffany: That's a really low percentage for representation of women.
>
> Lennis: We have just one African-American and one Hispanic faculty member.

Lennis then told Tiffany how this informed her own career goals:

> Three months ago, if you asked me if I wanted to be a college professor, I was like no, but now I see that there is a need to have Hispanics in academia, and females, I'm actually starting to consider it as a career path. I can help so many people if I do it probably, and help my community as well.

In a later session, Lennis talked more specifically about her experience as a Hispanic woman in chemical engineering. After sharing an article with students on the under-representation of women in STEM, she told students:

> I've been faced with all kinds of situations as a women engineer. There's sometimes that people say to me, comments that they don't say to other people. People tell me, ‘oh it's going to be easy for you to find a job because you're a woman and you're Hispanic and you're an engineer. So, yeah, it's going to be easy for you.’ It's not going to be easy, they are just trying to fill a gap that society has created.

She went on to translate this into advice to students to “dream big,” and that she hopes they will “learn how to be a mentor for future generations.” Lennis also told the group that her experiences motivated her to become a STEM OUT mentor, and how she hoped to serve as a role model to them, the kind that she didn’t have as a young person:

> I do think that role models are still important, because... you know, I didn't have much information in high school and elementary school, but when I went to college I saw these women that were successful and that motivated me.

Developing a youth engagement practice through drawing on graduate student practices. For Lennis, successful mentoring involved feeling like she made a personal connection with students. In early sessions, Lennis felt that she struggled to foster a group dynamic. To help facilitate conversation with all four girls, she made a plan for her sessions by writing up bulleted lists of conversation topics.

Students’ project work was a predominant theme of these topics. Tiffany in particular consistently shared her project ideas with Lennis, in part due to the fact that she was often the only student in the “senior-only” first half of the sessions. Throughout their time together, they engaged around her work at all stages, with Tiffany sharing her research proposal and literature review on the connections between poverty and education in the United States, and giving practice talks for her final presentation. Although Lennis later reflected that she did not have background knowledge on this topic, given that she grew up in Puerto Rico, she gave close feedback to Tiffany’s written and performative work, reflecting her own practice as a graduate student to give presentations and receive feedback from her advisor and colleagues.

Through talking about Tiffany’s research, Lennis and Tiffany developed a close relationship, and shared about other aspects of their lives, similar to Lennis’s experiences with her graduate school mentor. For example, Tiffany shared with Lennis how she had a "panic attack" before meeting with teachers about her senior project. In a later session, Lennis had just come back from Puerto Rico and she showed Tiffany pictures for the first half of the session and shared stories about her family, friends, and Puerto Rican foods.

Over time, Lennis developed a rapport with all the girls in her group, mainly through these themes of engaging about students' research and mutual sharing about their personal lives. This resulted in positive outcomes for youth; for example, Tiffany reported on the end-of-year survey that Lennis' feedback was "super helpful" for strengthening her project, and further, that she learned from participating that "It's fine to get help or help others when stressed out." These outcomes, in addition to the increasing amount of youth talk over the course of her sessions, highlight the personal and professional dimensions of Lennis's mentoring practice.

STEM OUT as pathway to enact commitments to diversify STEM fields.

In her post-program interview, Lennis described how talking with her mentees in the early sessions was "challenging for me," and even that she was "really scared" about engaging the girls in a meaningful way. However, at the time of the interview, she had recently volunteered to run a density experiment for middle schoolers at a science festival and felt that "I did it because I had this experience with STEM OUT. I don't think I would have done it if I hadn't been doing this the past year." Additionally, during the STEM OUT end-of-year field trip, Lennis designed and ran a protein purification activity in her lab for a large group of the students. These changes in Lennis's comfort level at working with youth show how crossing disciplinary and personal boundaries to mentor with STEM OUT enabled her to develop a practice to which she was committed in her future work, and for which there were limited opportunities to do so in graduate school.

In the year following her participation in STEM OUT, Lennis sought out more of these opportunities, to contribute to efforts to diversify STEM at the university level. She became president of her university's chapter of the Society for Advancement of Chicanos and Native Americans in Science (SACNAS) and participated in a campus-wide initiative to increase recruitment of under-represented minority students into graduate school. She attributed her taking on these roles to her participation in STEM OUT, explaining that she:

> would never have done this if it wasn't for this program. I was so shy and introverted, I pushed myself to do this and it was, 'I need to do it.' It's helping me to do things I never would have.

Amy Schumer: "Outsider" Positioning in Graduate School

Amy expressed strong ambivalence about her experiences in graduate school, specifically around the Chemistry department's practices and power dynamics that she perceived as minimizing students' experiences outside of their research productivity. She was a founding member of a Women in Chemical Sciences group, and described in her interview why she sought support through its formation: "I was frustrated by what I thought was this lack of concern for what our experiences were like in [graduate school]…. it was this cultural lack of concern, for how we feel when we're doing this research." In response to a male graduate student who attended an initial meeting and "'just [wanted] to hear the work that women are doing in science,'" Amy further articulated her idea of what the group could provide: "My vision was more about, kind of dealing with the culture of being a graduate student, and especially about being a woman in the graduate program."

Amy's ambivalent feelings about the "culture of being a graduate student" contributed to her decision to not pursue a research-focused academic position after graduating, despite this being a goal when she had applied to graduate school. Amy reflected on the challenges of changing her career goals while in graduate school: “It was really tough to reconcile that I didn't like that [R1 tenure track] lifestyle, I couldn't reconcile who I was with what that would be like for me.” Instead, in her final year of graduate school, Amy pursued university teaching and lecturing positions, with the goal of attaining “a job in academia, preferable a PUI [primarily undergraduate-serving institution], where I have a lot of time teaching.” She was conflicted about this decision, in relation to her identity work as a woman in the sciences: “I have a [graduate advisor] who's a woman in the chemistry department and she's been nothing but encouraging, but I have told her before that 'I feel like I'm letting you down, I feel like I'm letting women down.’”

Youth-focused engagement for broadening participation. Amy’s commitments to broadening participation in the sciences which brought her to the STEM OUT program were based both on her personal experiences of marginalization as a woman in chemistry, as well as her observations of the lack of racial/ethnic diversity in the field. Especially after doing a job shadow at a liberal arts college and noting that “everybody is white in this,” Amy was interested in working with youth to get “more people interested in science, from diverse backgrounds.” For STEM OUT in particular, she was also looking forward to interacting with high schoolers and “practice making science approachable and exciting to students, which will help me with my career in academia.” As framed by Laursen et al’s (2012) study on the identity work of science graduate students who taught in K-12 classrooms, Amy was a strategist, in that she “anticipated in advance, and valued in retrospect, the ways that [teaching] experience furthered their career development” (p. 65).

In line with this goal, Amy was anticipating students’ experiences of the program before STEM OUT began. In a pre-program brainstorming activity, she shared that she was excited about “contributing ideas, giving feedback, making [students’] work stronger,” and “getting to hear more about their projects.” Her concerns were about her own possible lack of expertise, such as “I won’t know how to further their project- getting stuck,” and “I won’t have the background knowledge they are looking for.”

Mentoring as relational practice. Amy continued this focus on students’ experiences into her mentoring practice. Topics in her mentoring sessions primarily focused on the themes of students’ future trajectories, high school, and the social aspects of college. These topics were generally student-sourced or followed from students’ expressions of interest. In one session, Mia, one of the seniors, discussed how her mom wanted her to go to college to become a nurse, but Mia was worried that it would be too hard and not interesting to her: “So I need to find something for college with talking. I was thinking about being a counselor, I could solve everyone's problems, but not mine." Amy built on Mia’s ideas, brainstorming, “Communication, psychology, marketing- you seem like you're a good salesman, you seem like you're pretty good at pitching ideas…a lot of people would find that terrifying, but you keep going."

Like Lennis, Amy’s mentoring approach involved sharing her own experiences, as well as validating and empathizing with students’ experiences. At a later point in the conversation with Mia, Amy surfaced her own experience as a young person figuring out her career goals: “Am I just being a professor because my mom told me to be a professor?" Additionally, in one of their first sessions, Amy’s mentees asked her if being an adult and out of the house was as scary as she had thought it would be while she was in high school. She shared her own similar feelings when she went to college and added, "The hardest thing is right before you start, because that's when your brain is thinking scenarios and telling you how impossible it is. But as soon as you're in it, it really isn't so bad." This kind of reassurance was a common theme of Amy’s mentoring conversations, often validating her mentees' feelings of anxiety about their future trajectories during and after college with statements like, "But you don't have all the information yet, you don't have to know!"

In Amy's mentoring group, mentees' feelings and experiences were relevant, with Amy creating space for these to be shared. In a later session, Amy's mentees discussed their experiences as first-generation college students and the resulting pressure they felt from their families and communities to succeed. During this conversation, Amy primarily listened, giving students space to share their feelings and experiences, even when Mia passionately indicted Amy and teachers at RTA, "Sometimes, like you guys encourage us to go to college, a lot of people from college don't even have a job! It just charges us more, go to school, and what's the point of it? It pisses me off!" Amy validated these feelings by responding, "I think you bring up a good point, which is, do you have to, is this the best choice for everyone?" and the conversation continued, with Amy asking questions about her mentees' experiences of family pressures. Amy later reflected on the challenges of supporting students around these issues, with which she had limited personal experience. She talked about how she wanted to tell Mia that it would be okay to not be a nurse and that she could make her own decisions later on, "but I don't know if that is actually true."

Leveraging relationship-building for accountability. Amy employed her relational approach to mentoring (and the resulting relationships with mentees) as a way to hold students accountable for their project and schoolwork deadlines. She was one of the only mentors to utilize an optional goal-setting tool provided to help structure their sessions. Every session ended with Amy asking students about their goals, such as, "All right, so let's do some goals while you're finishing up your pizza. So whoever wants to start first, what do they think they can get done in two weeks?" Amy then followed up on these goals at subsequent sessions; she generally had her binder open to the previous session's notes and referred to it while talking to students. She also set goals for herself using this tool, as when she offered to give feedback on Mia's senior project proposal.

Students' reflections on Amy's mentoring show how her balance of reassurance and rigor worked well for them; in the post-program focus group, the senior mentees agreed with each other about how much they liked the program, and about how Amy "gave us support, she was our counselor!"

Boundary crossing as reparative identity work.

Through Amy's positioning herself as similar to students (despite their differences in age, class, and race) within the figured world of STEM OUT, she directly related students' anxieties about their future to her current situation as an imminently graduating student. In her post-program interview, she explicitly identified with students' anxious feelings about upcoming transitions: "It kind of mirrors my experience too, because I'm reaching the end of grad school, and I'm kind of doing the oh no, I have to have a real job, and where am I going to live. I could empathize with them a lot more than maybe in previous years… So I think that I was surprised by how much I could empathize with my students, because, we're different."

Moreover, Amy's experience of marginalization in her graduate program directly mediated her practice as a STEM OUT mentor. She attributed her empathetic mentoring approach to the lack of mentorship that she experienced in the chemistry department:

> [In] some ways I was kind of treating [students] the way that I would like to be treated in my own program, which would be to have someone who is a little bit further ahead who can validate and say, hey, it's okay to be feeling this way.

In her applications for university lecturer positions, Amy specifically highlighted the work she had done with youth as a STEM OUT mentor. She described not only how she helped students navigate academic and social issues, but also the empathetic role that she took on and its connection to her self-authorship as a graduate student: “As a graduate student I often felt like an outsider, and so I could share my own personal examples of when I felt like I didn’t belong. I want to bring this same understanding to my teaching.”

This quote also shows how, for Amy, boundary crossing into teaching and youth engagement through her mentoring practice directly informed her motivation and identity work as an educator. In this vein, she discussed during her post-interview how being a STEM OUT mentor confirmed her decision to not pursue an R1 tenure-track career path:

> I think it helped solidify for me, that I really like more personalized interactions, I like getting to know students. And that's the thing where R1, it's just not a thing that's encouraged, is to really get to know the people that you're teaching. And so I think that did kind of encourage me to be like, ‘okay, you need to be in an environment where you have time with your students and you get to know them.’

Accordingly, after her participation in STEM OUT and graduating with her PhD, Amy successfully secured a lecturer position in the Chemistry department at a public regional university, thereby realizing this professional goal for which STEM OUT had helped to prepare her.

Dave Keuning: Privileged Positioning: Mentoring to Counter Structural Inequities in STEM

Dave came to STEM OUT with an interest in teaching through his experiences as a Chemistry teaching assistant, but at the beginning of his first year of participating, planned to pursue a post-PhD career in academia or industry. Unlike Amy and Lennis, he did not feel isolated in the figured world of graduate school in chemistry, and acknowledged how his positioning as a “middle-class Caucasian male” had likely contributed to his success as a scientist.

As part of his own process of recognizing that privilege throughout his undergraduate and graduate career, Dave wanted to be a STEM OUT mentor to support students from minoritized backgrounds in the sciences. In response to the Year One pre-survey, Dave described his view of how this support could help to address the structural inequities inherent in the STEM fields:

> I believe the difficulties faced by minorities in STEM fields derives in no small part from a lack of support; a non-problem for those in the majority because the institutions and around STEM were created by the majority and support them implicitly. As such, I believe providing more support to minorities in STEM will help them succeed.

Moreover, his commitment to diversifying STEM was rooted in the idea that diversity was a means to generate creative ideas and solve real world problems, in line with a wealth of social science research (reviewed in Guterl, 2014; Phillips, 2014). Dave described his stance in his Year One post-interview:

> Because when it comes to post-school, we're actually trying to invent something or improve something. Having a diverse basis of the people working on the problem is just going to increase the likelihood of coming up with better solutions overall.

Group brainstorming to generate ideas for students’ research projects. In line with these motivations as a mentor, Dave, like Amy, established a mentoring context in which he followed students’ lines of interest, as well as encouraged their creative thinking. Dave had a deep history with creative problem-solving, through participating as a youth in the problem-solving competition Odyssey of the Mind, which was further leveraged during his graduate student career, in which his advisor and research group privileged collaborative solutions. Even in Dave's first session meeting with students, his mentoring approach involved brainstorming ideas related to youths' project work. When one of the seniors professed that she needed to narrow down her project scope, Dave responded, "Okay, let's brainstorm now, if you don't mind?" and asked clarifying questions as she described her idea. Later on, Dave encouraged the other senior, Parv, to share his thoughts on her project as well. When the group struggled to reach a shared understanding of her research question, Dave attempted to reframe by giving them perspective on formulating questions:

> By the way, I'd just like to mention that this is a great question, because some of the best questions are the ones that are really hard to ask. We're having trouble thinking about how to ask this question. In fact, one of the reasons I wanted to work on this is the more clearly you can state the question, first of all you can answer it, but second of all, the more clear the problem itself will become. So part of it is whether or not you have direction, where do you go after that? What else do you want to incorporate in there with it?

Beyond talking through their ideas, Dave's mentees incorporated the suggestions that came from these brainstorming sessions into their research projects. For example, Parv used an idea from Dave to build a stress reduction toolkit for students as part of his senior project. In Year Two, another senior told Dave how the survey he had designed for his project on access to technology and educational outcomes "would have been lost without your suggestions."

Improvising an educator identity and exploring professional pathways through seeking out teaching opportunities. By the end of Year One of STEM OUT, Dave had shifted his post-PhD goals to focus on teaching, an idea he was still getting used to in his post-program interview:

> I never really considered for myself as a possibility, is maybe I want to be a community college professor because, you know, I'm not sure I want to do the R1 institution because of the prestige thing and I don't want to play that game. But, you know, [at community college] you get students who maybe have had a less advantaged background or who just don't have the money to pay for a fancy school and I think it's really important to provide a

> nice education for them as well, and so suddenly that is becoming a more attractive potential, a future possibility for me.

For Dave, this decision entailed navigating issues of identity work as a scientist and positioning in the figured world of his department, in which he recognized that "there's not a lot of cultural support for [teaching]." Additionally, he later cited how his decision to focus solely on teaching as a future career path required an "important acceptance step" to "embrace the decision even if it would be looked down on" by faculty or peers for being less prestigious than focusing on research.

To prepare for a teaching career, Dave crossed further into the figured world of education by undertaking a variety of endeavors that focused on teaching and learning, including participating in STEM OUT for a second year. These activities largely took place outside of the chemistry department, although Dave's advisor had connected him with some of these opportunities once she knew that he was interested in teaching. For example, Dave participated in reading groups on evidence-based teaching strategies with other scientists, secured a position as instructor of record for an undergraduate class that prepared entering freshmen for the Intro Chemistry series, and volunteered with high school chemistry teachers who were receiving accreditation to teach their students for college credit.

STEM OUT as context to try out novel approach to teaching. In parallel with his dual focus on teaching and research, Dave's mentoring practice in Year Two shifted to incorporate some of the teaching tools he was learning about in other contexts, while also directly drawing on his experiences as a scientist. One example of this was Dave's use of growth mindset language (e.g., Mangels, Butterfield, Lamb, Good, & Dweck, 2006): in a session towards the end of the year, the senior student in Dave's group expressed frustration that he should have noticed sooner that the data he had collected wasn't able to help him answer his original research question. Dave reassured him, “It’s a skill you’re developing, next time you’ll notice faster,” and then described how research can shift over time from an initial idea:

> This is something that you encounter in science, technology, engineering, math, but also I would say, even art… Whenever you're working on something, right, there is the idea that you have when you embark on the journey. Like let's say sculpting, you have this idea of a person. And then, you're working with the rock and then maybe you just notice, you have the pose with the hands on the hips in your mind. But as you're working, you notice the way the rock is moving, it would just be really awesome to have the hand pointing out toward the horizon. So suddenly your idea shifts because what you're working with is now back-informing. So you always start with some idea. But as you move an idea into reality, it tends to be shifted, back-informed by aspects of reality.

In his post-program interview, Dave explained his intentions during this conversation:

> I was like, in real research questions change, right? Because you don't know what you're doing, which is why it's research! …. and because I think he was feeling stuck, I also made sure I was like, ‘And this is the skill that people develop.’ So it's a skill to identify, ‘Oh this is no longer a relevant question. I should change it and what should I change it to?’ Because I also want him to not feel like he was incompetent or anything, and then again not lying, right? So it's something you get better at the more you do it.

Mentoring as a pathway to becoming an equity-focused educator.

Through the above explanation, Dave demonstrated how he was leveraging his experience and identity as a scientist into his emerging teaching practice. Additionally, Dave’s purposeful use of tactics like growth mindset language during his mentoring practice showed how in Year Two he increasingly attended to his positioning of youth, exemplifying how his conception of teaching was expanding beyond leading students through scientific content (Christodoulou et al., 2009). During a member check interview, Dave further explained how his views on teaching changed over his time in graduate school:

> [At the beginning,] I really thought about teaching as more about disseminating information like textbook type facts and any fun unique creative way of teaching as a tool to help students learn the facts better. But now I would really think more teaching is about

> raising critically thinking, creative problem solvers where there's an emphasis on the process and any facts that they learn are just tools to help them learn problem solving.

Importantly, Dave attributed his participation in STEM OUT as being the activity with "the biggest impact" on this teaching philosophy. As such, Dave fit the "seeker" profile described by Laursen and colleagues (2012), given his "growing dissatisfaction with previous career plans together with [the] use of [youth engagement] to explore another option" (p. 67).

He further connected his mentoring experience in working with students who were not necessarily interested in his field of chemistry to the type of teacher he hoped to be, one who can connect with

> any student in [my] class, and be supportive. Not just, 'I teach this subject. Come to me if the subject is interesting,' but like, 'I am teaching you in this college and you can come to me for advice about things that you need.'

Dave also discussed how he planned to integrate his scientific research experience into his practice as a community college professor, "because my main interest in doing research with students would be that research itself is a learning opportunity." Dave went on to describe how cultivating these research experiences could help students who may not otherwise have access to them, providing further evidence of how he was envisioning equity as a key dimension of his future teaching practice.

Like Amy, Dave attained a position as a Chemistry lecturer at a public regional university after graduating with his PhD. In the process of applying for the position, he leveraged the teaching and engagement techniques that he had learned about during his two years of STEM OUT mentoring and other teaching experiences that he had sought out. This demonstrates how his professional trajectory was not only informed by his STEM OUT mentoring practice, but also helped to practically prepare him for the teaching career that he began to envision.

Discussion

In this study, I sought to understand the relationships between three scientists' graduate school experiences, their engagement with youth in a science mentoring program, and their subsequent orientations towards teaching and youth/community engagement. Elements of the Figured Worlds framework (Holland et al., 2001) helped to theoretically frame these connections in the following ways: the focal graduate students in this study decided to participate in STEM OUT for specific reasons that related to their identity work as scientists. During sessions with youth, scientists undertook mentoring practices that were informed by their identity work, and, by so doing, they authored themselves as education-interested scientists in particular ways. These authoring moves then had implications for the scientists' resulting positioning in the figured worlds of the sciences and education, enabling them to improvise novel ways of accessing resources to affirm their participation in these contexts and identity work as education-interested scientists.

Below, I further detail the contrasts and connections between the three focal scientists, drawing on the Figured Worlds framework to make high level claims. The three cases represent different identity-related trajectories through specific settings. Although these scientists' experiences are by no means the only pathways by which science graduate students can pursue their interests in teaching and learning, analysis of their representative cases demonstrates how understanding the identity-related implications of scientists' experiences can help to support their sustained engagement in teaching and working with youth.

Authoring Expansive Selves in the STEM OUT Context

Across the settings of this study, the focal mentors showed through their interactions and reflections how their participation as a STEM OUT mentor directly related to their identity work as scientists. These connections, in turn, acted as resources from which they drew as they worked with youth. For example, Lennis directly discussed with her experiences of marginalization as the only Hispanic female student in Chemical Engineering with the girls in her mentoring group, while Amy's empathetic approach to mentoring was grounded in her feelings of being an outsider in Chemistry. In his mentoring practice, Dave utilized the brainstorming and creative thinking practices that enabled him to feel successful as a graduate scientist. In line with other findings on STEM graduate students working with youth (Christodoulou et al., 2009), mentors' subject matter expertise became secondary to focusing on students' experiences of the STEM disciplines, as informed by their own experiences as scientists and learners. Leveraging these socio-emotional and epistemic experiences during mentoring sessions also undergirded the mentors' abilities to develop relationships with mentees and recognize students' expertise, which, as explored elsewhere (Klein, 2018), resulted in positive outcomes for participating youth.

The graduate students in this study sought out STEM OUT and other kinds of education-related opportunities outside of their departments, to get a particular kind of experience that was not otherwise afforded to them. As a figured world reflecting different sociocultural norms than the disciplinary sciences, the participants undertook practices in STEM OUT that they felt passionate about, such as supporting youth from diverse backgrounds to pursue the sciences, relating about feelings and life transitions, or trying out teaching techniques. By doing so, the scientists were able to be particular selves in the STEM OUT context, ones that were less available to them in their respective versions of the figured world of graduate school: for Lennis, as a scientist role model for girls of color; for Amy, as an empathic, supportive resource; for Dave, as an equity-minded post-secondary educator. Being a STEM OUT mentor, then, became a way for the graduate students to refigure their participation in science, by making it possible for them to bring a wider repertoire of identity-related experiences into their processes of authoring themselves as scientists.

In parallel with how STEM OUT provided a context in which youth could author themselves in ways that differed from their science classrooms (e.g., Barton & Tan, 2010; Bell et al., 2009; Bricker & Bell, 2013; Carlone et al., 2015; Gonsalves, Rahm, & Carvalho, 2013), it also enabled the mentoring scientists to build novel trajectories of identification (Polman & Miller, 2010; Wortham, 2006) over time. By encouraging scientists to engage with their identity work as resources from which to draw during their mentoring practice, STEM OUT acted as a figured world distinctive from graduate school, within which participants could "enact connections between past, present, and future, through reference to identities that are dialogically negotiated, while serving purposes that give meaning to participant roles and agency, in an intentional borderland welcoming particular kinds of people and practices" (Polman & Miller, 2010, p. 885). Through this process of boundary crossing, each of the focal participants was able to pursue (Amy and Lennis) or find (Dave) identities as scientists that contradicted the idealized archetype of research professor at a top-tier research institution, as found in other research on scientists' identity work as they participated in educational outreach (Thiry et al., 2007; Wilk, 2016). In the next section, I discuss the implications of this for their participation in their respective disciplines.

Novel Positioning in the Figured World of Science by Resolving Conflicted Narratives in STEM OUT

STEM OUT was a context for mentors to resolve their conflicted narratives as scientists, in that their respective identity trajectories described above had impacts on their subsequent positioning in the figured world of the sciences. Over their year-long (or, in Dave's case, two year-long) participation in STEM OUT, the repetition through their mentoring practices changed how they viewed themselves as education-interested scientists. This process is framed by other scholars as their identity trajectories "thickening" over time (Wortham, 2006), with Holland & Leander (2004) extending the metaphor: "The person and the [identity] category plus the memories and artifacts of past episodes of positioning become virtually laminated on to one another and so come to constitute a hybrid unit in social and emotional life" (p. 132). Each focal scientist transformed and worked through conflicting identity narratives in different ways through their own version of this ongoing, stabilizing lamination process. As they related with youth about their experiences outside of the lab to who they were as scientists, all three mentors were concurrently improvising their identities as scientists, graduate students, and teachers. As detailed in the Findings section and Table 3.1, this work was consequential for the professional trajectories for all three mentors, in that it helped them navigate how to reflexively position themselves as education-interested scientists and seek out additional education-related activities and communities. Here, I review the main claims for each focal case, and make connections between them.

Lennis's participation in STEM OUT allowed her to integrate her experiences as an Hispanic woman into her identification as a scientist and feel empowered to enact change through her work with youth. Her experience in the program led to her continued involvement in youth engagement, as well as becoming a leader in the university's efforts to diversify graduate admissions (as described in the Findings above). Unlike Amy and Dave, Lennis continued to pursue a research-focused pathway through graduate school and professional goals, demonstrating how participating in the figured world of youth engagement and teaching does not have to entail leaving disciplinary research (Laursen et al., 2012). Lennis's case also parallels findings on strategies of persistence for women of color in academic STEM fields (Ko, Kachchaf, Hodari, & Ong, 2014), given that her mentoring motivation and practice were rooted in her identification as a scientist from a minoritized background. Ko and colleagues (2014) frame STEM-related volunteer work as a particularly dialogic persistence strategy, given how participating in community engagement serves as a way for minoritized scientists to "help others after them pursue science, but sometimes also as a way to help themselves in the process," (p. 187) by combatting isolation or working to change existing departmental cultures.

In contrast to Lennis, Amy's participation in STEM OUT in her final year of graduate school confirmed her identity trajectory as a science educator and post-graduation goal of becoming a full-time Chemistry lecturer (*sensu* Laursen et al 2012). During her time with STEM OUT, Amy was struggling to make sense of her experiences in graduate school, in terms of feeling like an outsider to research culture, but simultaneously conflicted, as she worried about disappointing her female advisor and other women in the academic sciences by pursuing her goals in teaching. As such, Amy was navigating what De Welde & Laursen (2011) describe as the "glass obstacle course" for women with PhD's in the STEM fields: her decision to not pursue a tenure track research career was due in part to the masculinized, competitive culture of her department, but was further complicated by doubting her chosen career path of teaching, which is more stereotypically associated as a feminine activity. Mentoring with STEM OUT allowed

Amy to re-connect to the practices she valued as a teacher- getting to know students on a personal level, brainstorming together, finding and sharing the connections between mentees' experiences and her own. In so doing, Amy was able to author herself as being successful with her PhD in Chemistry, rather than seeing a career in teaching as failing, or "leaking out" of the so-called STEM pipeline (for a critique of this metaphor and its implications, see Blickenstaff, 2006; Gibbs & Marsteller, 2016). Instead, as Amy improvised her identity as an empathetic teaching scientist, she envisioned how her post-PhD career as a Chemistry lecturer at a regional comprehensive university could help to diversify the field in the future.

Dave's identity trajectory differs from those of Lennis and Amy, given that he was not marginalized from research culture or experienced conflicts related to who he was in regard to being successful in graduate school. However, he recognized the politics inherent in being a research professor at an R1 institution and how he didn't "want to play that game" to be successful in his future career. Like Amy, Dave resolved conflicted feelings related to pursuing a teaching career and identity through his engagement with youth. Through contrasting his experience as a TA at a large research university with his experience as a mentor with STEM OUT, Dave began to view teaching as a venue for supporting youth from minoritized backgrounds to pursue chemistry, not just those students like himself who benefited academically from their privileged race/ethnicity, gender, and class status. Trying out identity work and novel practices as an educator and mentor in his two years of participation in STEM OUT enabled Dave to, like Amy, author a new pathway for himself as a post-secondary teaching scientist.

Making Worlds: STEM OUT as Counter Space

All three participants' trajectories demonstrate how crossing the boundaries between figured worlds can be a process of integration rather than separation, as they forged new identities as education-interested scientists (Lennis) or teaching scientists (Amy and Dave). In the process of doing so, each focal scientist developed boundary skills (Akkerman & Bakker, 2011) to facilitate their navigation across different contexts, learning through their mentoring practice not only how to teach, but also how to author themselves differently than in their graduate school departments.

The cases presented here demonstrate how participating in the figured world of youth engagement can provide opportunities for scientists to try out alternative skills and identity work. They can concurrently resolve conflicted narratives as scientists and find professional trajectories that align with their values, which may differ from those promoted in their department (Thiry et al., 2007). Marginalized practices and identities are at the boundaries of a figured world for socio-historical reasons— across academia, teaching has historically been associated with women, while research and the sciences privilege characteristics associated with White masculinity and Western epistemologies (Aikenhead, 1996; Bang & Medin, 2010; Brickhouse, 2001; Carlone & Johnson, 2007; Eisenhart & Finkel, 1998; Thiry et al., 2007). Thus, the structures that organize the figured world of the sciences privilege certain practices and identities while marginalizing others. As shown by the experiences of the scientists in this study, these structures impact individuals' positioning (e.g., Carlone & Johnson, 2007; Malone & Barabino, 2009), as well as have implications for perpetuating a figured world that reflect these values (Ong et al., 2011).

In the absence of teaching support from their university departments, then, science community engagement programs can serve as *counter-spaces* for graduate students to develop their sense of selves— as scientists, educators, or, as in this study, an integration of these identities. Nasir and colleagues (2012) describe counter-spaces as contexts for students from historically marginalized groups to craft narratives for themselves that run counter to the dominant racial and gendered storylines— in essence, to enact agency to push against the structures of a figured world. As a graduate student in the disciplinary sciences, mentoring youth is not solely about gaining skills or pursuing interests; particularly for graduate students like Lennis and Amy who feel marginalized in their program, the figured world of youth engagement provides a context in which to "resist the subject positions that the social world attempts to invoke for them" (Nasir et al., 2012, p. 293), allowing them to create novel trajectories through their discipline. In line with other research on scientists from non-dominant backgrounds participating in youth engagement activities, these pathways are often "more congruent with their values and interests," (Thiry et al., 2007, p. 410) thus empowering them find ways to be scientists while also being themselves, rather than having to constrain aspects of their identity in order to be a certain kind of scientist (Carlone & Johnson 2007; Ko 2014).

Over time, these kinds of individual, agentic moves on the part of science graduate students undertaking community engagement can contribute to *making worlds*, the final element of the Figured Worlds framework (Holland et al., 2001). Through agentic actions grounded in subjectivity and improvisation, individuals' activities can forge new collective structures with attendant histories, meanings, and novel configurations of positioning— new figured worlds can be created or expanded from the old (p. 272). For example, many science departments at research-intensive institutions are evolving to support graduate students in activities that prepare them for career pathways beyond traditional tenure-track jobs in academia. In consideration of the expansive possibilities involved in making worlds, the metaphor of boundary crossing becomes apt once again:

> Dialogical engagement at the boundary does not mean a fusion of the intersecting social worlds or a dissolving of the boundary. Hence, boundary crossing should not be seen as a process of moving from initial diversity and multiplicity to homogeneity and unity but rather as a process of establishing continuity in a situation of sociocultural difference. (Akkermann & Bakker, 2011, p. 152)

Conclusion

The findings from this study show how youth engagement opportunities for scientists are viable and important contexts for science graduate students to develop as educators. Although graduate school is often conceived of as an immersive training experience from which newly awarded PhD holders emerge with all the skills they need to be professionally successful, the experiences of the participants in this study show that this is not the case, especially for scientists who have marginalizing experiences during graduate school (e.g., Lennis and Amy) or want to pursue a career in teaching (e.g., Amy and Dave). Working with youth in an informal educational context such as STEM OUT provides a relatively low-stakes opportunity to develop teaching skills that can also be employed in classroom environments, an idea that has been leveraged in K-12 teacher preparation (Luehmann & Markowitz, 2007). Scipio (2015b) discusses the importance of scientists developing teaching identities by engaging in "authentic experiences in rich contexts;" by doing so as a STEM OUT mentor, participants emerged with the skills to teach and engage students, but also a sense of who they were as educators, and who they could be as scientists.

Focusing on these aspects of identity work that science graduate students undertake across settings (in this study, youth engagement and graduate school), and the structural differences of those settings as framed by the Figured Worlds framework, helped to illuminate how navigating these larger systems can be complex but also generative. For example, the experiences of Lennis and Dave showed how scientists can forge a pathway through graduate school that incorporates both research and teaching, rather than the strict dichotomy often portrayed in the higher education literature. Beyond just focusing on how they developed skills in these dual realms, taking an identity perspective enabled me to show how participants could articulate the dominant norms and culture of their respective departments, how they were finding ways to figure out who they were both within and outside of those contexts, and how they could productively coordinate their different areas of personal expertise in productive mentoring interactions with youth.

Acknowledging the complicated identity work that scientists are potentially engaging in when they participate in youth engagement experiences should be important aspects of designing programs that bring youth and scientists together. As shown in this study and elsewhere (Klein, 2017), leveraging these identity-related experiences as scientists work with students can have powerful outcomes for youth participants. Even short-term interactions between scientists and youth can benefit from surfacing identity-related issues in the sciences, especially for participants from minoritized backgrounds (e.g., Hazari et al., 2013; Prunuske, Wilson, Walls, & Clarke, 2013).

Additionally, it was valuable in this study to incorporate social practice perspectives on identity. Using this lens more broadly to understand the experiences of graduate students would greatly benefit studies in higher education, given the ability to capture a nuanced and shifting view of research participants' experiences that are more closely aligned to their real-life experience (rather than a single dimension, as is positioned through more static views of identity). Higher education scholars should consider adapting the Figured Worlds framework in particular for their contexts, given the ability to understand the structures that impact students as they navigate universities and other institutions, and therefore situate the locus for change as people-navigating-systems rather than individuals.

This work demonstrates how scientists' experiences during graduate school, especially for those who complicate or reject the socially normative pathway of pursuing a research-focused career, can be leveraged productively into sustained youth engagement, rather than discounting work with youth as an ancillary or optional pathway. As the number of tenure track, research-focused positions in the sciences continue to decline (Cyranoski, Gilbert, Ledford, Nayar, & Yahia, 2011), PhD students will need more opportunities to develop their skills and identities as teachers (or other professional pathways), and, further, to see these post-PhD trajectories as socially normative. Science community engagement programs are one way to help shift the norms within university departments, but are by no means the only way to do so (Austin et al., 2009; Connolly et al., 2016; Ebert-May et al., 2015; Reeves et al., 2016; Rybarczyk, Lerea, Whittington, & Dykstra, 2016). Changing norms requires shifts both at the individual and systemic level to collectively remake the figured world of the disciplinary sciences. The barely discernible outlines of this new figured world do not mean that the historic norms of the figured world of the sciences are entirely unsettled, but rather that there is a dawning acknowledgement of other ways to be a scientist beyond solely focusing on research.

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Chapter 4. “It's Just a Cultural Thing”: Science Graduate Students’ Development of Teaching Self-Efficacy and Practice-Linked Identities in an Education Research Seminar

With the recent increasing focus on teaching and learning in the sciences through discipline-based educational research (DBER; Henderson, Beach, & Finkelstein, 2011; National Research Council, 2015; Singer, Nielsen, & Schweingruber, 2012), there is a wealth of empirical evidence to support undergraduate science instructors’ teaching practices. Early DBER efforts in particular were grounded in K-12 STEM education research, leveraging theories and practices that had been derived or employed from contexts with younger learners to post-secondary learning environments (e.g., Bransford, Brown, & Cocking, 2000; National Research Council, 2011). For example, active learning techniques (reviewed in Dolan, Collins, & Kellogg, 2015; Tanner, 2013) have students using classroom discourse strategies that improve their learning outcomes (Freeman et al., 2014), especially for students from minoritized backgrounds that are under-represented in the sciences (Eddy & Hogan, 2014; Haak, HilleRisLambers, Pitre, & Freeman, 2011). Adoption of these strategies in classrooms, then, has the capacity to not only improve students’ understanding of scientific content, but also to change who decides to enter and who persists in the disciplinary sciences (e.g., Commission on the Future of Undergraduate Education, 2017; Dika & Amico, 2016).

However, most PhD students in the sciences are not introduced to education research of any kind, and receive little (if any) training or systematic support for their teaching practice (A. E. Austin et al., 2009; Golde & Dore, 2001). Instead, doctoral candidates are prepared for research careers, through developing skills involving lab techniques or fieldwork, and are urged to minimize the time and energy they spend on teaching (Connolly, Savoy, Lee, & Hill, 2016; Fuhrmann, Halme, O’sullivan, & Lindstaedt, 2011). This is especially true for graduate students at research intensive institutions, which often do not incentivize a focus on teaching, either for professors or the graduate students whom they train (Anderson et al., 2011; A. E. Austin, 2002; Brownell & Tanner, 2012).

Despite being minimally prepared to teach, many doctoral students in the sciences—not just those with professional goals as educators—are supported for at least one year by teaching assistantships (Connolly et al., 2016; National Science Foundation, 2014). Further, upon graduating, many people with science PhD's pursue career paths that involve some degree of teaching or public communication (Connolly 2016; Cyranoski, Gilbert, Ledford, Nayar, & Yahia, 2011; National Science Board, 2014; NSF, 2013). These positions range from the "hyper-competitive" (Alberts, Kirschner, Tilghman, & Varmus, 2014) research university positions that require some teaching (Cyranoski et al., 2011) to adjunct lecturer jobs and K-12 education and outreach organizations (National Research Council, 2002): experiences for which their graduate training does not prepare them (Anderson et al., 2011; A. E. Austin, 2002; A. E. Austin et al., 2009; Brownell & Tanner, 2012; Connolly, 2010; Fuhrmann et al., 2011; Golde & Dore, 2001; McCook, 2011).

The implicit message underlying this phenomenon (which is pervasive throughout academia more generally) is that attaining a PhD in a discipline signifies that the degree holder has the proficiency to teach about that disciplinary content. However, research on K-12 and undergraduate teaching demonstrates that teaching expertise involves a suite of skills that go beyond deep understanding of a discipline's content (reviewed in Bransford et al., 2000; Gili Marbach-Ad, Egan, & Thompson, 2015; National Research Council, 2015b; Parsons et al., 2017). Being able to lead learners through complex subject matter involves cultivating one's pedagogical content knowledge (discipline-specific approaches to make disciplinary ideas accessible to novices; Shulman, 1986), as well as supportive opportunities to develop one's teaching practice (e.g., Ball & Cohen, 1999; Ball & Forzani, 2009; Grossman, Hammerness, & McDonald, 2009; Windschitl, Thompson, Braaten, & Stroupe, 2012). There is a need, then, for scientists to be supported during graduate school in developing their teaching practice as they concurrently teach undergraduate courses and for future teaching opportunities , ideally incorporating active learning strategies that promote equitable classroom participation and increased learning outcomes (Freeman et al., 2014).

The Research/Teaching Dichotomy

An integral aspect of why PhD students are not prepared to teach during graduate school is because research is generally privileged over teaching. In his interviews of graduate students and post-doctoral researchers, Connolly (2010) notes that, an interest in teaching is viewed as "a sign of a failed researcher" (p. 1). Austin (2002) also cites this internalized perception by graduate students, with an interviewee from zoology reflecting, "Teaching takes a back seat to research . . . research gets the glory" (p. 108). More broadly, a survey study of over 4,000 PhD students in Biology/Life Sciences, Chemistry, and Physics at 39 research-intensive universities found that the majority of respondents had a strong interest in teaching, but perceived departmental and advisors' encouragement to pursue research rather than teaching (Sauermann & Roach, 2012). These perceptions are not limited to graduate students: the dichotomy between research and teaching in the sciences was acknowledged in an editorial in *Science* by an inter-institutional group of biomedical professors (Anderson et al., 2011). As noted above, the authors cite the lack of systematic institutional incentives to develop a teaching practice as a research professor, especially through the heavy weighting of research activities during the tenure review process. These mixed messages are further embodied by the fact that university faculty in the sciences report that they received little to no training for their roles as teachers (likely only the scant preparation offered to graduate teaching assistants, plus at best a few days of faculty development workshops; Ebert-May et al., 2011; Tanner, 2011).

Resolving Challenges to Professional Identities through Engagement with Educational Research

In this study, I take the stance that it is not only the lack of institutional incentives that perpetuates the disciplinary sciences' narrow focus on preparing graduate students as researchers, but that it also is deeply related to individuals' professional identities. University science departments are social entities, in which individuals are subject to dynamics of power and positioning (Pifer & Baker, 2016). For a graduate student, who has relatively less social power than faculty members, deciding to focus on teaching can entail taking on a social risk (Connolly, 2010; Laursen, Thiry, & Liston, 2012). Therefore, participating in activities related to teaching can become a matter that challenges their developing professional selves (Brownell & Tanner, 2012).

One way to demonstrate that teaching and research are not incompatible is to provide opportunities for scientists to directly engage with education research, providing a basis for them to develop their teaching practice in an evidence-based manner (Baumgartner, 2007; Brownell & Tanner, 2012; Nelson, 2005; Schussler et al., 2008). For graduate students in particular, an ideal way to prepare them for this kind of teaching can be through orienting them to the primary DBER literature in their field (Schussler, Read, Marbach-ad, Miller, & Ferzli, 2015). Doing so leverages their orientation towards drawing conclusions based on empirical evidence, which they have been developing through their training as a research scientist. Learning about education research with like-minded colleagues could enable graduate students to develop teaching self-efficacy (i.e., confidence as a teacher) and navigate career pathways as education-interested scientists, without challenging their professional identities as research scientists.

Here, I explore the motivations, interactions, and identity-related outcomes for a group of science graduate students who took a seminar on Biology education research at a large, research intensive university in the western United States. I first detail the conceptual framework that informs my research questions and approach. This is followed by a description of the research context, and methods of data collection and analysis.

Conceptual Framework

A Socio-Cultural Perspective on Learning & Identity

Learning during graduate school goes well beyond the content of coursework or an individualized, vertical apprenticeship into research skills (as portrayed by cognitive apprenticeship models for graduate education, e.g., Austin, 2009): by participating in particular intellectual communities, as well as discovering the priorities and analytical approaches within disciplines, individuals continually construct their academic selves. As exemplified by the relative status of research and teaching in the disciplinary sciences, these processes are not value-free; graduate students' relationships and communities of which they are a part deeply impact their learning as a scientist (Flores-Scott & Nerad, 2012; Hall & Burns, 2009; Lovitts, 2005; Pallas, 2001).

To focus on teaching while in graduate school involves learning not only how to teach in a specific discipline (i.e., developing one's pedagogical content knowledge), but also *who to be* as an education-interested scientist. Green (2005) aptly illustrates this relationship: "doctoral pedagogy is as much about the production of identity ... as it is the production of knowledge" (p. 162). This study brings these ideas together by taking a situated perspective on learning (Lave &

Wenger, 1991; Rogoff, 2003). Reflecting a broader scale of sociocultural theories of learning, any learning process is directly bound up with identity (e.g., Bell, Tzou, Bricker, & Baines, 2012)— both in the sense of how individuals conceive of themselves and how they are positioned by others (Davies & Harré, 1990; Harré, Moghaddam, Cairnie, Rothbart, & Sabat, 2009) in a learning context. From the sociocultural theoretical family of perspectives, I specifically leverage a social practice view of identity development (Holland & Lave, 2009; Holland, Skinner, Lachicotte, Jr, & Cain, 2001), which recognizes that people navigate and tell who they are through particular interactions in specific contexts (Sfard & Prusak, 2005), and that these narratives may—and often do—differ across settings (Dreier, 2009). For example, graduate students may construct their professional selves differently, depending on various situational factors, i.e., if their advisor is present, if they are among peers who are interested in teaching, or if they are at happy hour versus a professional conference session.

In order to account for the complex fluctuations involved in individuals' identity development from a socio-cultural perspective, I take up the term "identity work" used by other scholars (Allen & Eisenhart, 2017; Bell et al., 2012; Carlone, Scott, & Lowder, 2014; Jackson & Seiler, 2017; Thompson, 2014; Wortham, 2006), to acknowledge how:

> the actions that individuals take and the relationships they form (and the resources they leverage to do so) at any given moment [are] constrained by the historically, culturally, and socially legitimized norms, rules, and expectations that operate within the spaces in which such work takes place. (Calabrese Barton et al., 2013, p. 38)

In this study, analytically employing the "identity work" concept helps to portray how the context of the education research seminar impacted how the participants could construct themselves as graduate students and scientists, in comparison to their lab or department. With this conception, the process of graduate students navigating multiple identities (as characterized by more static notions of identity, such as Erikson, 1980) is more aptly portrayed as working through various, possibly conflicting identities-in-action simultaneously (e.g., Varelas, House, & Wenzel, 2005) as they make sense of who they can be in particular settings as scientists who are also interested in teaching and learning.

Teaching Identity

> [L]earning to teach requires opportunities to engage in [identity] negotiation work with others in order to develop a grammar of practice – a language and structure for describing practice and one's own perspectives and positions related to that grammar. (Luehmann, 2016, p. 24)

Socio-cultural approaches to identity have been taken up in studies on teachers' learning and development, especially within the past decade (reviewed in Avraamidou, 2016). Consideration of individuals' identity work as they learn how to teach is crucial to highlight how their developmental trajectories as teachers are impacted by contextual factors of the learning setting, their personal histories as learners, and broader socio-historical factors (e.g., class, age, gender, race/ethnicity; Avraamidou, 2014, p. 164). Given this study's focus on a particular setting for learning how to teach, I focus primarily on this first affordance of utilizing identity as a research construct.

Within the sciences in particular, the process of becoming and identifying as a teacher is complex, as "the learner seeks not only to gain acceptance to the community but simultaneously wrestles to change it" (Luehmann, 2016, p. 21; Lave & Wenger, 1991). Although Luehmann (2016) discusses the relevance of this for reform-minded K-12 teachers in light of the recent policy changes recommended by the Next Generation Science Standards (NGSS) and accompanying *Framework on K-12 Science Education*, it is equally applicable to scientists preparing to teach at the undergraduate level (Brownell & Tanner, 2012; Henderson et al., 2011). As discussed in the Introduction, the broadening basis of DBER literature is gradually starting to impact university science teaching, with implementation of policy recommendations similar to the NGSS (e.g., for Biology, Brewer & Smith, 2011). Therefore, graduate students learning how to teach are also engaging in identity work as they develop a "grammar of practice" (Luehmann, 2016) that differs from how they were taught and how others around them are teaching.

In this study, I am interested in how issues of identity work arose in the context of a biology education research seminar, as graduate students learned about key research findings and discussed how to use them to improve their teaching practice. I use two main constructs to understand identity-related implications of participating in the seminar: self-efficacy and practice-linked identities.

Teaching Self-Efficacy

Self-efficacy addresses how individuals conceive of their capabilities in regard to a specific set of practices, which in this study is teaching undergraduate science classes. Self-efficacy frames the ways in which an individuals' beliefs about their skills in a particular area are directly connected to their abilities to employ those skills (Bandura, 1977, 1982). In line with this, teachers' sense of self-efficacy has been shown to positively correlate with effective teaching practices, measures of students' academic and affective outcomes, and lower rates of teacher burnout (reviewed in Zee & Koomen, 2016).

Self-efficacy is a socio-cognitive concept, such that identity is thought to impact learning by mediating behavior rather than identity and learning being inseparable (Hand & Gresalfi, 2015). However, self-efficacy is relevant to this study by acting as a gauge for participants to consider their identity work as educators before and after the seminar, and unpack specific practices undergirding their confidence as a teacher. Since the seminar was a space in which scientists potentially undertook social risk by committing time and effort to learn how to teach, self-efficacy provided one way to understand how participating in the seminar impacted graduate students' identity work. In this study, I use pre/post measures of participants' self-efficacy ratings to gain a sense of the collective identity-related outcomes of participating in the seminar.

Prior findings suggest that teaching self-efficacy develops early in a teacher's career (Morris & Usher, 2011). Therefore, it is crucial to identify elements of teaching professional development experiences that can foster or inhibit graduate students' teaching self-efficacy (Dechenne, Enochs, & Needham, 2012). Additionally, given the lower social status that accompanies a focus on teaching during graduate school in the sciences, it is important to attend to the processes by which individuals simultaneously develop teaching self-efficacy and social resiliency. This is especially salient if they are located in research intensive institutions (Luft, Kurdziel, Roehrig, & Turner, 2004; Morris & Usher, 2011), as was true for the participants in this study.

Designing for Practice-Linked Identity Development

To consider the broader factors that influence the development of teaching self-efficacy, I draw from an identity-related construct from the learning sciences: *practice-linked identities* refers to the identity work that individuals take on as they participate in social or cultural practices within a particular community (Nasir & Hand, 2008). To develop practice-linked identities, individuals, especially as novices, must be engaged and recognized by others in order for this identity work to take place (e.g., Holland et al., 2001; Luehmann, 2016; Polman, 2010). In their work on African American high school students' positioning and learning across settings, Nasir and Hand (2008) conceptualize three integral elements of engagement to foster practice-linked identities: access to the domain, integral roles, and opportunities for self-expression. Whether a practice is within the realm of a math class, a basketball game, or a microbiology research lab, an individual should have opportunities to learn about the practice and its specific tasks and sub-skills, be held accountable to develop expertise in the practice, and have contexts in which to incorporate aspects of themselves into a practice (Nasir & Hand, 2008, p. 148). When the context encompassing that practice—high school, a basketball team, or a biology department— does not provide opportunities for engagement in these ways, individuals will likely not undertake identity work around those practices, gradually being positioned and positioning themselves as marginalized relative to the broader community and its values.

Considering the adverse social positioning that can result from focusing on teaching while in graduate school, graduate students need contexts in which they can develop practice-linked identities as education-interested scientists (Ash, Brown, Kluger-bell, & Hunter, 2009; Connolly et al., 2016; Laursen et al., 2012). In this study, I explore how a seminar on education research served as a space in which scientists could collaboratively do so, by undertaking a number of different practices to inform their pedagogical approach and, concurrently, their sense of selves as teachers.

In the class, scientists moved across the boundaries of the disciplinary sciences, in which commitments to scientific research are privileged above teaching, to a setting in which they could develop their skills and try out practice-linked identities as educators. In order to be a space in which they could successfully do so, the seminar needed to coodinate with scientific epistemologies in certain ways, such that participants could directly envision how their educator identities did not have to conflict with being a scientist. Through my analysis, I highlight these points of coordination by focusing on aspects of the seminar's design and how they impacted graduate students' participation in the seminar. I also consider how their engagement, in turn, had implications for who they could become—both during and following the seminar (e.g., Nasir & Cooks, 2009). Although I was not involved with designing the seminar, this work is informed by a design-based research perspective on the design of learning environments (Brown, 1992; Cobb, Confrey, Lehrer, & Schauble, 2003; The Design-Based Research Collective, 2003), such that, in the final section of the paper, I present formative design principles for creating similar experiences for graduate students to learn how to teach in other science departments and universities (as is being increasingly recommended by other scholars; Connolly et al., 2016; Schussler et al., 2015).

Research Questions

Building on the framework outlined above, I specifically ask in this study:

How did participating in an education research-focused seminar impact graduate students' self-efficacy and identity work as educators?

How can experiences for scientists to learn about teaching be designed to promote their teaching-related practice-linked identification?

Research Context & Methods

Study Context

The context for this study is a graduate-level seminar on education research offered through the Biology department at a large, research-intensive university in the western United States. The 10-week class was two credits and taught by Simon, a Principal Lecturer in the department who had published extensively in the DBER biology literature. The course was designed to introduce students to undergraduate STEM education research, mainly drawing from literature in the DBER and cognitive psychology. At the time of the study, the course was in its fifth iteration, with two sections to accommodate the 22 participants.

The weekly 80-minute class took place through a highly structured student-led journal club format, in which participants read a selection of articles around a common theme—ranging from constructivist principles of learning to backwards course design to active learning techniques. In-class discussion usually incorporated some of these same techniques, such as turn and talk or jigsaw discussion groups. Students also independently observed a Biology class and reflected in class on the pedagogies they observed. At the culmination of the quarter, they wrote personal teaching statements, a standard component of academic teaching job applications, which were reviewed by Simon and their peers.

Research Approach and Unit of Analysis

In line with a design-based research approach, I investigated how designed features of the seminar impacted participants' identity work as educators, scientists, and graduate students, with implications for how to design a similar type of seminar in other settings. Therefore, my approach to data collection and analysis reflects the links between design and outcomes, with implementation data playing an important role in understanding how these links became evident over time through participants' interactions during the seminar. Conclusions discussed in the findings section are drawn from themes of the aggregate data rather than individuals' specific storylines, with the unit of analysis being the collective experience of the seminar.

As in other studies that focus on the identity work involved with short term learning experiences (Carlone et al., 2015; Laursen et al., 2012), I do not make claims regarding participants' longer-term identity trajectories. Instead, I aim to understand the features of the seminar that enabled them to begin to develop practice-linked identities as educators, with the understanding that their initial foray into education research and reflection on their teaching practice could lead to more enduring identity work as educators, if supported over time (e.g., Bell et al., 2012).

Data Collection

I collected a variety of data in order to understand how elements of the seminar surfaced participants' identity work as education-interested scientists. Participants completed a pre-survey that included open-ended questions on their motivations and goals for taking the class, as well as their previous teaching and training experiences. The post-survey elicited their feedback on the structure and content of the seminar, and asked participants to reflect on what they learned in the course. Both surveys included 28 5-Point Likert scale (1 = Not Confident; 5 = Very Confident) questions to assess their teaching self-efficacy. These questions were adapted from an instrument specifically designed to understand STEM graduate teaching assistants' teaching self-efficacy (DeChenne, 2010; Dechenne et al., 2012). As a way to understand how or if they employed pedagogical strategies from the course in their teaching, participants completed a follow-up survey six months after the seminar had concluded.

To triangulate pre/post measures with implementation data from the seminar, I observed the class to take ethnographic field notes (Emerson, Fretz, & Shaw, 2011) and collected audio/video data of participants' interactions during nine out of ten of sessions from one of the course sections (Derry et al., 2010). Course artifacts, in the form of the course syllabus and pictures of text and drawings made during the focal section were also collected. As the instructor of both sections, Simon verified similarities in content and discussion across the two classes, which I confirmed via comparison of audio of one session. Ongoing reflections from participants in both sections were recorded via exit tickets for each session, with questions prompting consideration of how they participated in the class, the most relevant idea or practice they took from the session, and their emergent questions. Finally, I conducted focus groups with students from both sections at the conclusion of the quarter and interviewed Simon to gain a sense of his intentions and subsequent design for the seminar. Beyond these interactions outside of class, I did not guide or take part in the seminar discussions, taking more of an observer role rather than an active participant.

Methods of Analysis

Analysis of Self Efficacy Data. I analyzed paired responses (*n*=14) to the pre/post teaching self-efficacy assessment. For each question, I performed two calculations: 1) aggregate mean of all respondents' ratings at the pre and post survey time points, and 2) the mean change in the *difference* between individuals' ratings on the pre and post-survey. Given the small sample size, I used the factor analysis produced by the author of the original instrument (Dechenne et al., 2012) to determine which dimensions explained the majority of the variability in the original dataset (*n*=253). I then assigned each survey question to one of these two factors: pertaining to graduate students' confidence in promoting the "learning environment" of their classroom or feeling prepared to undertake "instructional strategies."

Qualitative Analysis. For the open-ended responses that comprised the majority of the pre, post, and follow-up surveys, I undertook an iterative coding process, initially using open coding (Glaser & Strauss, 1967) to understand themes in participants' goals for participating and eventual outcomes from the seminar. I also employed constructs of interest from my conceptual framework (e.g., references to power dynamics with graduate advisors) as codes, to track how/if these arose in their reflections (Coffey & Atkinson, 1996). I then searched for themes and patterns among the coded data to generate low-level claims grounded in the data (e.g., "multiple occurrences of experience of teaching as devalued").

These themes then guided my iterative analysis of the implementation and reflective data from the seminar: observational field notes and content logs of the audio/video data from class sessions, and transcripts from the student focus groups and instructor interview. By doing so, I sought to understand how students' motivations impacted their participation in the class, and how their collective learning outcomes— in terms of changes in self-efficacy and navigating identity work—came about. As such, I used a process of writing memos that triangulated between the data sources, seeking connections or disjunctions between design features, participants' interactions, and their reflective data from the focus groups and surveys (Emerson et al., 2011; Strauss & Corbin, 1990). These memos allowed me to make increasingly higher-level claims as I abstracted up from the data (Erickson, 1986; Miles, Huberman, & Saldaña, 2014), in order to identify interconnected aspects of particularities in the setting, connect to theoretical constructs, and build formative design principles (Gravemeijer & Cobb, 2006). In keeping with methods for ensuring validity of my findings (Erickson, 1986, p. 147), I worked with colleagues to check that my claims were representative of the breadth and depth of the dataset, and grounded in sound interpretation of the evidence. In my search for disconfirming evidence, I note below when counter-examples were present in the data. Additionally, the two main findings sections each begins with a narrative vignette (Erickson, 1986) that is based on excerpts from transcribed episodes from class discussions that were particularly representative of my high-level claims related to self-efficacy and identity work.

Design Principles. Taken together, this rich dataset allowed me to build and test claims about the design of the seminar and the impacts that it had on graduate students' identity work as educators and scientists, as well as changes in their professional goals or stances towards teaching and learning. For example, the pre/post teaching self-efficacy measures used in this study give one view of participants' shifting sense of themselves, which I then compared to identity-related findings from other data sources, such as seminar discussions and daily exit tickets. The reflective data then enabled me to connect these findings to particular contextual features, such as "encouraging participants to share their experiences and expertise."

I then used these to build formative design principles for scholars to test when developing other experiences for science graduate students to learn how to teach. In design-based research, a design principle is "a claim about how to organize learning environments abstracted from particular projects or initiatives" (Penuel, Lee, & Bevan, 2014, p. 5). Particularly since this study only encompasses one enactment of the seminar, the design principles presented here are nascent and meant to inform how to design for graduate students' identity work in similar learning environments. This intention is further emphasized by Penuel and colleagues: "A design principle is not a generalizable or replicated finding about how best to promote a particular kind of learning aim; however, it is something that is intended to be a useful guide for design that can be tested, refined, or even dropped through empirical study" (p. 6).

Findings

In order to better characterize scientists who seek out experiences to learn more about teaching, I summarized demographic data that describe the seminar participants. Drawing from pre-survey data, I provide details on participants' motivations for joining the class and how these relate to their professional goals. The pre/post teaching self-efficacy data illuminates how the class impacted their confidence in specific teaching practices. Finally, I present findings focused on the identity work that participants undertook during the seminar. The self-efficacy and identity work sections both begin with representative vignettes drawn from the implementation data to illustrate how these outcomes were supported by specific interactions and prompts during the course.

Summary Statistics on Seminar Participants

The majority (59%) of seminar participants identified as White, and 68% identified as female (Table 4.1). Of the 22 total participants across two sections of the class, 20 were graduate students and two were post-doctoral scholars[3]—the individual students' year in graduate school and department for all participants are shown in Table x. Not surprisingly, the majority (59%) were enrolled in a Biology graduate program, as the seminar was offered through the university's Biology department.

The twenty graduate students all had experience as graduate teaching assistants (GTA's), although only three of them were teaching concurrently with the seminar. On average, participants had one academic year of undergraduate teaching experience and had taught 3.4 different courses. However, 75% of the group had one year or less of teaching experience, with 59% having taught only one or two different quarter-long courses (Table 4.1). Additionally, as in other studies of STEM doctoral students (Connolly et al., 2016; Dechenne et al., 2012), participants' experiences as teaching assistants varied widely, from independently leading lab sections or entire courses to only grading for a class. Their heterogeneous roles demonstrate the different levels of responsibility that participants had for preparing and teaching courses. Taken together, these findings indicate that seminar participants were relative novices to formal teaching practices, which will be important when considering the findings below.

[3] The demographic data in this section includes the post-doctoral scholars. However, all subsequent analyses focused only on the twenty graduate students, as the focal participants for this study.

Table 4.1. Self-Identified Demographic Data and Previous Teaching Experience for Seminar Participants (*n*=22). * Includes data only from graduate students (n=20)

Category	**Number of Participants**	**Percentage of Total**
Gender		
Female	15	68%
Male	7	32%
Race / Ethnicity		
White	13	59%
Latino / Hispanic	3	14%
Black / African American	2	9%
Asian	2	9%
South East Asian	1	5%
Multi-Racial	1	5%
Year in Graduate School		
1st	1	5%
2nd	3	14%
3rd	7	32%
4th	2	9%
5th	3	14%
6th	3	14%
7th	1	5%
Postdoctoral Scholar	2	9%
Home Department		
Biology	13	59%
Environmental & Forest Sciences	2	9%
Aquatic & Fishery Sciences	2	9%
Immunology	2	9%
Computational Biology	1	5%
Neuroscience	1	5%
Psychology	1	5%
Number of Quarters of Graduate Teaching Experience*		**Mean**
1	7	4.00
3	6	
4	2	
5	1	
6	2	
14	1	
Number of Different Courses Taught*		
1	9	3.40
2	4	
3	2	
5	1	
6	1	
11	2	
12	1	

Motivation to Participate: Not Prepared for Teaching

Findings from this study are in agreement with other research demonstrating that graduate students are not prepared as educators (A. E. Austin et al., 2009; Brownell & Tanner, 2012; Connolly, 2010). Seminar participants did not feel that they had been adequately prepared for teaching, and were taking the seminar in order to improve their practice for both current and future teaching opportunities. Supporting evidence for this claim is detailed below.

Previous Experiences to Develop as Educators. All respondents, with the exception of one student in psychology, had some form of training during graduate school to learn how to teach. These experiences ranged from weekly GTA meetings to formal professional development sessions. However, participants overwhelmingly reported that these experiences were ineffective, both in regard to preparation to teach and to work with students. This is significant, given that previous studies (Dechenne et al., 2012; Prieto & Altmaier, 1994) have found that graduate students' *perception* of their learning through teaching professional development experiences are positively correlated with their teaching self-efficacy, rather than actual number of hours spent in those PD experiences or even amount of time spent teaching.

While this study did not have a large enough sample size to undertake correlational analyses, some participants cited how, in contrast to their teaching development experiences, their time spent actually teaching and mentoring were integral in preparing them to teach and work with students: "My actual TA experience was quite valuable but the university training was not very useful," "[The training was] not effective - I've gained more information from seminars where presenters discuss teaching research and from my mentoring experiences." This last response also highlights how participants conceived of opportunities outside of formal teaching as contexts to develop their teaching practice. All of the graduate students except one had experiences in which they viewed themselves as educators, ranging from leading after-school science clubs to volunteering at science museums to mentoring undergraduates in their research labs. These experiences varied in the kinds of formal training involved, but it is notable that seminar participants sought out these opportunities and saw them as integral to their teaching approach. For education-interested scientists, developing their pedagogical content knowledge by teaching or mentoring in other related contexts played an important role in their perceptions of their own learning about how to be an educator.

Professional Goals and Graduate School Preparation. Participants reported aspiring to careers that involve both research and teaching, such as becoming a professor at a liberal arts college or a post-doctoral position that included teaching. This finding contrasts with the perceived dichotomy between research and teaching that is often presented to graduate students in research-intensive universities, and contributes to other bodies of work demonstrating that many graduate students in the sciences are committed to professional goals that are not tenure-track research professor positions (Connolly et al., 2016; Fuhrmann et al., 2011; Gibbs & Griffin, 2013; Sauermann & Roach, 2012). However, in this study, all of the participants had career goals that involved academic institutions. As other authors have shown (Thiry, Laursen, & Loshbaugh, 2015), this group of graduate students situated within science departments at a research intensive university are perhaps less aware of post-PhD career trajectories that are outside of academia, as represented by this quote from a participant: “I’m very interested in science communication to lay audiences but don't yet know much about opportunities and careers.”

As follows from their reflections noted above on the ineffectiveness of their experiences in teaching professional development, participants did not feel prepared by graduate school for their career goals involving teaching. Students described instead how their graduate training oriented them toward a research career, as represented by this response to a pre-survey question about how graduate school had prepared them for their future goals:

> As an academic - immensely --> [the university] as an RI school is excellent at teaching research + publishing, skills. As an educator - F- I've received no assistance from faculty to improve as an educator, classes are pawned off on graduate students, and there is little regard for A/V and other student/classroom support. The only thing the [university] has given me is the knowledge that one should never teach at an RI school if that is what their goal is - to teach.

Consequently, many participants cited how they wanted more opportunities to teach and improve their practice in graduate school. These motivations, then, led them to the education research seminar.

Participating in Seminar to Improve Teaching Practice. Participants' desires to improve their practice for current and future teaching opportunities directly influenced their decision to sign up for the seminar. One student succinctly described this as "I'm teaching a neuro undergrad course in the winter and I feel underprepared! I hoped this class would help me change and build my teaching approach." Another student spoke more specifically to how the seminar would help them to improve their practice:

> I have just completed my 3rd TA position, my first with a quiz section. While I truly enjoyed teaching and got positive feedback from the students, I suspected I could've been even more effective if I was familiar with the evidence-based literature about teaching college level STEM classes. I signed up for the class to become acquainted with the literature and hopefully better prepare myself for the teaching I hope to do in the future.

As in these responses, many participants reflected on feeling unprepared for previous teaching experiences when they described their motivations for joining the class. The seminar, then, played a role that they had sought out through informal teaching experiences as described above, but was grounded in a basis of empirical evidence that, as graduate students and scientists, they had come to value. Additionally, as a formal university offering, the course was seen as a much-needed supplement to the ineffective teaching training that the participants had otherwise received.

Vignette: Connecting Education Research Findings to Evidence-Based Teaching Practice

The below vignette portrays a scene that occurred at the end of the second class session. It was the first occurrence in the data set of a class discussion in which students directly surfaced connections between what they had been reading and their own teaching practice, but it became a common pattern during subsequent sessions. Bolded text indicates particularly relevant exchanges to these connections between research and practice.

The theme for the session, as Simon stated at the beginning of the class, was, “Who are our students?” given that “novice teachers go into classrooms thinking that all students are like [themselves].” Fourteen participants, a few of whom had not been there for the first class, were crowded around a large oval table. The first half of the class had been spent in whole group discussion, first discussing two papers on Bloom’s taxonomy from the prior week, followed by points that they had found interesting after reviewing graphs in the National Science Foundation Report on Women, Minorities, and Persons with Disabilities in Science and Engineering. Over the course of these discussions, there was an increase in the number of people who participated in the conversation, as well as students beginning to respond to each other’s comments and questions.

This pattern continued as three students described a review on stereotype threat (Steele & Aronson, 1995) that they had been assigned to read. Barika described the concept from the original study, and then Stephanie and Jessica, picked up with describing aspects of other follow-up studies on the phenomenon. Simon concludes, “So stereotype threat is all over the place. Depending on what group you're a member of. If you're not part of a group, it's in your classroom. As an instructor, you have to be aware of it.” Students continue talking about some of the methods of the studies, and then another student then directly connects the idea to pedagogical practice:

> Cal: **How would you address that, stereotype threat in a classroom?**
>
> Simon: Ooooh! Walton and Cohen!

Some students laugh as he excitedly points them to the next paper for discussion. He prompts the presenting group:

> Simon: But if you guys can get us started at least on **what can you do about it?**
>
> Avery: I guess I'll start with the introduction. So, so this paper is looking at methods to alleviate stereotype threat and the under-performance that results from it. And they're kind of addressing the potential for a recursive process, which is like a feedback cycle, where you feel like, you'll worry that you'll underperform based on a stereotype about your group, and then you underperform, and then it reinforces the stereotype, and then you continue to decline. And so they did it in 7th grade classes, they repeated this with 3 different cohorts of about 130 people, students in each cohort. And there was a control group that had to report on just a daily routine. **They described a, some other value...**
>
> Sandra: **An unimportant value.**
>
> Avery: **An unimportant value, we didn't really know quite what that was, but that was, I dunno, maybe that's like something to us as a group feels important, but so I'm not reflecting on myself.** Cause that was the treatment group, was reflecting on something that was important to you. And then they tracked the performance of these treatments over time, using GPA as their response variable. And I should say there was three groups- there was European Americans, high performing African Americans, and low performing African Americans. And then within those three groups, they each received the control and the treatment.
>
> Simon: What happened, what happened? I can’t wait! [Students laugh]

> Sandra: The students that got the self-affirming assignment, so reflecting on this value that's important to them, the European American students were not affected by the difference in assignment at all, but the African American students were affected by the assignment. **So the low-performing African American students in particular showed an increase in GPA with the self-affirming assignment.** [As she is talking, Avery draws a graph from the paper on the board; see Figure 4.1] **And this was also true of the high performing students, but not to quite the same degree.**

As noted above, students who had not read the article began to ask questions about how the intervention was implemented and interpretation of the study's findings:

> Barika: **When did they do the assignment relative to when they were (inaudible).**

> Sandra: So they did the assignment three to five times at regular intervals throughout the first year. And then actually- the second, they're evaluated through the first and second year. And before starting the second year, some groups were split and got like a booster, of affirmational assignments, but that seemed not to have an effect. So as long as they did it the first year, they saw this effect.

> Simon: Avery is putting the key graph up here.

> Avery: I was just- I'm, this is a relative graph**. But there's one relationship that's pretty interesting. The effect size of this was pretty small, but I think important more than just statistically significant.** [Students laugh]

> Stephanie: So what, the improved GPA, was that for all of the African American groups, or was just the ones that were low-performing?

> Sandra: It was both, but the increase was bigger for the under-performing students.

> Barika: It might be that you have a ceiling effect for the high-performers.

> Sandra: It was on average .24 grade points on a 4.3 grade scale.

> Samantha: It should be pointed out that it was actually more of like a slope, so these are all over time- well, he'll show you with the graph, everybody's GPA kind of declined, but the higher performing- sorry, the lower performing students who got affirmation declined less than the control.

> Sandra: You know what, I should tell you this again. Overall, for African Americans, it was .24 grade points, but for the low achieving African American students, it was .4.

> [Some murmurs]

Simon (quietly): **That's a C minus to a C, C to a C plus.**

Sandra: And also, the rate of students that were repeating grades or going to remediation classes decreased.

Simon then turned back to the pragmatics of using the affirmation exercise in the classroom, citing his own experience in using and studying it:

Simon: **You guys, this exercise takes 15 minutes.**

Samantha: **What are they writing about? I want to know the prompts!**

Simon: **The prompt is, you pick out, I can bring it in if you guys want it.** We just are submitting a paper to *Science Advances* again this weekend, we've done it in Biology 101, and we've wiped out the achievement gap for URM students using this.

Samantha: So it actually does work. We were like, how does this work!

Simon: When the first paper was published, Cohen- Cohen is a Claude Steele protégé from way back when on stereotype threat, and he published first paper on it in 2006 and people didn't believe it. There's no way.

[Some laughs and overlapping talk]

Simon: **It's been used in physics, with women in calculus-based physics at University of Colorado Boulder, this is a majority African American middle school in Baltimore, urban Baltimore. We used it in Intro Bio where our URM students are maybe 8 to 12 percent. It is, when it works, it's unbelievable.**

Aneni: **A 15 minute reflection, writing exercise?**

Simon: **We do it online, doesn't even take-**

Liz: **Just in the beginning of your class?**

Simon: Yeah, that was something Cohen really emphasized when we first got in touch with him. We said, we want to try it in our class, he said do it right at the start, the minute they walk into the threatening environment.

One of the presenting students then connects back to the underlying theory from the paper that guided the design of the intervention, invoking her classmates to help her explain the idea.

Samantha: **And I think this paper would probably argue that the reason you need to do it early is so that you can basically stop any sort of spiraling out of control of the under-performance**. So if you do it early, then if you're going to perform better, then, you have less- I'm not explaining myself well.

Simon: No, you got it.

Samantha: Somebody else fill in, help!

Simultaneously, another student presses Simon and the group to give details of the prompt for the exercise.

Stephanie: **Wait, so what was the affirmation?**

Simon: You don't get into the vortex you were talking about.

Samantha: Mm-hm!

Stephanie: **You just write about...**

Aneni: **Self-affirming values.**

Stephanie: Like something they value about themselves, or something they value about like...

Simon: **They're given, the prompt, they're given a list of values like musical ability, or family, or religious belief, or- it's not related to academics, sometimes there's one on reading or writing or something like that, but it's just-**

Samantha: **Something that's important.**

Simon: **-athletic ability, something that's important.** And the treatment group writes why is it important to me or how it's helped me, and Cohen- they didn't even read the responses. Now there's some literature on whether the students' act of writing is that important. And then the control is, as Avery was explaining, same values, but you identify the least important one and write about why it might be important to somebody else. But you nail that it's not personal, that's the key psychological thing.

Avery: **Yeah, so it seems like it's, it's instead of focusing on why you shouldn't perform well, it seems like it alleviates that anxiety.** But they provided, presented as evidence for the importance of that initial one, and it became a recursive process, in that when they split the group later on, it didn't make a difference. So in year 2 when they were giving, providing more affirmations, it didn't improve performance. So really the only difference, it's hard to parse this out statistically, but logically it makes sense, it makes a big difference here [gesturing to the peaks indicating increased GPA during Year 1 on the graph he drew on the board; Figure 4.1], but it doesn't make a difference anywhere else.

Brandon: And this is GPA, this is total GPA, right?

Sandra & Avery: Yeah.

Brandon: **Yeah, so the cool thing is like you can look at tools that are helping in your classroom, but this is hypothetically a tool that you can help in your classroom but it helps in everyone else's classroom as well, right?**

Avery: Yeah.

The discussion ended with students making connections to other studies in social psychology (e.g., Amy Cuddy's work on power posing) and questioning how the intervention actually causes a shift in participants' mindsets, with almost everyone staying until the end of the discussion, despite the class going fifteen minutes over time.

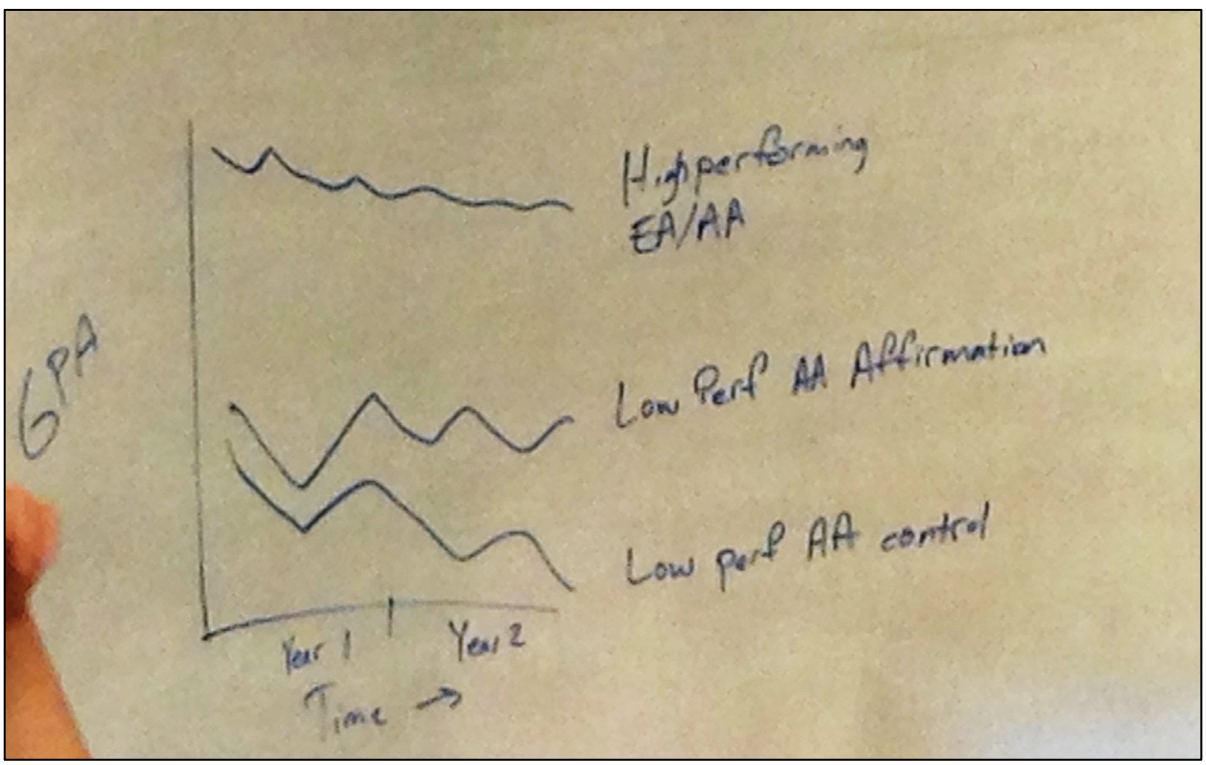

Figure 4.1. Graph Drawn on Board During Class Discussion by Avery (Vignette 1)

Understanding Findings from Education Research to Apply to Practice

As shown in the vignette, seminar participants drew from their collaborative understanding of education research studies and discussed how to apply findings in their subsequent teaching. This eventually routine practice aligned with their expectations for the course: the majority of participants related how they wanted to improve their teaching by having a better sense of teaching approaches that were grounded in empirical evidence. One student articulated this motivation for taking the class as: “[I am] interested in a better understanding of how we learn (both myself and students) and in becoming a better, evidence driven teacher.” Another student described wanting to gain “a greater understanding of the current STEM education literature & how to apply that in my teaching.”

Students’ practice-focused motivations informed the outcomes and modes of their participation in the course. Despite the seminar being focused on education research, only one participant expressed an initial interest at the beginning of the course in undertaking education research, with one additional person interested in doing so at the culmination of the seminar. Additionally, as shown in the vignette, participants were interested in the methodological details of the studies insofar as the study design may have impacted the outcomes of an intervention, rather than how they might undertake a similar study in their own classrooms. Finally, participants’ post-survey ratings of the value of different aspects of the seminar (Figure 4.2) indicated how they valued applying findings over learning methods: “Learning about evidence-based teaching” practices received the most valuable mean rating (6.62), while “learning about methods of educational research” was rated as one of the least valuable practices (mean=3.15).

These scientists, then, were interested in reading and discussing educational research in order to understand the evidence underlying rigorous ways of teaching undergraduate science,

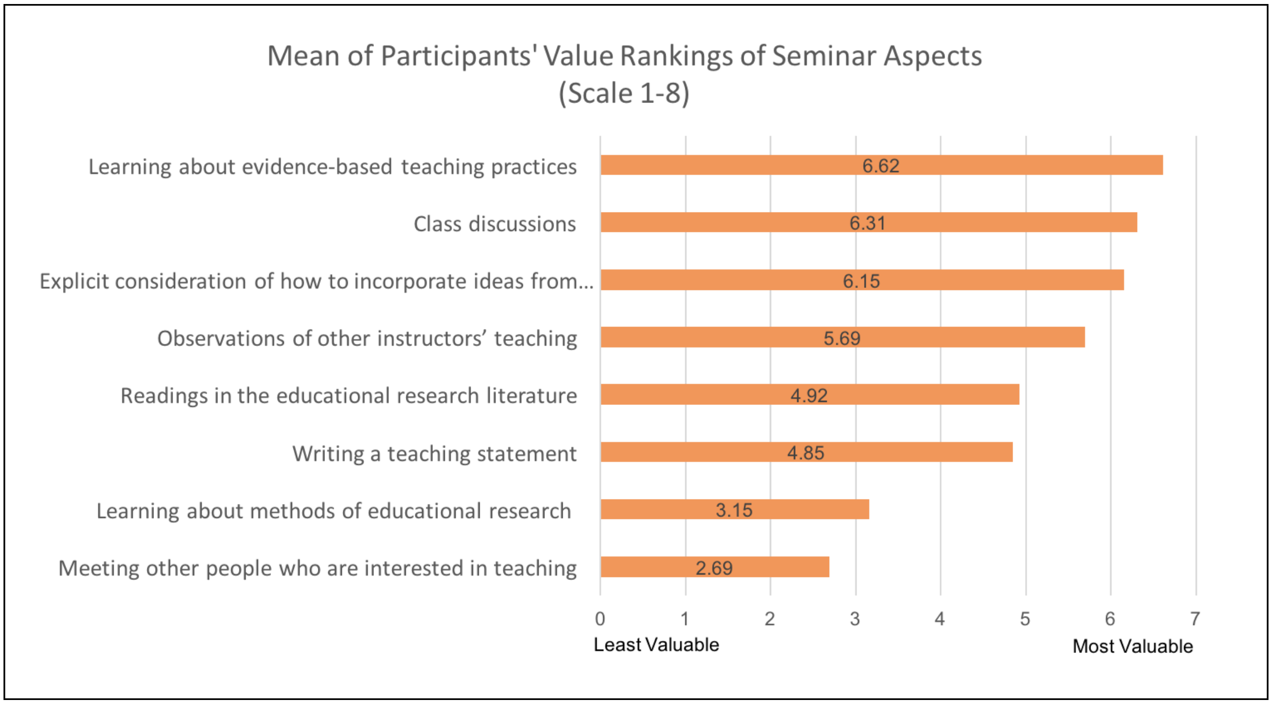

Figure 4.2. Mean of Participants' Value Rankings of Seminar Aspects

which, for this class, was largely centered around active learning strategies (but not solely, as evidenced by the vignette). This evidence-based approach aligned to the epistemological orientation that also guided their disciplinary research, in which conclusions are drawn based on extrapolating from empirical findings in one setting—either experimental or observational, but are often bolstered by statistical analyses—to other contexts. Applying this framework to their nascent teaching practice fits with graduate students' above-stated intentions to shift their teaching by incorporating "evidence-based" pedagogies.

Some participants wanted to spend more time during the seminar learning from peers' teaching experiences, with one student suggesting "more time for people to describe what has worked well for them in their classes - time to exchange suggestions." This is representative of a broader theme of feedback from students on their desire for more time to design and practice teaching techniques during the seminar, demonstrating how they saw the seminar as one of the few spaces in which they could develop as educators during graduate school.

Teaching Observations to Connect Between Research and Practice

Beyond talking about studies in education research, participants' observations and reflections on other instructors' teaching constituted another important dimension of the class. After the third session, Simon e-mailed students with a schedule of Biology courses, noting instructors who use active learning strategies, and a guide to structure and record their observations. The guide pointed observations towards what he characterized in class as the "hard and soft skills" of teaching, asking participants to notice the learning objectives and opportunities for formative assessment during the class they observed, as well as the "feel" of the classroom, as gauged by the mechanics of the instructor's presentation and how much time students spent on tasks other than listening or taking notes.

Towards the end of the course, participants discussed what they saw during their observations. This class was markedly different from other sessions, given the discussion's focus on students' observations rather than research findings. Although Simon made occasional connections between their observations (e.g., undergraduate students seemed distracted while using their laptops in large lecture classrooms) and his knowledge of research findings ("There's actually some literature with people watching computer screens and, in a general classroom, about 15% of the time, students will be distracted if they've got a laptop open"), he continually guided participants' talk to what they saw in classrooms. Consequently, participants cited their observations as evidence for any claims they made about an instructor's teaching practice. This was apparent during the group's discussion of instructors' "presence," or, as Simon put it, the instructor's "command of the classroom." Tamara described how an instructor was "no nonsense," and Liz, who observed the same instructor, built on this to describe what the instructor actually did to accomplish the "reciprocal respect" with students that she and Tamara had noticed:

> In the language that she used when students did get answers incorrectly, she never directly said, 'oh you're wrong.' She would always go back to- she wouldn't just answer the question, she would go back to the rest of the students, 'oh did all of you guys think that? Is this, what did other people think? Okay, that might be part of it, but let's talk more.' And so there was more discussion rather than just saying, 'no you're wrong, this is the answer, let's move on.'

In so doing, participants began to generate their own sense of how to actually carry out the pedagogies they had been reading about (e.g., facilitating equitable group discussions, incorporating formative assessment methods into lectures, structuring opportunities for students to interact in large sections), synthesizing their teaching observations through their newly acquired lens of education research. This process that continued into consideration of their own practice through writing individual teaching statements, as explored in the next section.

Additionally, observing other instructors' teaching gave participants an opportunity to ground what they had been learning about from the seminar readings in authentic practice. Although a few participants directly cited a reading or topic from class in their observation notes (for example, "For this and most of the other clicker questions (I counted about 7), Dr. M relatively consistently followed Mazur's pedagogical approach to peer discussion, without skipping steps"), the connections between their understanding of education research and observations of pedagogical practice were mainly evident from their end-of-course reflections. As an aspect of the seminar, "observations of other instructors' teaching" was ranked moderately high (see figure), with one student characterizing its value as: “The literature provides background, and the classroom observations and teaching statements give ways to consider putting the information in them into practice.” Participants who observed multiple instructors were able to directly witness active learning strategies’ effects on students’ engagement, as noted in this response:

> Observations of instructors who had two different approaches in lecturing was effective. I sat in on a course that was lecture only, and noticed the blank faces of students. I sat in on a course that was active learning and was amazed as to the amount of student participation occurring.

In all, the teaching observations allowed seminar participants to begin to consider how to accomplish the student-centered pedagogies they had read about and discussed, which may have impacted their self-efficacy at carrying out those same pedagogies in the future—similar to shifts in K-12 teacher education to focus on continuities across teaching practice (e.g., Ball & Cohen, 1999).

Increased Teaching Self-Efficacy through Seminar Participation

Given participants’ motivations to improve their teaching practice and the ensuing activities that took place during the seminar as described above, the self-efficacy measures on the pre- and post-survey served to ascertain if the ten-week class had impacts on their confidence in themselves as educators. The findings below are based on analysis of the pre/post measures of teaching self-efficacy from the 14 participants for whom there were paired survey responses.

After the seminar, participants reported increases in their teaching self-efficacy, across all dimensions of the instrument. The mean of individuals’ changes in ratings between the pre and post survey for all questions is shown in Table 3.2. Across questions, there was wide variability in the mean amount of change on the 5-point Likert scale, (1 = Not Confident; 5 = Very Confident) ranging from 0.07 ("Stay current in my knowledge of the subject I am teaching") to 1.29 ("Promote my students' confidence in themselves").

The study that developed the survey on teaching self-efficacy for STEM graduate students (Dechenne et al., 2012) found through exploratory factor analysis that the majority of the survey items clustered along two main dimensions to explain the variability in responses from their sample (n=253), which was much larger than this study (n=14). The authors conceptualized those dimensions as having to do with graduate students' confidence in undertaking "Instructional Strategies" or cultivating a "Learning Environment." Mapping these classifications to the survey results from participants in this study shows that the items that had the greatest mean changes all aligned with the "Learning Environment" dimension (Table 4.2, Figure 4.3). In contrast, the practices that showed the lowest changes in mean self-efficacy rating were associated with "Instructional Strategies," involving logistical skills related to grading, planning, and preparing teaching materials (Table 4.2).

Participants' increased confidence in fostering an inclusive learning environment likely followed from Simon's expertise on active learning techniques in large undergraduate classrooms, and therefore the seminar's focus on both the theory and practice that supported those particular techniques. While active learning pedagogies involve a certain degree of strategic instructional moves on the part of the teacher, discussions in the seminar also focused on how successfully implementing these practices promoted a more equitable environment for students' science learning. The affirmation exercise discussed in the above vignette was not specifically an active learning technique; however, the discussion's focus on how employing it

Table 4.2. Analysis of Self-Efficacy Ratings from Paired Pre/Post Responses (*n*=14)

Responses were on a 5-Point Likert scale (1 = Not Confident; 5 = Very Confident). Factor categories are based on factor analysis from the original research instrument (Dechenne, Enochs, & Needham, 2012). See Figure 4.3 for comparison of means of individual differences.

Question: "How confident am I in my ability to…"	Aggregate Mean Rating: Pre-Survey	Aggregate Mean Rating: Post-Survey	Mean of Individual Differences
Factor Category: Learning Environment			
Promote my students' confidence in themselves?	2.52	3.64	1.29
Actively engage my students in the learning activities ?	2.86	3.64	1.07
Ensure that my students consider themselves capable of learning the material in the course?	2.33	3.36	1.00
Think of my students as active learners?	2.95	4.07	1.00
Evaluate the degree to which the course objectives have been met?	2.81	3.71	0.93
Encourage my students to interact with each other?	3.00	4.07	0.86
Encourage my students to ask questions during class?	3.09	4.00	0.86
Provide support/encouragement to students who are having difficulty learning?	3.24	3.93	0.86
Let students take initiative for their own learning?	2.23	3.07	0.79
Promote student participation in my classes?	3.05	4.00	0.79
Make students aware of the relevance of what they are learning?	3.24	3.93	0.71
Promote a positive attitude towards learning in my students?	3.38	3.71	0.50
Create a positive classroom climate for learning?	3.43	3.79	0.43
Maintain high academic expectations?	3.52	4.14	0.43
Make students aware that I have a personal investment in them and in their learning?	3.71	4.07	0.43
Show my students respect through my actions?	3.90	4.36	0.43
Factor Category: Instructional Strategies			
Evaluate accurately my students' academic capabilities?	2.62	3.50	0.79
Select the appropriate materials for class activities?	2.62	3.21	0.79
Develop my teaching skills using various means?	3.14	4.07	0.79
Specify the learning goals that I expect my students to attain?	3.10	3.71	0.71
Calmly handle any problems that may arise in the classroom?	2.86	3.36	0.64
Be flexible in my teaching even if I must alter my plans?	3.19	3.71	0.57
Clearly identify the course objectives?	3.29	3.79	0.50
Prepare the teaching materials I will use?	3.29	3.43	0.43
Appropriately grade my students' exams/assignments?	3.09	3.71	0.36
Spend the time necessary to plan my classes?	3.24	3.36	0.21
Provide my students with detailed feedback about their academic progress?	3.33	3.64	0.14
Stay current in my knowledge of the subject I am teaching?	3.62	3.79	0.07

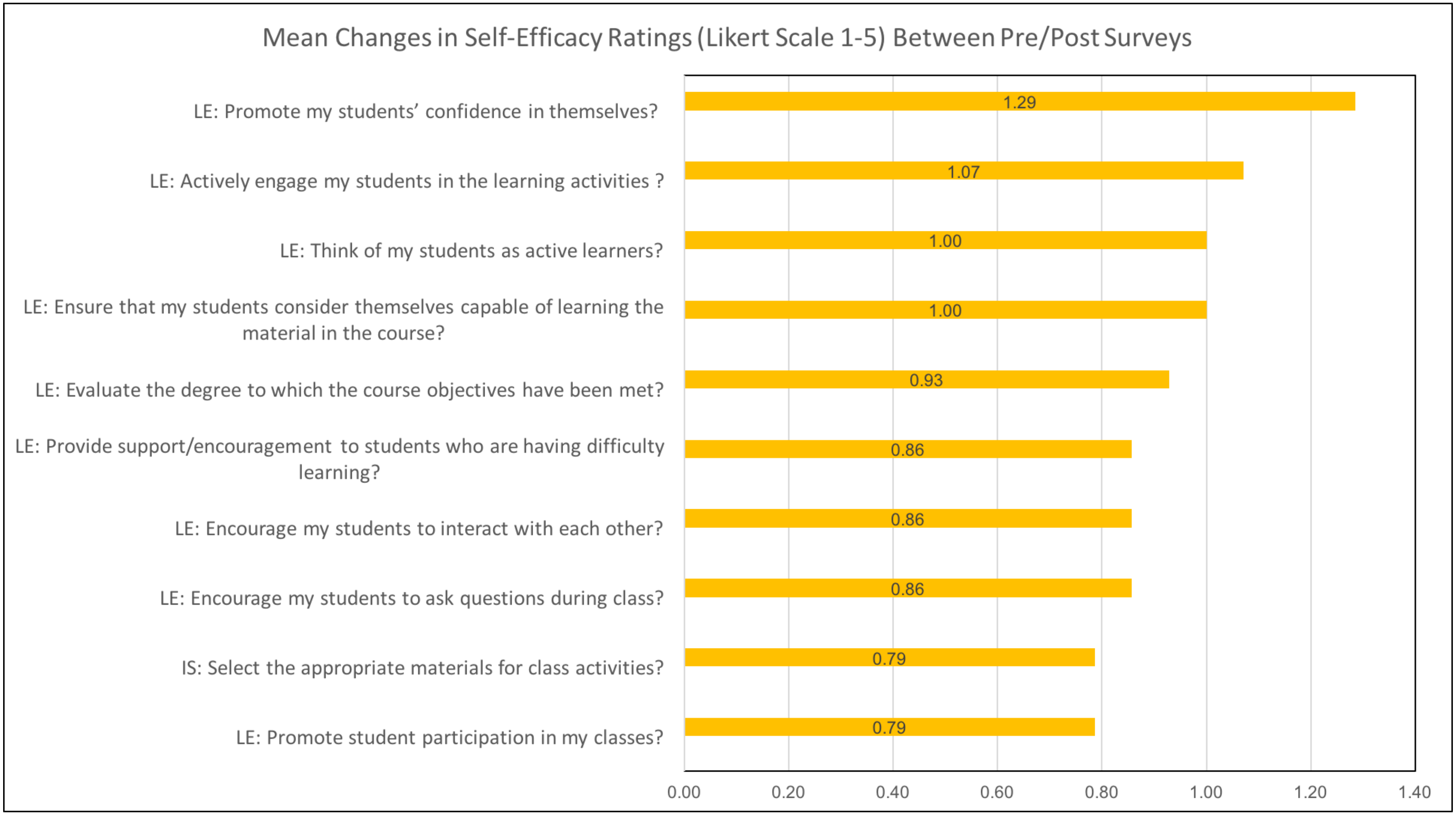

Figure 4.3. Mean Changes in Self-Efficacy Ratings from Paired Pre/Post Responses (*n*=14)

across a variety of settings resulted in improved course outcomes for students from minoritized backgrounds provides one example of how the seminar was structured around principles of educational equity.

Incorporating Strategies from Seminar into Teaching Practice

Although increases in teaching self-efficacy do not necessarily translate to changes in classroom teaching (especially for novice teachers; Settlage, Southerland, Smith, & Ceglie, 2009), teachers' increased self-efficacy can be associated with higher quality teaching practices (Zee & Koomen, 2016). Accordingly, there is significant evidence from my findings that seminar participants began to change how they approached teaching as a result of what they learned. Responses on the six-month follow-up survey from graduate students who had taught during that time demonstrate that they had implemented ideas that they learned about in the class. These included: (a) using backwards design in planning a course (Wiggins & McTighe, 2005); (b) having students work in small groups (e.g., Jensen & Lawson, 2011); (c) using methods of formative assessment via clicker-style questions and peer instruction (reviewed in Vickrey, Rosploch, Rahmanian, Pilarz, & Stains, 2015). For those participants who had not yet taught, all reported that they planned to use ideas from the class in their future teaching, as in this example:

> I'll definitely implement much of the group activities discussed in papers we read and used in class. I love the idea of flipping so that students work on problem sets together in class and can get instant feedback from instructors.

Although this study does not include long-term measures to ascertain if participants ultimately employed these practices in their teaching, Connolly and colleagues (2016) sought out similar questions in their longitudinal study of over 3,000 doctoral students in the STEM fields. They found that increased levels of engagement in a teaching development experience during graduate school (such as the seminar) were positively correlated with evidence-based teaching behaviors during early career teaching, as well as increases in teaching self-efficacy over time. This finding suggests that, despite the possible lack of support in their departmental contexts for further developing their teaching practice, participants in this study are likely to undertake some of the strategies that they learned about in the seminar in their future teaching.

Seminar as Context for Graduate Students' Identity Work as Education-Interested Scientists

The above findings characterized how science graduate students decided to take a seminar on educational research in order to improve their teaching practice, and how their practice then shifted during and after participating. This section builds on this idea to show how participants' motivations and interactions were undergirded by their identity work as education-interested scientists. Further, I illustrate how the seminar was a social space in which they could share their experiences, ideas, and resources on teaching with like-minded peers, contributing to processes of practice-linked identification for participants(Nasir & Hand, 2008). All of these elements are illustrated by a class discussion that occurred at the beginning of a session late in the quarter, presented here in the below vignette.

Vignette: "Who is Here Undercover?"

Most of the twelve students arrived before class began, and casually settled around the large table, opening computers and getting coffee from the communal pot that Simon made before every class. A few people talk quietly, while others listened to three female students talk about how they used Individual Development Plans (IDP's) to tell their advisors (or as is standard to call the principal investigator in many science labs, their "PI") about what they are interested in taking on in their research projects— "like microbiome, big data stuff." IDP's are written reflections on short and long-term goals that students who are funded through National Institute of Health grants have to complete annually and share with their PI's. The three students ask each other questions and share experiences about their research progress and dissertation committees. Their conversation peters out as class begins, but Simon draws attention to it as he launches the class discussion:

> Simon: People were talking about individual development plans [before class]. I actually wish they'd existed when I was a grad student because, you get trained to do your mentor's job. [….] And you guys are going to end up, statistically, in lots of different jobs, and so I really like the IDP, meaning that's something you should be thinking about from Day One. […] You're not strictly here to make your PI's life better, you're supposed to be getting something- I see this course as part of that effort you guys are doing to get the skills you want to have when you come out of school. [laughs] Anyways, that's my whole soap box about IDP's.

As had become standard practice in the class, one of the students who had been part of the original IDP conversation, Stephanie, picked up right where Simon left off, referencing the articles on faculty teaching development that they had read about for the day's session:

> Stephanie: **I was thinking about the papers we read, in terms of the stigmas associated with teaching- or scientists wanting to go into teaching.** And it made me reflect on the IDP, because I really like doing it. Because it opens up a dialogue- a deliberate dialogue with my PI that this is something I'm interested in doing. I'm required to do that. Whereas otherwise, **I think I would be more fearful to have that conversation with him.**
>
> Liz: I definitely agree with that. Doesn't mean that the PI is receptive, but it gives you a platform to talk to them. I keep telling my PI that I don't want to be a PI and he keeps telling me that I'd be a great PI and I'm like, that's not helping. [Students & Simon nod, laugh quietly.]
>
> Samantha: I have the same situation, my boss is going up for tenure in about a year. **And I didn't even tell him I was doing this course-**
>
> Liz: Yeah, me neither.
>
> Samantha: But I sat down with him with my IDP, my little printed out sheet. And he literally said, okay let's get this over with. And I was like, oh great.

As the conversation continued, however, it became clear that even having the IDP as a communication tool may still be counter-balanced by students' perceptions of how their PI's privilege research over teaching:

> Tamara: **I think I played down my interest in teaching on my IDP.** [Sandra nods, others laugh softly] **But that's cuz, I don't know, I'm kind of scared of my PI.**
>
> Stephanie: I think it's also helpful for my committee. Because them knowing that I'm not going to follow an academia track, they can concede that then you don't need to save up for this high-powered paper, you can publish what you have in one of these smaller, nice journals, and kind of, help me in that way.
>
> Samantha: **But you're right, it is a balance between what your committee wants and my PI wants. My committee is seemingly very supportive of me, but my PI really wants those high impact papers [Stephanie: yeah, mine too.] Really just wants me to spend all my time in the lab and not developing. I think he forgets that he's supposed to be my mentor instead of my boss.** He's supposed to help me develop as a scientist and help me develop my career goals, as opposed to just telling me what to do. And that's really challenging. So the IDP is useful, it's just how you can present it.
>
> Simon: Anyone else have any insights? **These are fantastically asymmetrical power relationships that you're in as a graduate student.** If it goes sideways, it can be horrible. I mean, someone said, 'I'm scared of my PI,' it's just out there, it's part of the deal. You don't wish that on yourself or anybody, but it can happen.
>
> Stephanie: I think it's just hard if your committee is like, pulling for you and wants to help you graduate and they're like, just write up this and then you're good to go but then your PI is like, oh no, you have to do all of these other things before you leave. It creates bad blood if you- there's a concern about creating bad blood if you kind of, utilize your committee to get out against the wishes of your PI.
>
> Simon: **How does this course and your interest in teaching fit in?** It's popped up a couple of times here. **How many of you are doing this course undercover?**
>
> [Liz, Samantha, Tamara raise hands, Cal waves his in a 'sort of' gesture. They look around, some nervous laughs]
>
> Cal: I just didn't really talk to him about it. Not because... [trails off]
>
> Samantha: **I sneaked it into my IDP, but he doesn't read my IDP, so. It's there!**
>
> Liz: **I'm a big fan of the ask forgiveness, not permission.**

> Tamara: **It helps that it's so early in the morning, because then they don't even notice that we're gone** [Liz and others: Yeah!]
>
> Simon: [laughing, high fives the student sitting next to him] Eight o'clock start time strikes again!
>
> Samantha: **I'm probably getting into lab earlier than I normally would after this class. It's a benefit, really.**

This led to a discussion of how focusing on research over teaching is a structural issue, supported by the culture of academia and reinforced by organizational practices:

> Samantha: I think one of the things that really stood out to me in the paper I read was just like the emphasis on needing to change the culture. And one of the things, I think I put a big exclamation next to it- was [reading from paper] "faculty are mixed in the belief in being recognized, evaluated, and rewarded for effective teaching." **And I think that is part of the cultural thing, where they think that if I just focus on teaching and stuff- or if my students focus on teaching, then we won't get the recognition we deserve. I think that's part of the problem, it's just a cultural thing, we've been developing academia this way.**
>
> Simon: So where does that culture come from?
>
> Stephanie: I guess, I mean, **the stigma is that the people that are thought of as PI's are more considered scientists, and they're considered to be higher up.** In one of these papers, actually talked about that age-old adage,"those who can do, those who can't, teach," **so people think, there's a stigma that people who go into teaching, are just not good enough scientists.**
>
> Tamara: I also think the career trajectory has changed over the years, and so- it wasn't as difficult to get tenure-track positions or become a PI. And so I think the culture is built around that, and then I think, accepting these alternate career paths become more difficult.
>
> Simon: So people grew up in a different environment, is what you're saying? So they're like, ‘what's your problem?’ [soft laughs]
>
> Tamara: And yeah, all of the reward systems for faculty are still based on the fact that-
>
> Samantha: -it's super research-focused.
>
> [Simon stands up to board]: Okay, so Tamara is on the essence, the reward systems. Do you understand indirect costs recovery?

Simon goes on to explain how research grants that faculty members attain then contribute to funding universities' overall functioning, such that the more research money they bring in, "the more value you have." In contrast, revenue from undergraduate students' tuition does not change, no matter the quality of teaching: "If I do a crappy job, the university still makes money."

Research Valued Over Teaching

Students' talk in the above vignette demonstrates the ways that they experienced their PI's devaluing of teaching. Despite the IDP serving as a tool that some of them used to communicate their interests, they also shared about the common experience of navigating a working relationship with their PI while having professional goals involving teaching, which did not align with the research-focused pathway that their PI's expected.

Pre-survey responses from the entire group of participants further detailed how teaching was not valued in their departments. One question asked them to consider why other science graduate students do not take part in opportunities to learn more about teaching. A dominant theme of responses was that teaching was not respected by their advisor and/or department, as illustrated here: "[There is a] tendency for being good at teaching to be de-emphasized (and sometimes demeaned) within research settings." Other responses pointed to graduate students' lack of time to focus on teaching, given the perceived need to solely focus on research while in graduate school. Given these social and logistical pressures to not participate, then, choosing to take the seminar involved both the ability and the desire to navigate being an education-interested scientist in a research-focused community—even if this entailed attending the class "undercover."

Additional evidence for how participants had experienced teaching as devalued in their departments came from reflections on their professional trajectories. This representative example was in response to a question on how graduate school had prepared them for future career goals:

> There is the sense that anything outside academia must be explored on the side, in pseudo-stealth mode. I definitely feel there is not enough training for teaching. We are just thrown into TAing with only the [university TA preparation] (which is pretty useless) under our belts.

This reflection connects the ineffectiveness of teaching assistant training described by many participants to the lower position that teaching occupies relative to research. It also echoes the language of concealment used by students in the class discussion above, suggesting that this perception is not limited to only being “undercover” from one’s PI when it comes to being interested in teaching.

Many students in the seminar have learned through their experiences in graduate school, then, that being a successful scientist means being good at research instead of teaching, and that interests in teaching may need to be pursued surreptitiously, without the knowledge and support of their PI, departmental resources, and possibly even peers. Attending the seminar was an act by which students could not only learn how to teach, but also pursue their interests and professional goals in teaching, possibly without the judgement and/or approval of their PI’s. The “undercover” nature of some of the students’ participation highlights how pursuing teaching as a scientist during graduate school directly relates to graduate students’ professional identity work, with implications for who one can be, and what it means to be successful.

Seminar as Space to Share Experiences, Ideas, & Resources

In contrast to their lab or department, the seminar provided a respite from having to be a solely research-focused scientist. This was clear from discussions on topics that did not necessarily directly relate to the papers they had read. As exemplified in the second vignette, these types of discussions routinely took place during the class. On their post-survey reflections, many students discussed how the group consistently ran out of time from the weekly 80-minute sessions. In part, this occurred because, as one participant reflected, they often got "a bit off topic and pursue[d] some interesting, albeit tangential conversations." Some participants expressed frustration that this meant they did not present on their assigned paper in the session in which they were prepared to do so. However, many others highlighted how hearing about other people's experiences and sharing ideas and resources was an affordance. At the beginning of the vignette, the exchange between students about how they used IDP's was an example of students' sharing experiences and tips related to being a teaching-interested scientist in a research-focused environment. As described in the previous section, there were multiple instances across the ten weeks of the seminar in which participants shared ideas on how they had implemented particular teaching techniques that followed from research findings. Additionally, as Stephanie did in the beginning of the vignette conversation, students often found ways to connect their conversation on seemingly tangential topics to the articles that they had read for the day's session.

A tangible benefit for seminar participants was finding out about resources and opportunities for education-interested scientists. For example, Simon frequently told students about post-doctoral fellowships that provided support for hybrid research and teaching positions, or highlighted how different types of colleges and universities enable faculty to pursue both research and teaching. Occasionally, this led to a wider sharing of teaching and education research opportunities by other participants as well. For example, during a session half-way through the quarter, students built on Simon's description to share about a post-doctoral program for adjunct teaching and research at a regional liberal arts college, a graduate teaching fellowship for independently designing and teaching a course, and a professional learning community in the Biology department focused on improving pedagogies. The seminar became a space to share and learn about opportunities to develop their teaching practice and explore a broad diversity of professional pathways, mutually sourced from the wealth of knowledge of all participants, not solely imparted from the instructor to the students.

A different kind of resource-sharing was represented at the end of the vignette, when Simon guided the discussion to the underlying funding structures that contributes to academia being focused on research instead of teaching. He brought this up multiple times throughout the course, and doing so helped to situate the phenomenon as a systemic one rooted in socio-historical factors, rather than particular to individual disciplines or institutions. This in turn provided participants with a framework to understand their PI's and departments' research-focused motivations, prompting them to ask questions on that session's exit tickets such as "How do we change the system?" and "How to change the culture around being a teacher vs. scientist?"

Teaching Statements as Opportunity to Engage in Identity Work

Similar to their observations of other instructors, participants' writing a teaching statement was a way for them to connect the ideas they had learned about in the seminar with actual practice. However, unlike the observation, they were tasked with taking a stance in regard to how they would incorporate what they had been learning about into their own pedagogical approach. In assigning it, Simon provided a structural break-down of the elements of a teaching statement, characterizing it as "an exercise in persuasive writing [..] to convince your reader that you are intentional, scholarly, experienced, and effective in teaching." Students wrote their statements towards the end of the course, and undertook review of their peers' anonymized statements, on which Simon also gave feedback to use for a final revision.

After the course, many participants cited the utility of writing the teaching statement as they prepared for the job market for positions that involved teaching. In the words of one student: "I have already been using the teaching statement I wrote during the class as a base for teaching statements for teaching-intensive postdoctoral positions." Beyond this important, practical consideration of the statement, it also provided a space for them to "try on" being an education-interested scientist. While the teaching observation activity served as a way for students to start developing their disciplined noticing of evidence-based pedagogy, writing a teaching statement provided them with an opportunity to practice describing how they planned to incorporate what they had learned in the seminar into their own teaching and, simultaneously, tell who they were becoming as teachers (e.g., Sfard & Prusak, 2005).

Developing Practice-Linked Identities: Seminar as Professional Preparation and Envisioning

For many seminar participants, the above activities that directly involved their consideration and discussion of who they were as education-interested scientists, served to not only clarify their professional pathways but also gave them the tools to pursue these types of careers. A primary theme of students' talk during the post-course focus group demonstrated how the seminar supported their initial professional goals involving teaching (usually in tandem with research pursuits, as noted in the "Motivation to Participate" Findings section above). Barika, who was about to graduate with a Psychology degree, shared the following:

> I think it has really cemented the idea that I do want teaching to be part of [my future work]. So I don't really know exactly how I'm going to make that happen, but it made me reflect on the amount of joy I got from previous teaching experiences versus simply just doing my research. And trying to value that when I'm considering jobs. I haven't been doing the best job of looking for employment, but as I start to do that, I'm going to consider whether or not there will be opportunities for teaching.

This response highlights how the seminar helped her to value her teaching experience and identity as she prepared to go on the academic job market (as also found in a larger study of teaching development experiences for STEM PhD students; Connolly et al., 2016). Other students discussed how Simon's descriptions of different types of colleges helped them to clarify how they can pursue a career that fits their goals:

> Natalie: [The class did not] necessarily change [my future career plans], but maybe helped define it better, I think. I knew I primarily wanted to be an instructor going into this, but I wasn't entirely sure what setting that would be besides not an R1 school. But seeing that there is, various flavors of undergraduate institutions- coming into this I thought liberal arts, and tech schools, and R1's- that's it. But there are more niches than I realized.
>
> Liz: I agree with that.

Finally, on the follow-up survey, one student described how she saw the ideas she had learned about in the seminar as integral to securing an assistant professor position at a community college:

> I applied for jobs this past fall and have one lined up. I used the information from the seminar VERY extensively during the application/interview process. I thought a lot about the studies we learned about and tried to incorporate associated-active learning strategies into my teaching demo, including PBL, metacognition, application, clicker questions, and concept maps. During the interview, I also talked a lot about targeting higher orders of Bloom's in my teaching and what the science has shown us about effective teaching strategies. My knowledge regarding science education research is what I would consider to be the item that singularly put me over the top during the interview process and landed me the position.

By engaging students in the above-described activities and discussions, the seminar provided a variety of resources that participants leveraged after the class, as they entered (or prepared to enter) the academic job market. While sharing about hybrid research/teaching post-doctoral fellowships and writing a teaching statement served this pragmatic purpose, they also related to students' ongoing identity work and abilities to envision themselves in the future as education-interested scientists. To frame this in terms of the practice-linked identities framework (Nasir & Hand, 2008), the seminar provided *access to the domain* as students learned about education research and had space to share about future professional opportunities that were not dichotomized between research & teaching. These gave them opportunities to consider their pedagogical practice and career trajectories that would highlight their teaching skills and interests. Seminar participants also had to take on *integral roles*, by becoming experts in the articles they had read, in order to describe them to the rest of the class. Simon also continually positioned students as having expertise, both in terms of their experience as graduate students (as shown in this section's vignette when he prompts the discussion on students' IDP's to continue), and as fellow teachers (as shown in the previous section's vignette when he urges participants to use the self-affirmation exercise in their own classrooms). Despite being relative novices to teaching, students' contributions to the seminar were valued, such that they were able to recognize themselves as part of a broader community of scientists who valued teaching—which many did not even know existed prior to joining the seminar. Most importantly, pursuing students' interests and ideas during class discussions and prompting their self-reflections as teachers through writing the teaching statement gave them *opportunities for self-expression.* These are crucial for individuals to directly integrate their new-found knowledge and practices (e.g., evidence-based approaches to teaching) with their ongoing identity work (e.g., self as education-interested scientist), ultimately enabling them to envision, pursue, and attain professional trajectories that aligned with how they were beginning to view themselves.

Discussion

Despite the majority of PhD-trained scientists pursuing or ending up in careers that involve teaching, they are not adequately prepared by graduate school to do so, given the current structural incentives in the academy that incentivize research over teaching activities (Austin & Alberts, 2012; Brownell & Tanner, 2012; Connolly et al., 2016). This study presents analysis of data documenting the motivations, outcomes, and processes of graduate students' participation in a seminar on education research at a research-intensive university. The analyses show how an experience for graduate students to learn about evidence-based teaching practices provided opportunities to develop their teaching self-efficacy and practice-linked identities as education-interested scientists. By accounting for these dimensions through intentional design of similar learning experiences, the formative design principles that emerge from this study can be implemented and tested in other settings, in order to expand and improve teaching development experiences for graduate students that incorporate an identity focus.

Findings from across the data corpus reflect themes found in the literature on graduate education: (a) participants did not feel prepared to teach through their graduate training, despite the ubiquity of their participation in teaching professional development experiences (Dechenne et al., 2012; Golde & Dore, 2001); (b) this group of graduate students at a research-intensive university aspired to academic careers that included both research and teaching, transcending the perceived dichotomy between the two (Connolly et al., 2016; Fuhrmann et al., 2011; Gibbs & Griffin, 2013; Sauermann & Roach, 2012; Thiry et al., 2015); and (c) they sought out the seminar on education research in order to improve their teaching practice by cultivating an understanding of evidence-based teaching techniques (Baumgartner, 2007; Connolly et al., 2016; Schussler et al., 2015).

The theoretical lenses of self-efficacy and practice-linked identities helped to illuminate two different dimensions of graduate students' simultaneous learning and identity work during the seminar. Self-efficacy highlighted the changes in participants' conceptions of themselves as teachers as a result of participating, while identifying contextual factors related to their development of practice-linked identities revealed some of the processes that fostered changes in self-efficacy. Although self-efficacy has been employed in other studies of graduate students' learning how to teach (Connolly et al., 2016; Dechenne et al., 2012; Prieto & Altmaier, 1994), researchers interested in understanding the concurrent processes of learning and identity work that contributed to self-efficacy outcomes during a teaching professional development experience should consider adopting the practice-linked identities construct. Doing so will help to elucidate how to design learning experiences to promote graduate students' teaching self-efficacy and identification as educators, outside of what is presented here.

Below, I discuss my findings along these two dimensions in light of themes in the literature on teaching identity and graduate student teaching development. I then present formative design principles for architecting other experiences for graduate students to learn how to teach that incorporate supports for their identity work. Finally, I discuss the broader implications of creating these kinds of contexts.

Developing Teaching Self-Efficacy and Student-Centered Pedagogies through Representation and Decomposition of Practice

The findings from this work show how, like all teachers, scientists need opportunities beyond their teaching practice to build their knowledge and identities as teachers. Luehmann

(2016) reviews the connections between research-based recommendations for supporting teacher learning (e.g., “studying practice away from practice,”) and providing identity resources (e.g., “opportunities for meaningful recognition”) in contexts to learn how to teach. The confluence of these factors highlights how learning how to teach deeply relates to reflecting on who one is as a teacher, which, as shown in this study, can lead to increased teaching confidence.

Further, I found that participants’ increases in teaching self-efficacy, as well as their subsequent shifts in practice, were mainly in regard to cultivating an equitable learning environment, likely due to the seminar’s focus on active learning strategies. This aligns with other recent studies showing that scientists’ engagement with evidence-based pedagogies helped them to shift to a more student-centered teaching approach (Derting et al., 2016; Ebert-May et al., 2015; Marbach-Ad & Rietschel, 2016). One study in particular detailed the “change process” from teacher-centered to student-centered pedagogies in an intermediate-level undergraduate course being re-designed by two Biology professors (Marbach-Ad & Rietschel, 2016). Although the context and practices differed from this study, the focal professors’ motivations to redesign the course and process of shifting their teaching approach paralleled the experiences of the graduate students in the education research seminar. The teaching observation and structured debrief that this study’s participants carried out provided a shorter-term, less-intensive opportunity than a course re-design or practicum class to directly reflect on how to implement the pedagogical ideas they had been learning about in the seminar (as also found by Schussler et al., 2008).

The observation and debrief activities also embody two of the three key elements for novices to learn the practices of a particular profession, as identified by Grossman and colleagues (2009): representation and decomposition. Representations of practice provide opportunities for learners to see different exemplars of approaches to the practice, while decomposition “involves breaking down practice into its constituent parts for the purposes of teaching and learning” (p. 2058). Seminar participants, then, were gaining valuable preparatory experience by undertaking these practices, especially given that they were generally novice teachers (Table 4.1).

Grossman and colleagues (2009; 2009) advocate for expanding teacher preparation beyond these pedagogies of investigation (i.e., analyzing and critiquing representations of teaching practice) to incorporate pedagogies of enactment, in which novices can learn by “approximating” practice, i.e., trying out new teaching practices in a supportive environment. This echoes feedback from seminar participants, many of whom wanted more opportunities to try out the strategies they had learned about in the class, which should be taken into consideration by future designers of teaching development experiences for graduate students. After the iteration of the seminar described here, Simon planned to implement a mentored teaching experience for students to complete after the seminar, which he characterized as an introduction to the “greatest hits of education research,” rather than an in-depth practicum.

Recognition and Re-Imagining through Cultivating Practice-Linked Identities

My findings also show that as seminar participants learned about how to use education research findings to inform their teaching practice, they simultaneously undertook identity work to see themselves as teachers. In support of this, the seminar provided: 1) opportunities to envision themselves as education-interested scientists, and 2) tools to pursue professional goals involving teaching. Attending to the identity-related issues that participants navigated as they learned about education research revealed how important it is to have contexts in which scientists can develop their teaching practice, especially if it is devalued in their lab or department.

However, in her work on science teachers' identity development, Luehmann (2016) draws from Holland and colleagues' (2001) social practice theory of identity, noting that participating in the practices and work of a profession "is necessary but insufficient— it is in the *recognition* of that performance by self and others where meaning-making, and thus the development of a professional identity, occurs" (p. 23). Thus, the multiple ways that seminar participants' interests and expertise in teaching were valued by Simon and their peers were vital to their identity work as graduate students, scientists, and educators; as such, the seminar's discussions of how to implement evidence-based teaching practices and sharing experiences and resources enabled them to go beyond the constraints of their graduate training and begin to re-imagine themselves as education-interested scientists, supported by tools and practices that helped them to actually do so. As the instructor, Simon supported this process by allowing time for (and even prompting) conversations on professional goals and identity to take place, as well as providing reassurance through modeling and sharing resources that education-interested scientists did not have to choose between solely research or teaching.

The ways that graduate students' concerns about their nascent professional identities also surfaced organically during discussion and reflection in the seminar demonstrate how, even at advanced stages of education such as graduate school, learning is deeply intertwined with processes of becoming (Bell et al., 2012; Lave & Wenger, 1991; Rogoff, 2003). In this study, as graduate students collaborated to learn how to change their teaching practice, they revealed how they did not identify with certain ways of being a research scientist, as generally modeled by their PI's, other faculty members, and colleagues outside of the seminar—specifically, they were concerned about what their interests in teaching meant for their identities as scientists, as demonstrated by participants who were in the class "undercover." Connolly (2010) likens this phenomenon to "being in the closet" as a graduate student interested in teaching, given the processes of risk management, invisibility and isolation, evasion and deception, and emotional exertion and depletion that can result (pp. 2-3). Through the recognition work described above, and elements that promoted development of practice-linked identities as described in the previous section, the seminar provided an identity-safe respite from having to undertake these costly social processes, both at the time of the seminar and, ideally, in their future careers.

Conclusion: Designing for Identity Work in Teaching Development Experiences for Graduate Students

Given the calls to build more experiences for science graduate students to learn how to teach (Connolly et al., 2016; Schussler et al., 2015), it is vital to consider how their design should engage issues of identity, and understand how participants' motivations and outcomes of participating are directly connected to those issues. This study is one effort to do such work, providing formative principles of design (Table 4.3) grounded in my findings, which can be employed and tested in other settings. Additionally, by using ethnographic and other qualitative methods to depict how graduate students learn how to teach, I contribute to a nascent conversation in the DBER literature to not only study the outcomes from graduate students' participation in teaching development experiences, but also to understand the factors that contributed to those outcomes (Reeves et al., 2016).

The design principles that I identified focus on the key contextual features that promoted participants' simultaneous learning and identity work (Nasir & Cooks, 2009), which contributed to their engagement during the class and provided supports for their identities as education-interested scientists. In Table 4.3, I connect the design principles to my theoretical constructs of interest, as well as affordances for both individual participants and the departments of which they are a part. My recommendations for implementation are based on findings from this study and from across the broader literature on teaching development experiences for graduate students with the intent that they can be incorporated into a variety of settings with differing levels of engagement.

Broader Implications

Expanding opportunities for graduate students to learn how to teach will directly impact their professional trajectories. For example, in their Longitudinal Study of STEM Scholars, Connolly and colleagues (2016) found that scientists who had high levels (55 hours or more) of participation in a teaching development experience during graduate school were significantly more likely than their counterparts to secure a faculty position within five years of attaining their PhD, with about half of all participants employed at postsecondary institutions with undergraduate teaching responsibilities (p. 44). This finding suggests that graduate students who take opportunities to learn more about teaching will have improved professional outcomes after graduating, and, further, they will leverage the ideas that they have learned during those experiences in their teaching and with colleagues in the future. Indeed, the social-network potential for disseminating new ideas about teaching (Wise, 2011) has been recognized and embraced as a fundamental design tenet for broader teaching development initiatives for STEM graduate students and faculty (Austin, 2011; Gehrke & Kezar, 2017).

Broadening opportunities for graduate students to learn how to teach also has the potential to impact departmental and institutional values. As an example from my research context, after the seminar's conclusion, it was added to the Biology department's website as a recommended course for graduate students, demonstrating how institutional structures were beginning to shift, as the administration began to recognize the seminar's value. Over time, as more scientists, even

Table 4.3. Design Principles for Teaching Development Experiences for Scientists

Design Principle 1: Leverage the research identities of scientists when they are learning about teaching as an evidence-based practice.	
Relationship to Self-Efficacy	• Understand research basis that can be used to inform pedagogy • Make evidence-based decisions in how to approach teaching
Relationship to Practice-Linked Identities	• Access to the Domain: Learn about broad basis of research underlying teaching • Integral Roles: Build expertise in evidence-based teaching practices
Affordances to Participants	• Appeals to empirical epistemologies • Provides research basis for using specific pedagogical practice • Prepares for hybrid teaching/research careers
Affordances to Department	• Contributes to aligning departmental teaching approach with policy recommendations • Improved outcomes for undergraduate learning, especially for students from minoritized backgrounds • Improved rates of graduate student job placement • Resources department with teaching expertise
Examples of How to Implement	• Provide summaries of teaching strategies and their research basis • Read primary literature, focusing on short studies with obvious outcomes • Teaching observation to develop “noticing” of pedagogical approach and student experience • Develop a professional learning community and structures for approximating and decomposing new teaching strategies through reflective practice

Design Principle 2: Engage scientists in reflective discourse on teaching and learning to support their identification with education.	
Relationship to Self-Efficacy	• Build community with others who value teaching and want to improve practice • Hearing about and reflecting on teaching experiences helps to shift one's own practice
Relationship to Practice-Linked Identities	• Integral Roles: Position individuals as having expertise; validates their experiences • Opportunities for Self-Expression: ○ Allow integration of new ideas about teaching with past experiences ○ Provide opportunities for participants to consider their professional goals
Affordances to Participants	• Social recognition for being an education-interested scientist • Learn how to improve teaching practice without compromising professional identity • Value experience and identity work related to teaching during academic job search
Affordances to Department	• Foster a network of support for teaching • Minimize graduate student and faculty isolation and burn-out • Maintain or promote retention of graduate students and faculty from minoritized backgrounds
Examples of How to Implement	• Surface participants' motivations and professional goals, in relation to research and teaching • Elicit participants' experiences and expertise as scientists, graduate students, and teachers • Encourage relationship building through collaborative discussion structures and small groups • Incorporate discussion or exit ticket questions that prompt personal reflection

Design Principle 3: Intellectually and materially resource scientists to envision and pursue possible futures in education-related endeavors.	
Relationship to Self-Efficacy	• Promote increased teaching self-efficacy • Foster novices' abilities to decompose pedagogical practice and focus on student experience
Relationship to Practice-Linked Identities	• Access to Domain: Enable learning about multiple ways to integrate research and teaching interests • Opportunities for Self-Expression: Individuals identify how to pursue their professional goals
Affordances to Participants	• Open up professional possibilities that are not strictly research or teaching • Pursue career paths that are aligned with skills and interests related to teaching • Adapt tools for use during academic job search
Affordances to Department	• Retain graduate students and faculty interested in teaching and/or education research • Improved rates of graduate student job placement • Build alumni network and opportunities for future students interested in teaching
Examples of How to Implement	• Share professional trajectories that incorporate research and teaching • Provide, and encourage participants to share, teaching resources and opportunities • Structure opportunities for participants to write teaching statements • Identify goals for the duration of their graduate experience, to prepare for chosen professional trajectory

tenured professors at research intensive institutions, have either personally had or encountered peers who have pursued 'alternative' professional pathways, they are more likely to be supportive of their graduate students developing skills and identities that are not solely focused on research while in graduate school. As part of this effort, it will be essential to have contexts like the seminar described in this study, in which education-interested scientists can learn about teaching and figure out who they can be as a scientist—especially at research intensive universities at which it may be difficult to otherwise find support (Luft et al., 2004; K. Tanner & Allen, 2006).

Supporting graduate students and faculty in developing as educators also directly impacts issues of equity in the STEM fields, from undergraduate through faculty stages. Undergraduate students who experience a higher degree of course structure in science classes have improved learning outcomes (reviewed in Freeman et al., 2014), with some evidence that this is particularly salient for students from minoritized backgrounds (on the dimensions of class, race, and/or gender; Eddy & Hogan, 2014; Haak et al., 2011). However, for these learning gains to occur, it is essential that instructors 1) are at least minimally grounded in the underlying theory behind the active learning strategies they are employing (Andrews, Leonard, Colgrove, & Kalinowski, 2011) and 2) attend to issues of equity and student experience in terms of small group dynamics, which are often utilized in active learning interventions (Eddy, Brownell, Thummaphan, Lan, & Wenderoth, 2015; Theobald, Eddy, Grunspan, Wiggins, & Crowe, 2017). As accomplished in the seminar described in my study, both of these factors can be incorporated into the design of a teaching development experience, and can be particularly relevant for large introductory courses that often act as 'gatekeepers' to students' continuation in a STEM major (Malcom & Feder, 2016; National Research Council, 2015a). For example, for first-generation college students in STEM majors, early academic performance (in terms of first-semester GPA) has been found to be associated with persistence in the STEM fields (Dika & D'Amico, 2016). Additionally, as Simon continually did throughout the seminar, teaching development experiences serve as opportunities to make clear to graduate students that their success in traditional learning environments is not ubiquitous for their students. Through learning how to teach by drawing from research literature as well as personal reflection, scientists understand that there is a basis of evidence for developing pedagogy, enabling them to attend to student experience and ultimately feel more confident at fostering a classroom environment in which scientific ideas and epistemologies are clarified for all learners (e.g., Luehmann, 2016; E. Schussler et al., 2008; Windschitl, Thompson, & Braaten, 2011).

Additionally, early career stages have been proposed (Byars-Winston, 2014) as a key time to provide interventions that address the systemic barriers that keep scientists from minoritized backgrounds from continuing to pursue professional trajectories in the STEM fields (McGee & Bentley, 2017; Ong, Smith, & Ko, 2017). Given that many scientists who are women and/or people of color often have increased commitments to teaching or otherwise contributing to their communities (Bajaj, 2014; Connolly et al., 2016; Griffin, Gibbs, Bennett, Staples, & Robinson, 2015; Laursen, Liston, Thiry, & Graf, 2007; Ong, Wright, Espinosa, & Orfield, 2011), providing opportunities to develop teaching expertise during graduate school and exposing them to the broader range of careers for education-interested scientists are crucial to ensuring their individual success, as well as promoting demographic diversity in the scientific disciplines. Further, these individual and collective outcomes for scientists from minoritized backgrounds have the capacity to be expanded by intentionally designing teaching development experiences to address identity-related issues and create opportunities for participants to develop practice-linked identities as educators.

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Appendix A. Representative Coding Categories Used for Chapter Two Analysis.

Code	Definition	Example from Session Content Logs / Field Notes
Talk During Mentoring Sessions: *Talking About Project Work*		
Checking in on Progress	Focused questioning on what students have done to advance their project work.	Dave flips back through his notes and asks Parv (senior) about his project goal from two weeks ago. Parv says that he got permission from the school's tech manager, and just needs to get confirmation from teachers.
Giving Assignments	Setting tasks for youth to complete before next session.	Lennis to students: "And for you [to Tiffany, senior], if you have a deadline, you need to get advice or suggestions or comments, send to me. I'm going to try to send you some of the things that I find. I was looking today on the Ecuador thing, it was hard, so I think it was good you changed your question."
Giving Information	Providing details to youth on a relevant or interesting topic.	Claire talks with a senior about hearing back from colleges about financial aid packages. She explains EFC, expected family contribution, and how universities calculate it.
Offer to Give Feedback	Offering to review youths' work at another time or via e-mail.	Sasha talks with Ben (senior) about deadlines for college applications. She asks about submitting before break, asks if he needs help, she could look over application if he wants. He said already got feedback on essay, she says if he wants other feedback, she can help with that, just e-mail her.
Setting Goals	Eliciting goals from youth for next session.	Percival asks students about their goals for two weeks, clarifies assignment for project proposal. Percival reviews timeline with students, since they will only have one more meeting before December break.
Talk During Mentoring Sessions: *Talking 'In' Project Work*		
Brainstorming	Collaboratively generating ideas based on youths' interests.	Claire talks about iPhone screen as example of engineering project for non-senior. She asks him what features he thinks the iPhone 10 would have and "how would it look, how would people interact with it?"
Eliciting Feedback or Advice from Youth	Prompting youth to give feedback or advice on each other's work and ideas.	Evan asks non-senior to scoot around to look at Andrew's slides, and adds "what makes sense to you?"

Giving Feedback	Directly reviewing youths' work during session.	Maya looks back and forth between what she drew and Ellis's computer. She suggests, not sure if you'll be able to do all of this one graph, you can make it separate graphs if you need to. He plugs in his data to show her how it will look.
Joint Work	Mentors & youth engaging together in youths' work.	John (senior) asks Leah about how to cite sources. Leah explains that it's been a while since she's done APA formatting, but explains how she would cite. John [opens a file on his computer which they are both turned towards, and asks, "Like this?"
Practice Presentation	Youth presenting their project or other related work during session.	Ellis (senior) tells Maya, "Mine is Pichakucha, you know what that is?" Maya replies, no. Ellis explains format and says that he is still practicing, doesn't have it down yet. He starts his presentation by introducing himself and explaining how his project on the YMCA connects to his career goals to work in recreation and community service.
Talk During Mentoring Sessions: *General Mentoring*		
Asking Questions	General inquiries between participants.	Billie (senior) asks Len what were major obstacles he had to go through to get where he is today. Mike to seniors: "Sounds like things are coming together. Anything else you want to talk about? Last time, you said you had an outline to look at?"
Empathizing with Youth	Sharing how mentors relate to a situation or feeling that mentees are having.	A.J.: "I know how hard it is to do work when you don't have energy to anything. Do you have strategies to overcome that?"
Encouraging Youth	Providing positive support.	Evan responds to the non-senior about the water-driven turbine for his STEM Expo project: "You guys are going to rock it. You're already maxing out the generator! What else are you going to add to it?"
Giving Advice	Offering tips or guidance.	Tiffany (senior) asks John what to minor in during college if she's interested in medical school. John talks about double majors, they talk about difference between pre-med as a designation rather than major. John advises her to pick a major that she is interested in, if biology is what she really likes, pick that.
Providing Resources	Connecting youth with people, media, or texts, based on youths' interests or project work.	Denard describes the resource list on various colleges that he put together for students- GPA, cost, SAT/ACT scores, telling them that he will "give this to you at the end."

Sharing Own / Others' Experiences	Recounting experiences that mentors perceive as related to what youth are experiencing.	Pita tells students that she took a big step in her career on Tuesday by passing her second-year exam. She explains the process of presenting work and coming up with proposal for a committee. "And it's horrible, but I passed, all the stress in my life is gone."
Talk During Mentoring Sessions: *Mentor Positioning Move*		
Youth as Expert	Mentor promotes or foregrounds youth expertise.	Mark (senior) tells Pita that she needs to update her computer processor, update the RAM. Pita asks, “Can they just take something out or do I need to get a whole new computer?” Mark: “Do you know what kind of motherboard you have?” Pita laughs, “I've never seen it!”
Mentor as Learner	Mentor directly references their learning process or lack of knowledge about a topic.	Leah to John: “I don't know much about engineering, I'm learning a lot [from your literature review].”
Youth’s Work as Similar to Graduate Students’ Work	Mentor connects issues that students are encountering in their project work to their own experiences as scientists.	Miles (senior) discusses being worried that biodiesel project won't work, but "aiming for failure." Go with it, learn from it. A.J. responds how "most of science is failing a lot until something works. That's what science is." I've gotten really comfortable with failure, most of the time I'm just failing, so learning how to write that up in a useful way for other people, here's what didn't work and why, is an important skill, saying 'this didn't work, and here's why.'
Use of Designed Element		
OUT Tool (Year One)	Mentor using OUT tool with youth during session or referencing during reflection.	Amy reviews dates for prom and graduation. Amy says it seems like Jesus is on track, reviews status of students' grades, takes notes.
Mentor Matching Survey (Year Two)	Mentor referencing survey from youth during reflection.	Lennis’s “main concern” for the first day were the non-senior students and how she can help them, but that the were helpful- now she knew that she could help students to find a project topic. (10/29/15 Field Note)
Reflective Practice Protocol (Year Two)	Mentor using protocol during reflection.	Good reflection from Percival on drive back on interacting w/ senior (G). One of reflective practice questions resonated- surprised him. They went through survey that G had written, Percival giving him feedback. G said he would cut that question. Percival pushing him to not just cut, but think about how why he is asking that. (2/3/16 Field Note)

Appendix B. Mentor Matching Survey.

STEM OUT Program Pre-Survey

For Youth Participants

Name:________________________________ Date:____________________________

Grade: _____________

Personal Information:

Age ________________________ Gender _____________

How do you describe your racial or ethnic affiliation?

____

Mentorship:

- Either in or outside of school, have you been a mentor before? Yes ☐ No ☐
    - If yes, please give details on this experience:

      ____

      ____

      ____

      ____

- Either in or outside of school, have you had a mentor before? Yes ☐ No ☐
    - If yes, please give details on this experience:

      ____

      ____

      ____

      ____

- What type of person is a mentor? How is a mentor different than a teacher?

  ____

  ____

  ____

  ____

  ____

- What characteristics would you look for in an ideal mentor?

Senior / STEM Expo Project:

- What is the topic for your project?

- What project aspects are you most interested in getting support on from your mentor? (Circle as many as apply)

Narrowing down my research topic

How to formulate a research question based on my topic

How to design a realistic study from my question

Time management for carrying out my study

Writing a literature review/research proposal

Determining methods that will help me answer my research question

Designing the extension part of my project

Presenting my work to non-RTA audience

- What else would you like mentoring support on?

Research Experiences:

- Describe your previous experience with research projects. What aspects of research did you feel successful at? What aspects were challenging to you?

Academic & Other Interests:

- What is your favorite subject in school? Describe why you like it.

- What are your favorite activities outside of school?

- What do you think you will major in when you go to college?

- What career path(s) are you considering?

- Do you have any family members who have a job doing science, engineering, or research related activities? Yes ☐ No ☐
  - If yes, describe their relation to you and what they do for their job:

- Mark the box that indicates your agreement level with each of the following statements.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I would enjoy a career in the STEM fields.					
I am considering majoring in a STEM field in college.					
My family would be very supportive if I decided to work in the STEM fields.					

- Choose one of the statements above and explain your answer:

  ____

  ____

  ____

  ____

- Mark the box that indicates your agreement level with each of the following statements.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I like the sciences.					
I am good at the sciences.					
Learning in a science class is mostly memorizing.					
Science is used for solving community problems.					
Everyone can do well in school science subjects if they try.					
The sciences are boring.					

- Choose one of the statements above and explain your answer:

  ____

  ____

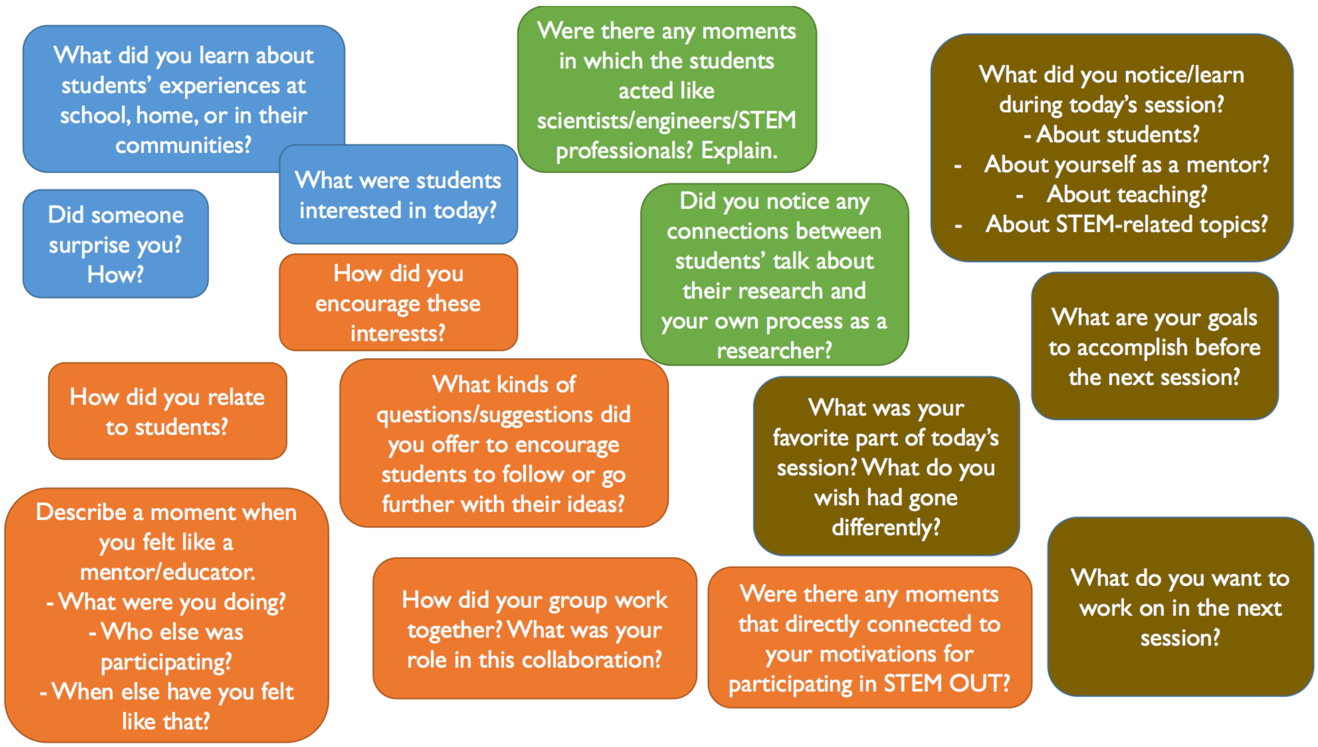
  ____

  ____

Appendix C. Year 2 Timeline for Project Work, Provided to Mentors.

			Seniors		Non-Seniors	
#	**Wed**	**Thur**	**Focus for this Week**	**Upcoming Deadlines / Events**	**Focus for this Week**	**Upcoming Deadlines / Events**
1	Oct. 21	Oct. 22	Introductions Check in on Project Status	Project Status Meeting #1 this week Lit Review Draft due Nov. 2	Developing a research topic for STEM Expo	
2	Nov. 4	***Oct. 29***		End of 1st Quarter Nov. 4 Student-Led Conferences: Nov. 5-6		End of 1st Quarter Nov. 4 Student-Led Conferences: Nov. 5-6
3	Nov. 18	Nov. 19	Review Proposal & Lit Review	Exhibitions: Nov. 18 & Nov. 19 Evenings Finalized Proposal due Nov. 23; Final Lit Review due Nov. 30		Exhibitions: Nov. 18 & Nov. 19 Evenings STEM Expo Launch: Nov. 23
4	Dec. 2	Dec. 3	Revising research to be manageable	Revised Plan Document due Dec. 7	Review Proposal	STEM Expo Proposal due Dec. 4
5	Dec. 16	Dec. 17				
6	Jan. 6	Jan. 7	Check in on Project Status Review materials	Project Status Meeting #2 this week Compiled lit review, proposal, analysis due Jan. 19	Check in on Project Status Review Proposal	
7	Jan. 20	Jan. 21	How to translate research to community engagement	End of 2nd quarter Jan. 28 Study Extension Proposal due Feb. 1	How to Write Up Research Results; Review Final Lab Report	STEM Expo Projects due Jan. 22 End of 2nd quarter Jan. 28 STEM Expo final lab report due Feb. 2
8	Feb. 3	Feb. 4	Practice STEM Expo presentations	STEM Expo Mock Presentations Feb. 8-10 STEM Expo: Feb. 13	Practice STEM Expo presentations	STEM Expo Mock Presentations Feb. 8-10 STEM Expo: Feb. 13
9	Feb. 17	Feb. 18	Reflection on STEM Expo		Reflection on STEM Expo	
10	Mar. 2	Mar. 3	Check in on Project Status	Project Status Meeting #3 this week	General Support- Academic & Personal	
11	Mar. 16	Mar. 17				
12	Mar. 30	Mar. 31	Meet w/ juniors to start brainstorming for their senior projects?	Exhibitions: Mar. 30 & Mar. 31 Evenings End of 3rd Quarter Apr. 1	Ideas for next year's STEM Expo & senior projects	Exhibitions: Mar. 30 & Mar. 31 Evenings End of 3rd Quarter Apr. 1
13	Apr. 13	***Apr. 21***		Student-Led Conferences: Apr. 14-15		Student-Led Conferences: Apr. 14-15
14	Apr. 27	Apr. 28				
15	May 11	May 12	Practice Senior Project Presentations	Presentation due May 16 Reflection Paper due May 23		

Appendix D. Reflective Practice Protocol for STEM OUT Mentors.



Appendix E. Coding Table for Mentor Identity Study.

Code	Description & Data Sources	Sub-Codes* & Examples	
Inductive			
Broadening Participation in STEM	Reflecting on the need for and ways to diversify STEM fields Interviews	Lennis: "You start with very young kids, they see people that look like them are doing this thing [science], so we put it in their heads. Then they grow up thinking that they can do it."	
Mentoring in Practice*	Types of mentors' conversational moves with youth	Asking Questions	Lennis: "So we were talking about your senior year, how you have to make a question to study. Do you have any area of interest that you want to explore more?"
	Mentoring Sessions	Encouraging Mentees	Amy: "But you're good at speaking! I feel like this is a moment for you to shine."
		Giving Advice	Dave: "When you find a [college] professor that clicks with you, you love it, take another class with them. Almost doesn't matter what topic is, it will be great."
		Sharing Own Experiences	Lennis: Yeah that was my experience [in high school]- I wanted to graduate from being in school, have a different learning experience, but missed the people."
		Empathizing / Validating	Amy: "You might be right. What I'm hearing is one of the hardest things to deal with, which is being accepted for who you are."
Mentoring Role*	How mentors characterized their role in working with youth during STEM OUT	Conversation (Re)Director	Amy: "They would say something where I was a little shocked. But I would be like, let's bring it back to somewhere constructive."
		Listener & Empathizer	Amy: "I've definitely done that same thing, of just like, okay, what are my fifty different options for what I could do next? And then you're like, it's too much."
		Project Helper	Lennis: "I tried to help as much as I could. I tried to search some information, but yeah, I think in terms of feeling that I helped them in their project, I didn't think it was much of help for them."

	Interviews and Other Reflection Data	Resource Provider	Dave: "I can box this up a little bit and be like, 'Here's some things for you to like use going forward,' or 'keep this in mind.'"
Mentoring Topics*	Discussion topics during mentoring sessions	College	Lennis: "Lennis: Yeah, college is going to be different, you meet new people. You're going to be busy and you'll need to get used to a new way of life, learning new stuff, need to be more organized with your time."
		Family	Amy: "Any transition is sad. I called my parents once a week after I started college."
		High School	Lennis: "Are you ready for the all-school exhibition tonight? What is your topic?"
	Mentoring Sessions	Jobs / Working	Amy: "You're bringing back memories of being in college. Yeah, I worked two jobs when I started college. It's exhausting, you'll have to watch yourself because it's pretty easy to overdo it.
		Student's Future Trajectory	Dave: "You never know what path life will take you down, nice to have an idea of what you want broadly so that when you have options, you'll take a path that you'll be happy with in the long run."
Deductive			
Graduate School / Department	Reflecting on their experiences during graduate school	Climate of Graduate School	Amy: "I had advisors who, well-meaning, were like, 'no you can do R1, you're good enough,' and I think they meant only the best, they just wanted to let me know that it wasn't from a lack of ability."
		Feelings about Graduate School	Lennis: "Graduate school has been one of the best experiences in my life. The environment in my department is very collaborative and made me realize that the best way of learning is sharing your knowledge with others."
	Pre-Survey, Interviews	Participation in Graduate Student Organization	Dave: "Over the summer I read Whistling Vivaldi with the Women in Chemical Sciences."
Mentor Positioning Moves	How mentors characterized their experiences relative to the youths' experiences	Self as different from students	Amy: "So I think that I was surprised by how much I could empathize with my students, because, we're different."

	Interviews, Sessions	Self as similar to students	Dave: "But because [backwards planning] has been so helpful to me, I was hoping to sort of share that with him a little, especially as he considers going off to undergrad, because having those skills can only ever help you."
Motivation to Participate in Outreach	Why mentors wanted to join STEM OUT and similar types of youth engagement opportunities	Lennis: "I want to help and motivate others. One of my major challenges in grad school was to be the only women in my class and I really want to increase diversity in STEM."	
	Pre-Survey, Interviews		
Professional Goals	Reflecting on what line of work they will pursue after graduating with PhDs	Lennis: "Academia can be a good fit for me. But I am always stressed in grad school, don't know if I'll be more stressed at this level, because looking for funding- if you get tenure position."	
	Pre-Survey, Interviews		
Reflections on Mentoring	Reflecting on their mentoring experience in STEM OUT and other contexts	Feelings about STEM OUT Mentoring	Lennis: "It's very different when you're talking to an adult and then you're talking to high schoolers, right? And it was challenging for me at the beginning."
		Mentoring Success	Amy: "My overall goal as a mentor was to temper helpful suggestions with acceptance and understanding about how stressful it can be to try new things, to prepare for big life changes, and/or to learn something that doesn't come easily."
		Talk About Mentees	Dave: "But I have a feeling because Parv is so independent that once he graduates I'll probably never hear from him again, which is totally fine, but I'm also completely open to him contacting me in the future."
	Interviews and Other Reflective Data	Other Experiences as Mentor	Lennis: "It was a reflection of my mentorship, how I guided them through the years so they were able to present their project, able to answer the questions and have a complete cost estimation and an idea of the final product that they were going to have, so yeah, that was my experience with the undergrads."
		Experiences as Mentees	Amy: "I chose her very specifically, because I knew I needed an understanding advisor."

Self-Authorship	Conversational move to position themselves in particular roles and trajectories	Educator	Dave: “And what [my dissertation committee] might do is pay more attention to my presentation skills for instance, 'cause you're going to be teaching, so can you teach us?”
	Pre-Survey, Interviews, Sessions	Graduate Student	Amy: “There does need to be output and productivity and we do need to get things done, but I was frustrated by what I thought was this lack of concern for what our experiences were like in [grad school].”
		Scientist	Lennis: “It took me two years to actually go to lab and feel that I really want to know what is going on, like I cannot wait for tomorrow to see these results. It took me a lot of time to really feel passionate about my research.”

* Only the most commonly applied sub-codes are listed.

VITA

Elaine Renee Klein has over ten years of experience in teaching and developing curriculum in the sciences. She is committed to advancing equity in STEM education through engaging scientists and teachers in improving their practice, and expanding ideas of what counts as STEM. She earned her M.S. in Evolutionary Biology from San Diego State University and a B.A. in Ecology and Environmental Studies from Simon's Rock College of Bard.