© Journal of Higher Education Outreach and Engagement, Volume 27, Number 1, p. 75, (2023)

Distributing Expertise and Building Relationships: Designing for Relational Equity in Youth–Scientist Mentoring Interactions

Elaine R. Klein and Philip Bell

Abstract

Science mentoring programs are powerful opportunities for youth to develop conceptual knowledge, undertake authentic practices, and have impacts on their science-related identity work. Here, we use design-based research to understand how a university–community partnership expanded upon traditional mentoring structures to facilitate *relational equity* (DiGiacomo & Gutiérrez, 2016) through distributing expertise and building relationships between participants. We analyzed qualitative data from 2 years of the STEM OUT mentoring program to develop claims about the elements of program design that led to distributed expertise and building relationships. Key findings include the need to design structures that position all participants as having expertise, highlight relationship-building as integral for youth–scientist interactions, and facilitate equitable power dynamics. Our findings are articulated as design principles for other youth–scientist mentoring programs, with the goal of broadening participation in the sciences by redefining not only who participates, but also what counts as science.

Keywords: science, mentor, design-based research, equity, sociocultural

Opportunities for youth and scientists to interact through university–community partnerships are powerful ways for youth to develop conceptual knowledge and undertake scientific practices (Linn et al., 1996; Pea, 1993; Sadler et al., 2010). Working with scientists to collect or analyze data enables students to "participate directly in ongoing practices of a [scientific] community," in contrast to the often abstract activities of science classrooms (Barab & Hay, 2001, p. 75).

Studies of youth–scientist interactions highlight the social aspects of learning science, foregrounding the processes of disciplinary identification for students (e.g., Van Horne & Bell, 2017). Using a social practice framing (Holland & Lave, 2009; Lee, 2017), we characterize these processes as youths' "science-related identity work," in recognition of the complicated and contextual nature of identit(ies) as young people navigate who they are in relation to science (Calabrese Barton et al., 2013). Youths' science-related identity work is integral for their continued interest and engagement (Bell et al., 2009; Bell, Tzou, et al., 2012) and contributes to broadening participation in the sciences (e.g., Aschbacher et al., 2010). However, the emphasis on bringing youth into science is limited by minimizing youths' expertise and reinforcing hierarchical power dynamics (Rahm, 2007; Woods-Townsend et al., 2016).

Here, we focus on two limits of traditional mentoring interactions:

1. A one-way transmission model of expertise does not recognize youths' knowledge or interests (e.g., Warren et al., 2001). Surfacing these can make youths' encounters with scientists consequential for science-related identity work (Carlone et al., 2015; Tzou & Bell, 2012). Additionally, recognizing how expertise is distributed among partici-

pants fosters mutual learning (Brown et al., 1993), such that sharing ideas is prioritized over scientists' knowledge (Klein, 2016).

2. Relationship-building is often overlooked in youth–scientist interactions. Interactions that extend beyond scientific content can help participants connect across their lifewide experiences (Banks et al., 2007). Scientists can learn from youth about how scientific concepts are relevant to their lives, enabling the scientists to improve their communication skills (Fitzallen & Brown, 2016; Hinko & Finkelstein, 2012). As scientists share who they are, youth develop an expansive sense of what it means to be a scientist (Rahm, 2007; Stromholt & Bell, 2017; Woods-Townsend et al., 2016). Although preparing youth for future scientific trajectories is one possible outcome, a broadened sense of who undertakes science can empower youth for their own aims (Basu & Calabrese Barton, 2007). Rahm (2007) framed this prospect with an essential question for designers of scientist–youth partnerships:

   > 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 designing for scientists and youth to share expertise and build relationships, university–community partnerships can broaden participation by shifting who gets to participate *and* expanding what counts as science. Although there is evidence for the integral role of relationship-building in science learning (Bell, Tzou, et al., 2012; Lemke, 2001), more empirical accounts are needed in science learning contexts, especially when bringing youth and scientists together. Here, we address this gap in the literature by taking a design perspective. We focus on a science mentoring program called STEM OUT, which brought together graduate-level scientists and high school-aged youth. This study follows the program across two enactment cycles, with analysis of interactive and reflective data from participants to support overarching claims and design conjectures.

Literature Review

Learning Environments Are Organized Through Discourse

This study is grounded in the idea that students' learning processes and outcomes are intertwined with their sociocultural environment (e.g., Lave, 1996; Lemke, 2001; Nasir et al., 2006; Vygotsky, 1978). Pathways to developing expertise are determined by opportunities for an individual to demonstrate and be recognized as having expertise, with implications for who one can be in a learning environment (i.e., their identity as a learner; Bell, Tzou, et al., 2012; Lee, 2017; Wortham, 2008). Therefore, there are opportunities and limitations on what a person can learn and their learning identity, based on the social organization of that context (Brickhouse, 2001; O'Connor & Allen, 2010).

Discourse is one way to understand these opportunities and limitations. Every interaction between individuals impacts how and if participants can demonstrate their expertise (Brown et al., 1993). Talk also illuminates how a context is structured, by participants and through tools and activities (Tabak & Baumgartner, 2004). In this study, patterns in scientists' and youths' discourse and participant structures ("the roles, rights, and responsibilities regarding who can say what, to whom, and when"; Lehrer & Palincsar, 2004, p. 389) were used to characterize opportunities for youth, and how they changed as the program was modified to promote certain kinds of interaction.

Science Learning Involves Social Positioning

Historically, the sciences have been exclusionary disciplines, with specific types of expertise and discourse privileged over others (reviewed in Carlone, 2004). Calabrese Barton and Yang (2000) described how teaching in science classrooms often presents "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 (Bang et al., 2012; Brickhouse, 2001; Lemke, 2001), which can impact youths' *positioning* in science learning environments (Carlone et al., 2014). Davies and Harré (1990) described social positioning as 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 [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)

Positioning determines how youth orient to scientific expertise and are recognized by others (Bell, Tzou, et al., 2012; Brown & Spang, 2008; Carlone & Johnson, 2007). Positioning changes over time and across contexts, depending on who is present and how interaction is structured (Calabrese Barton et al., 2013; Carlone et al., 2014; Wortham, 2006). For example, youth may orient differently toward science in classrooms versus at home (Bell, Bricker, et al., 2012; Bricker & Bell, 2013). Informal learning environments have the potential to expand what counts as scientific (Bell et al., 2009; National Research Council, 2015). Although science classes can include similar structures (Rosebery et al., 2010; Van Horne & Bell, 2017), informal learning environments that position youth as successful in science involve (1) eliciting and valuing youths' ideas, (2) offering opportunities for youth to connect between scientific ideas and everyday experiences, and (3) situating science as embedded in socially relevant pursuits (National Research Council, 2015).

Here, we focus on youths' positioning and how interactions with scientists and peers provided or constrained opportunities to showcase their expertise. We use *participant structures* to analyze how conversational moves have implications for participants' social positioning and power (Cornelius & Herrenkohl, 2004; Goodwin & Heritage, 1990).

Mentoring Structures to Disrupt Traditional Models of Expertise

Mentoring programs can be designed to disrupt hierarchical relations between adult and youth participants. For example, mentors who undertook reflective practices developed more symmetrical power dynamics in youth interactions, or what DiGiacomo and Gutiérrez (2016) termed "relational equity." By doing so, participants' positioning differed from traditional adult–youth configurations (Kafai et al., 2008).

Nontraditional mentoring arrangements foster stronger relationships, which benefits youth (Rhodes & DuBois, 2008). A respected adult mentor can connect youth to a broader network (Barron et al., 2014; Ching et al., 2016), especially when collaborating toward a goal (Chávez & Soep, 2005; Halpern, 2005; Heath, 2012). Mentoring relationships are particularly salient for students who are marginalized from school (Ching et al., 2015). In this study, we sought out mentoring structures that supported relationship-building, and we studied how relationships related to patterns of talk and positioning.

Foregrounding Youth Expertise

Experiences in which youth interact with scientists enable them to succeed in the sciences (Rahm, 2007; Woods-Townsend et al., 2016). However, scientist–youth partnerships often reflect a cognitive apprenticeship model (Collins et al., 1991), in which scientists are positioned as experts and youth as novices (Rahm et al., 2003). Although these types of experiences can be valuable (e.g., Barab & Hay, 2001; Sadler et al., 2010; Thiry et al., 2011), interactions that foreground youths' expertise provide opportunities to develop relational equity and complicate power dynamics. Rahm (2007) prompted youth to interview scientists, to "learn about science as a system of social practices and about the 'human element'" of doing science (p. 540). Interviewing scientists expanded youths' notions of science. Notably, the discursive and youth-led experience "erased status differences between youth and scientists temporarily. . . . No one voice was privileged over another" (p. 542). Mentoring programs' emphasis on relationships provides a context to expand upon these findings, especially if structured nontraditionally.

Science mentoring programs that bring together young people at various stages can also be beneficial. Tenenbaum et al. (2014) described a "near peer" mentoring program in which undergraduate students were guided by university faculty in working with youth on a structured research experience. Mentors 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 allows young scientists to highlight and leverage their developing expertise, as they are encouraged to integrate their personal interests with scientific research, teaching, and mentoring (Tenenbaum et al., 2014).

This exemplifies a social practice approach to science mentoring (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). Participants relate between practices across both everyday and professional pursuits. Making these connections can bring youth and scientists into a broadened image of what counts as scientific practices (Rouse, 1996), impacting their future "scopes of possibility" in the sciences and beyond (Bell, Tzou, et al., 2012, p. 277).

Designing for Relational Equity

Designing mentoring programs as partnerships is a crucial way to counteract deficit models of youth that undergird traditional mentoring configurations (DiGiacomo & Gutiérrez, 2016; Kafai et al., 2008). Direct interactions between scientists and youth have the potential to reposition youths' orientations toward science and shift scientists' orientation to K-12 education (Tanner, 2000; Woods-Townsend et al., 2016). Additionally, accounting for the experiences of all participants is crucial to equitable engagement and outcomes (Falloon, 2013; Miranda & Hermann, 2010; Sadler et al., 2016; Wormstead et al., 2002). Accordingly, a design-based research framework (Cobb et al., 2003; Design-Based Research Collective, 2003) enabled us to simultaneously focus on the unfolding dynamics of the program and map the design features that contributed to those dynamics. Specifically, we focused on how expertise was distributed and relationships were built within mentoring groups. Further, through an iterative, collaborative design process, we aimed to complicate the one-way expertise transmission 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.

Research Question

We 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?

Methods

Research Context

The STEM OUT program was a design-based research project that went through two school-year design and implementation cycles. The AAAS STEM Volunteer Program provided funding for this collaboration between a large urban university in the western United States and a small public school. University scientists—mainly graduate students, representing a range of scientific fields (Table 1)—met for an hour every other week with two to three high school students at Regional Technology Academy (a pseudonym; RTA). RTA aimed to empower students from underrepresented backgrounds in STEM, as reflected in the school's demographics (Table 2) and problem-based learning instructional approach.

Mentors supported youths' research projects: Seniors carried out year-long community engagement projects; non-seniors participated in a science and engineering fair. Mentors varied in their previous youth experience, with all having at least some experience (Table 1). Through an orientation session before each school year, mentors learned more about RTA and science education, discussed issues related to science and minoritized communities, and shared ideas about mentoring.

Tracing Outcomes to Design Through Conjecture Maps

We employed conjecture maps (Sandoval, 2013) to assess whether the outcomes for which we designed STEM OUT were supported by participants' observable interactions, reflections, and artifacts. Sandoval defined conjecture maps as "a means of specifying theoretically salient features of

Table 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	White	Tutor, international high school teacher, GTA
1	John Watson	2nd year PhD, microbiology	26	Male	White	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	White	Science fairs & festivals, GTA
1	Sasha Fierce	Postbaccalaureate research fellow, microbiology	24	Female	Hispanic	Tutoring, peer mentor
1, 2	A.J. Princeton	3rd year PhD, chemistry	25	N/A	White	Science fairs & festivals, GTA
1, 2	Dave Keuning	2nd year PhD, chemistry	24	Male	White	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 (PR)	Mentor to undergraduate research assistants, summer camp tutor
2	Maya Ayman	Postbaccalaureate research fellow, microbiology	22	Female	Middle Eastern	Tutor, undergraduate teaching assistant

Note. All data (including pseudonyms) were self-identified by participants. GTA = graduate teaching assistant.

Table 2. Regional Technology Academy Student Demographic Data, 2016

Demographic	Percentage
Gender	
Male	51
Female	49
Total	100
Race/ethnicity	
White	31
Hispanic	22
Black	18
Asian	15
Other (Pacific Islander, Native, multiracial)	14
Total	100
Other*	
Free/reduced-price meals	51
Special education	8
Graduate on time	95

* Percentages do not total 100 due to distinct categorization.

a learning environment design and mapping out how they are predicted to work together to produce desired outcomes." (p. 19) To help avoid bias and ensure validity of our design findings, the design conjectures were created in collaboration with colleagues outside the STEM OUT program, and the mediating processes and outcomes were reviewed by STEM OUT participants. We then used Year 1 findings to inform the design of Year 2. We also created retrospective conjecture maps to trace what emerged through participants' mentoring interactions as a result of the constructs of distributed expertise and building relationships (See Figure 1 comprised of 1a, 1b, 1c). This process helped to produce the broader design principles presented in the conclusions section.

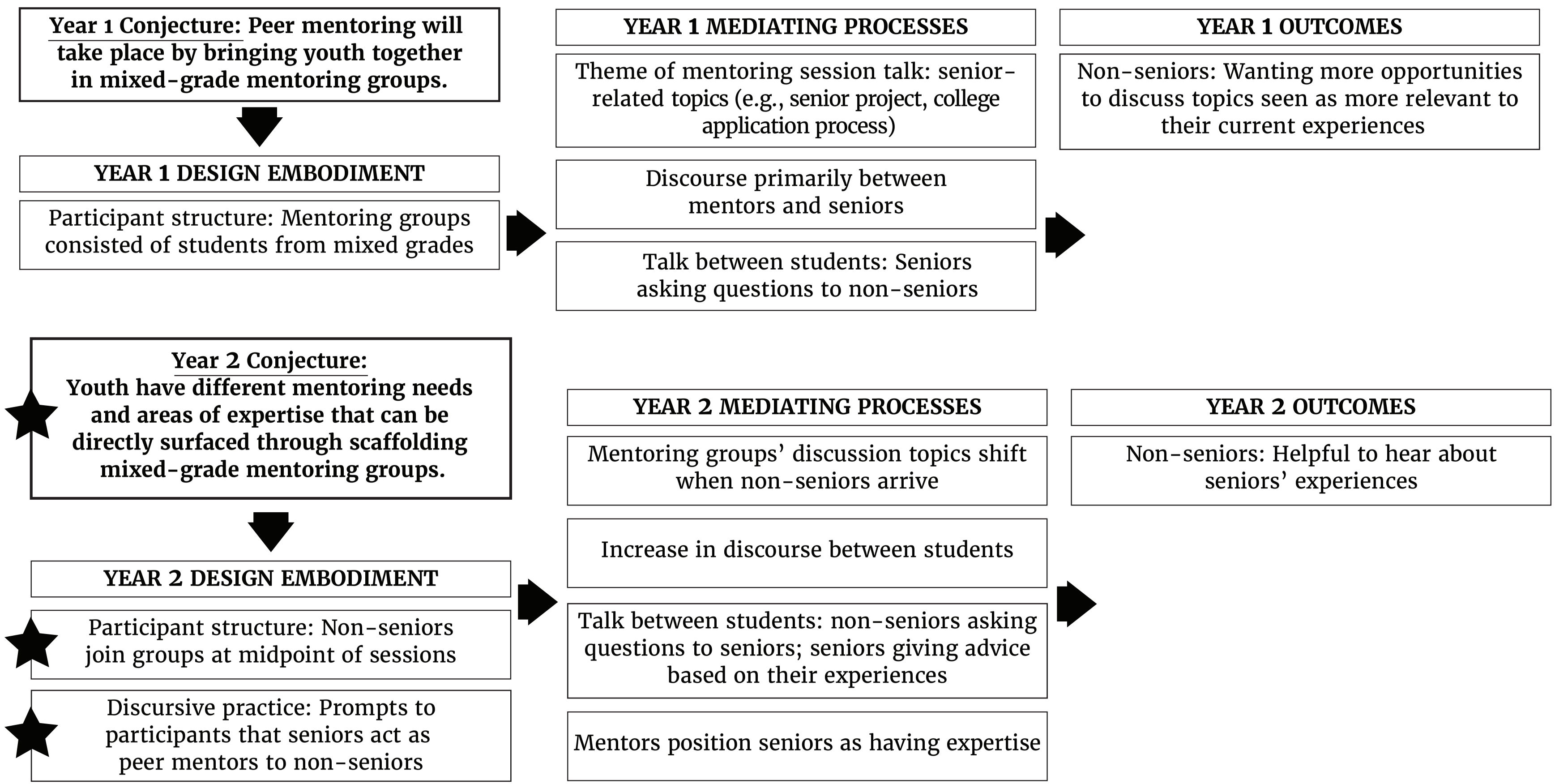
Data Collection, Sampling, and Unit of Analysis

Data comes from mentoring sessions between 15 mentors and 53 students (Table 3). We received IRB approval from the University of Washington Human Subjects Division, Application #48220. The first author (ERK) took ethnographic field notes (Emerson et al., 2011) on mentoring interactions and mentors' talk during car rides between the university and RTA. We conducted youth focus groups at the end of each school year; students were also surveyed in the middle of Year 1 and given an expanded pre/post survey in Year 2. ERK interviewed mentors at the end of each school year. Mentoring sessions, car rides, focus groups, and interviews were recorded using audio or video. Student focus groups and mentor interviews took place in person, involved semistructured protocols, and followed best practices for conducting group and individual interviews (Patton, 2002, pp. 339–427).

The reflective data (youth focus groups and mentor interviews; 20.5 total hours of recorded data) were transcribed to understand participants' experiences. To understand broad themes across the program and changes that took place within and between the two design cycles, we sampled across the interaction data (recorded mentoring sessions), selecting two sessions (one early, one late) from each mentor in each year. Each hour-long session was content logged (Derry et al., 2010), tracking the content and

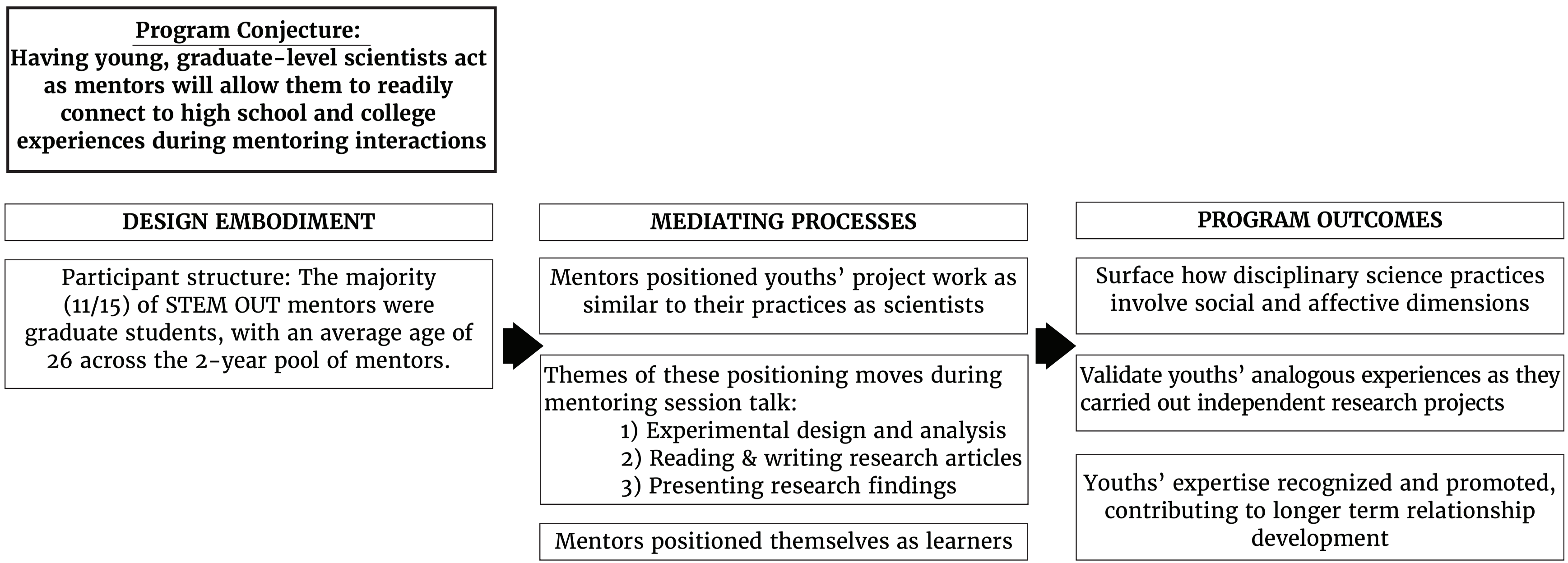
Figure 1. Conjecture Maps Highlighting Design Elements and Outcomes Across the Duration of the STEM OUT Program

Figure 1a.



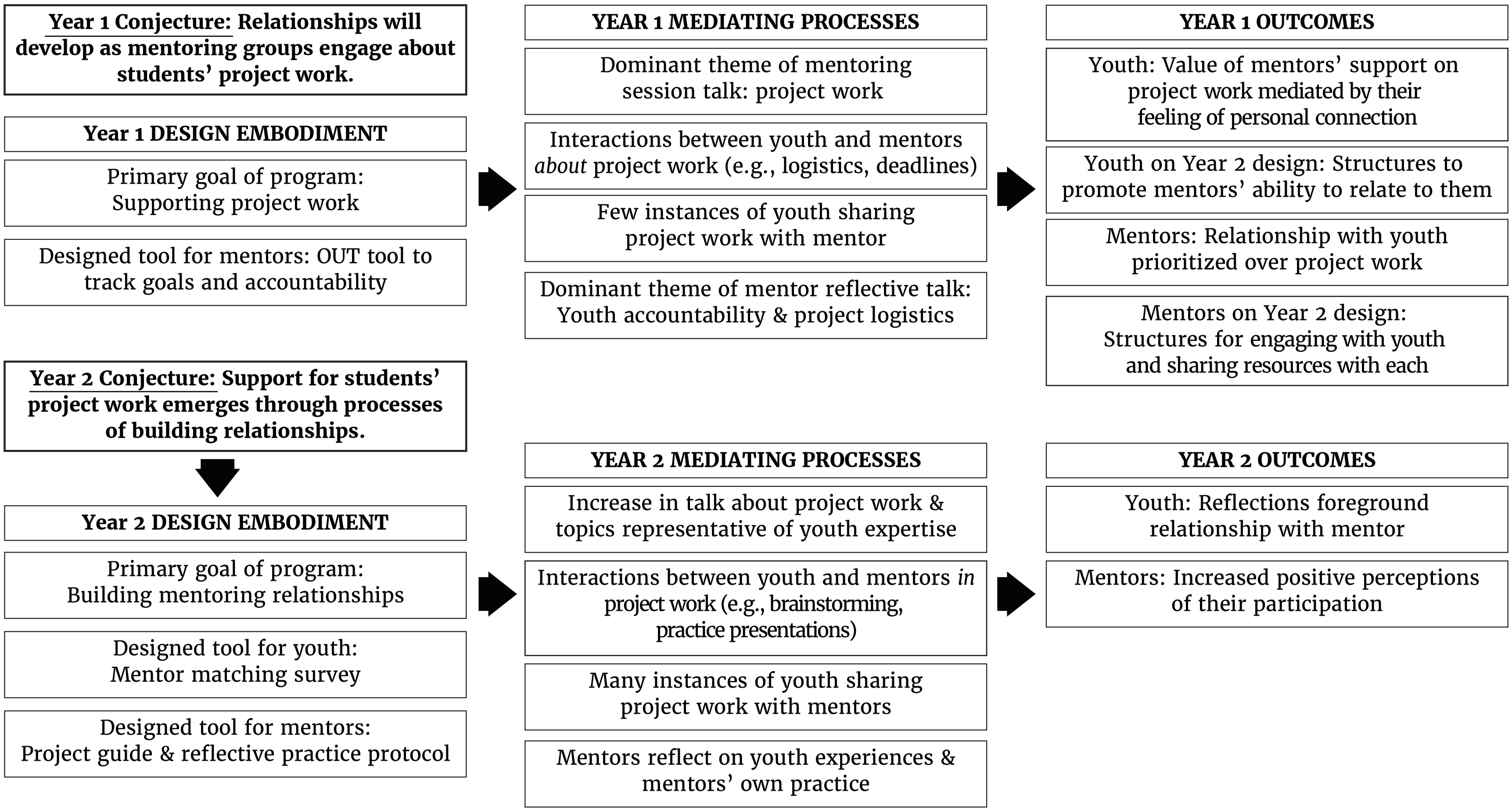
Note. Figures 1a and 1b relate to distributed expertise; Figure 1c relates to building relationships. Stars indicate pivots in the Year 2 program design, based on findings from Year 1.

Figure 1b.



Note. Figures 1a and 1b relate to distributed expertise; Figure 1c relates to building relationships. Stars indicate pivots in the Year 2 program design, based on findings from Year 1.

Figure 1c.



Note. Figures 1a and 1b relate to distributed expertise; Figure 1c relates to building relationships. Stars indicate pivots in the Year 2 program design, based on findings from Year 1.

direction of conversational turns (38 total hours of recorded data). We compared the logs with field notes to ensure that they were representative of a group's mentoring interactions (Erickson, 1986).

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

Coding and Analysis

All data sources listed in Table 3 were coded for the analysis. The content logs of mentoring sessions were coded using Dedoose v.8.0.33 and discourse analysis tools (Gee, 2011). For each conversational turn, we coded the direction (e.g., "student to mentor" or "non-senior to senior student"), type of talk (e.g., "brainstorming," "asking questions"; see Table 4), topic (e.g., "student's project work"; see Table 5), and source of expertise (mentor, youth, or mutual; Table 5). In addition to these emergent codes, we employed theoretical constructs of interest as parent codes, with emergent themes identified as subcodes. For example, we attended to how mentors' conversational moves positioned youth or themselves (Harré et al., 2009), but the data directed us to the ways that they were positioned, such as "youth as expert" or "mentor as learner." We also coded when participants used designed elements of the program, such as tools or activity structures. Coding themes foregrounded conversational aspects such as who is afforded opportunities to speak, how the framing of questions denotes the speaker's expectation of the respondent's expertise, and how designed elements enabled or constrained participants' talk. We open-coded themes found across participants' reflective data, to triangulate their experiences with the mentoring sessions.

Qualitative analysis of these themes, in conjunction with the conjecture maps and descriptive statistics of mentoring groups' discourse (Heath & Street, 2008), allowed us to make claims that (1) highlight how mentoring interactions created or constrained opportunities for distributed expertise and building relationships and (2) connect findings to the designed structures of STEM OUT (Blomberg et al., 1993). We wrote memos to triangulate between data sources, seeking connections or disjunctions between design features, participants' interactions, and re-

Table 3. Data Collected and Analyzed for This 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 Emails between mentors & youth
Car ride reflections	Mentors (15)	25 hours audio from 25 session days
Semistructured focus groups	Youth (44)	3 hours audio/video Posters with anonymous student responses (Year 1)
Midyear survey (Year 1)	Youth (12)	Open-ended (6 items) and rating (13 items) response data from 12 students
Pre/post survey (Year 2)	Youth (34)	Open-ended (9 items) and rating (17 items) response data from 14 students (pre-survey); 20 students (post-survey)
Semistructured post-interviews	Mentors (13)	17.5 hours audio/video

Table 4. Coding Categories, Codes, and Representative Subcodes Used for 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 email.	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 email 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 toward, and asks, "Like this?"

Table continued on next page

Table 4. Continued

Code	Definition	Example from session content logs/field notes
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 premed 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 a 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!"

Table continued on next page

Table 4. Continued

Code	Definition	Example from session content logs/field notes
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]." Miles (senior) discusses being worried that biodiesel project won't work, but "aiming for failure." Go with it, learn from it.
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.	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 1)	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 2)	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 survey was helpful—now she knew that she could help students to find a project topic. (10/29/15 field note)
Reflective practice protocol (Year 2)	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)

Table 5. Comparison of Ten Most Common Mentoring Discussion Topics Between Program Years

Year	Source of expertise	Topic	Number of talk turns	Percentage of total year dataset
Year 1	Youth	Project work	126	12.7
	Mentor	College—general	81	8.2
	Mutual	Hobbies	81	8.2
	Mutual	Family	59	6.0
	Youth	High school—general	53	5.4
	Youth	High school—systems & culture	50	5.1
	Mentor	College entry—logistics	49	5.0
	Youth	High school—schoolwork	46	4.7
	Mentor	College experience—academic	45	4.6
	Mentor	Science	41	4.1
	Varied	All other topics	358	36.1
Year 2	Youth	Project work	190	25.4
	Youth	High school—general	93	12.4
	Mentor	College—general	59	7.9
	Youth	High school—systems & culture	48	6.4
	Mutual	Family	38	5.1
	Youth	High school—schoolwork	34	4.5
	Mentor	College entry—logistics	30	4.0
	Mutual	Travel	26	3.5
	Mutual	Mental health/stress/feelings	23	3.1
	Mutual	Pop culture	21	2.8
	Varied	All other topics	187	25.0

Note. Total number of talk turns (Year 1) = 989; Total number of talk turns (Year 2) = 749 flective data (Strauss & Corbin, 1990, pp. 197–223). The memos led to increasingly higher level claims as we abstracted from the data (Erickson, 1986; Miles et al., 2013). In keeping with methods for ensuring validity of findings (Erickson, 1986), we worked with colleagues to check that claims were representative of the dataset and grounded in sound interpretation. We also searched for disconfirming evidence, and we note below when counterexamples were present in the data—which provided a rich area for subsequent theorizing (Erickson, 1986).

Findings

Below, we 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, we describe the initial design at the outset of Year 1, followed by the outcomes from the interactive and reflective data. We then detail how Year 1 findings informed the design of Year 2, and the subsequent changes in discourse, participant structures, and reflections.

Through a design-based research approach to modify the programmatic components by closely attending to participants' experiences, STEM OUT was responsive to youth and mentors, which impacted the resulting discourse. In terms of distributed expertise, the amount of talk between youth increased, and the amount of discussion focused on youths' expertise increased in Year 2. When the program shifted to highlight developing social relationships in Year 2, the amount of talk about youths' projects increased. The relationships between design, mediating processes, and outcomes are illustrated in conjecture maps (Figure 1); conceptual connections and design principles are detailed in the Discussion section.

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. Below, we describe how youth were afforded opportunities to signify their expertise and the outcomes of doing so over the 2 years of the program (Figure 1a). We 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 1 Design: Collaborative Design Leading to Structures for Peer Mentoring

Peer mentoring was an integral component of STEM OUT. Mentoring groups consisted of one scientist, two high school seniors (such that the program included the school's entire senior class of 20 students), and one to two non-senior students.

Year 1 Outcomes: Mixed-Grade Groups Did Not Facilitate Peer Mentoring

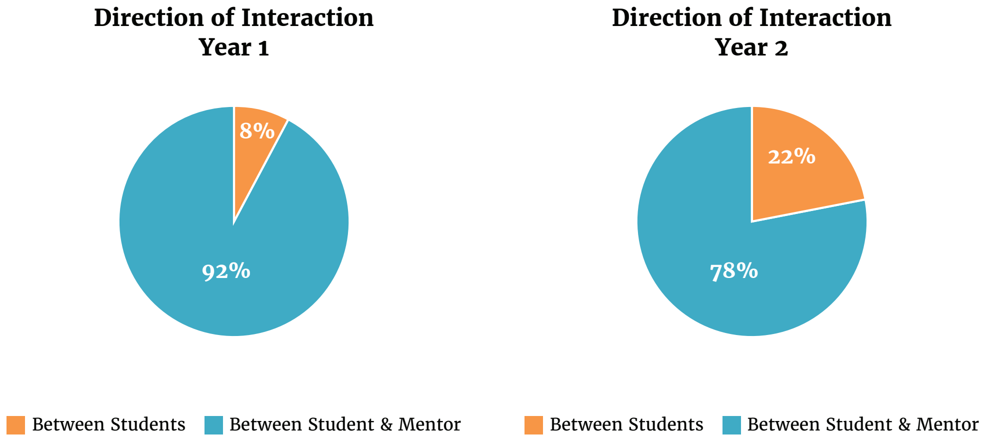
Over the course of the year, students expressed ambivalence about having mixed-grade mentoring groups. Non-seniors reflected that it was generally helpful to hear about the year-long senior research project and applying to colleges. However, some non-senior students felt that sessions were dominated by these senior-related topics and that they were not getting relevant support. Coded talk data from Year 1 supported the non-seniors' claims; this data showed that college was a dominant topic of conversation (17.8% of the dataset; Table 5). Although conversations about college may have been useful for ninth and 10th grade students as they approached their senior year, they may not have placed a high value on these discussions.

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). When dialogue did occur between students, it was initiated by seniors. For example, during an early session, Billie, a senior in Len's group, asked a ninth-grader about his project work and prompted him to share his life goals, ultimately leading to broader engagement by the younger student.

Year 2 Design: Rearranging Social Arrangements

These findings led to two design decisions for Year 2 to encourage peer mentoring (see Figure 1a conjecture map): (1) having the non-seniors join their mentoring groups

Figure 2. Direction of Interactions During Years 1 and 2 of the STEM OUT Program



halfway through the session, so that seniors and mentors could first discuss their independent project work and college-related topics and (2) directly positioning the seniors as peer mentors to the non-seniors.

Year 2 Outcomes: Shifting Patterns in Discourse and Youth Positioning

Year 2 showed a pattern of increased discussion between students, in comparison to Year 1 (Figure 2). 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 projects. 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, was trying to decide whether he wanted to pursue a career path in engineering or psychology. He told the group, "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 by encouraging Jaden to find out more about psychology by sitting in on a college-level class. He drew from his understanding of the opportunities available to RTA students, which was beyond the scope of the scientist mentors.

As seniors took these kinds of opportunities to listen to younger students and share their expertise, there was also a trend of mentors changing how they positioned students. In multiple instances, the graduate students specifically positioned the seniors as mentors, which did not occur during Year 1. As an illustration of this 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 in which the seniors shared about managing coursework and building relationships with teachers to support college recommendation letters.

The emphasis on peer mentoring interactions in Year 2 resulted in changes in students' reflections. Non-seniors reflected 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."

Both Years: Youths' Work as Similar to Graduate Students' Work

The 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' project work as similar to their work as scientists and graduate students. Mentors identified connections in three categories of practices:

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 scientific work involves failure. In response to Billie asking her mentor, Len, about major obstacles he navigated as a scientist, he shared about the emotional impact that failure in research can have: "You can fail really hard and like things just won't go your way. . . . 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." Len went on to share an experience when his research did not go as planned, and advised students that "you shouldn't be discouraged by failure. It's a natural part of the research process."

The third category, in which participants bonded about the stress of presentations, was the most common across the dataset. This topic especially arose in sessions at the end of the year, as seniors brought up anxieties around the culminating public presentation for their projects. Mentors shared their own experiences feeling anxious about presenting on their work, reassuring students that they were not alone in those worries. For example, in Year 2, 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, however, A.J. leveraged a growth mindset approach (Dweck, 1999), emphasizing that although 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.

Additionally, many mentors across both years of STEM OUT continually positioned themselves as learners and nonexperts. Although 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. 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 released from incarceration to supportive housing. Percival asked questions to understand more about the details, 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 by asking questions, but simultaneously supported youth by giving advice on nontechnical aspects and connecting them to people with app development expertise. Being honest about the limits of his expertise did not inhibit, and even contributed to, the development of relationships with youth (e.g., Bransford, 2007). Indeed, Courtney and Tony continued to meet informally with Percival after graduating, demonstrating how 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 integral to STEM OUT. The findings below show that when developing social relationships was emphasized as a leading focus, there was an increase in mentoring groups' sustained engagement and collaboration on students' project work (Figure 1b).

Year 1 Design: Focus on Project Work by Scaffolding Interactions

In the first iteration of STEM OUT, building relationships was situated as a secondary aim, with mentors primarily positioned as supporting students' project work. For example, the focal tool provided to mentors in Year 1 was the OUT Tool, intended to scaffold mentors' interactions by recording "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 1 Outcomes: Shallow Engagement About Project Work

Over their 13–15 hours together, mentors and youth discussed other topics and ideas, but, in line with the program's initial framing, participants mainly focused on students' project work. It was the dominant topic during mentoring sessions (12.7% of the dataset; Table 5). Talk about projects often took the form of mentors asking questions, one theme of which involved probing on details of project design.

Project logistics were another common theme of questions in Year 1 mentoring sessions, with mentors asking about project deadlines, or trying to unpack the specifics of what students needed to do for a particular part of the project (Figure 3). 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.

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. Mentors tried to discern the deadlines for students' project work, occasionally tempering their inquiries with concerns about building relationships. For example, Percival discussed wanting to balance "being supportive, but also, [students] need to get this done."

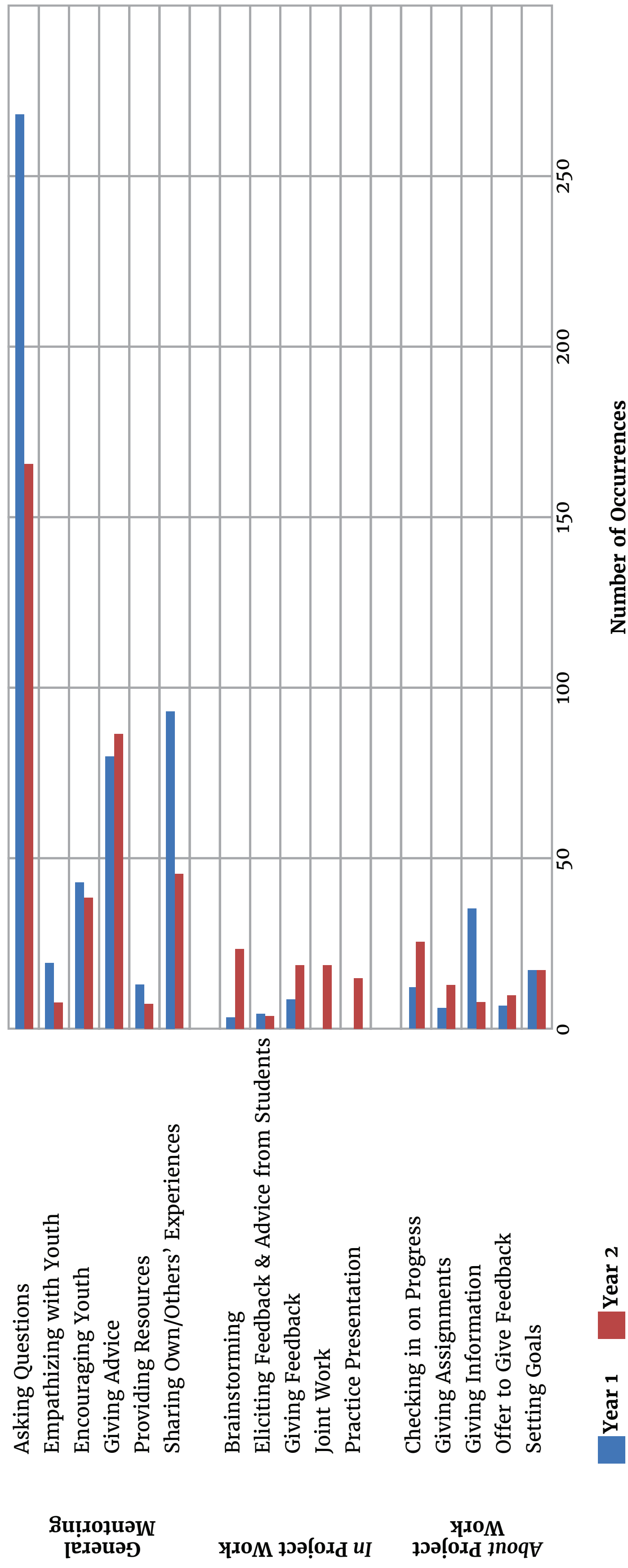
This tension between accountability and building relationships was further exemplified by the use of the OUT Tool. In Year 1, only two mentors routinely utilized the OUT Tool during their sessions, citing its utility for helping youth set goals, but also keeping track of what students had been up to since the previous session. The mentors who did not use the OUT Tool were mindful of not wanting to be another adult in students' lives reminding them what to do. One mentor, Mike, characterized this approach as being an "ally" and not wanting to be "super prescriptive."

Overall, the above quotes and excerpts from mentoring interactions are representative of the discussions between mentors and youth on students' project work in Year 1. Participants talked *about* projects on a surface level, but did not deeply engage *in* project work together, such as collaborative brainstorming, mentors giving feedback on writing, or youth practicing presentations of their work.

A counterexample to this claim demonstrates how being *in* project work together was mediated by the mentor–youth relationship (Rhodes & DuBois, 2008). In two exchanges in the Year 1 dataset, a mentor directly interacted with a student's project work. In the following interaction, 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—

Figure 3. Types of Talk Between Mentors and Youth During Mentoring Sessions in Years 1 and 2 of the STEM OUT Program



> Mia: [opening her laptop] Whatever's better for you.
>
> Amy: Okay. Also, you can send it to me by email. 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.]

Mia and Amy's established relationship informed Mia's decision to share her proposal. Amy then gave detailed feedback on Mia's proposal.

Feedback from Year 1 participants provided further evidence of the importance of relationships as a foundation for deeper engagement about project work. Focus groups revealed how students' favorite aspects were getting to know their mentor and talking about topics outside their projects. Youth participants reported that mentors were somewhat helpful with projects, 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 Year 2 focused on the ability of a mentor to relate to them, which further supports how the mentoring relationship was integral to engagement.

In their postprogram interviews, many mentors 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's project work by sending him articles he requested and spending their in-person time talking about shared experiences. Finally, mentors' feedback for Year 2 centered on wanting more structures to support building relationships with youth and for learning from each other.

Year 2 Design: Foregrounding Mentoring Relationships Through Multiple Tools

As a result of the cumulative findings from Year 1, building relationships was highlighted as one of the primary goals for Year 2 of STEM OUT. Relationship-building occurred in part during the mentor orientation workshop and when introducing the program to RTA students, as returning participants shared their experiences and favorite aspects of the program. Four mentors participated in both years, and the 12 youth participants who had been nonseniors in Year 1 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 all Year 2 mentoring groups involved building new relationships.

To intentionally support relationship-building activities, we designed three new tools:

1. Youth survey used to elicit their project interests and match with mentors' expertise;
2. Project guide for mentors, including a timeline and project assessment rubrics;
3. Reflective practice protocol to frame mentors' debriefs during the car rides between RTA and the university.

The reflective practice tool was intended to scaffold mentors' focus during their sessions, similar to supporting novice teachers in 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?"; and "What were students interested in today?" Although the OUT Tool was also available in Year 2, it was offered as part of this suite of supports.

Year 2 Outcomes: Collaborative Engagement in the Project Work

Across Year 2 mentoring groups, participants used the tools to undertake diverse ways to get to know each other. These processes of building relationships led to sustained engagement around youths' projects and discussions that drew on youths' expertise, with both youth and adult participants reporting increased feelings of success compared to Year 1.

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 2 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 than 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." Over time, it became a ritualized norm for the group that the youth began to prompt themselves, which led to extended conversations about superhero movies and TV shows, topics that Leah and the youth participants discovered they were all deeply passionate about.

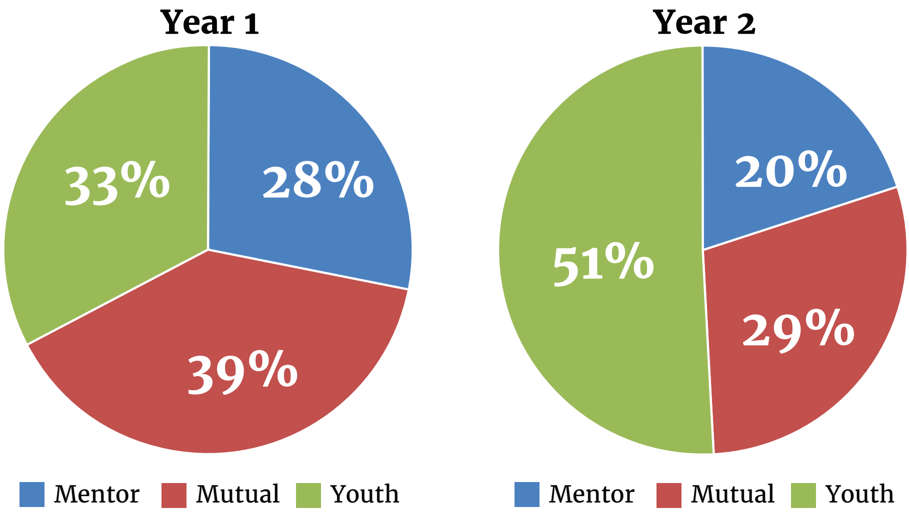
However, Year 2 mentoring interactions were not only centered on shared experiences and getting to know each other: In comparison to the Year 1 data corpus, there was ultimately more talk about students' project work (126 instances in Year 1, 190 instances in Year 2; Table 5). Further, these conversations generally differed qualitatively from talk about projects in Year 1 (Figure 3). For example, there were fewer interactions about project logistics and deadlines, due to providing the project timeline to the mentors. In an early session, Leah used the provided rubric for the senior project literature review to mediate her feedback and structure conversation with students on their project work, leading eventually to this constructive exchange with John about the purpose of a literature review:

> 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 [your] 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 questions and opening 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 2 data corpus, as well as increased numbers of interactions involving brainstorming and giving feedback compared to Year 1 (Figure 3). There were also 14 occurrences of students giving practice presentations, which did not occur in the Year 1 data. For example, in Maya's group, the seniors presented talks on the connections between their senior project topic and their chosen career path. These kinds of talk activities demonstrated how, in Year 2, fostering relationships enabled mentoring groups to

Figure 4. Sources of Expertise for All Topics Discussed During Years 1 and 2 of STEM OUT Mentoring Sessions



more substantially engage in youths' project work together.

Besides project work, the topics discussed in mentoring groups in Year 2 in comparison to Year 1 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 change is evident from Table 5, which shows the most common topics in mentoring discussions across both years; Figure 4 shows the sources of expertise for all discussion topics more broadly across the data set. Notably, half of the topics discussed in Year 2 were grounded in youths' expertise, as opposed to one third of topics in Year 1. Intentionally emphasizing developing relationships and structuring groups to facilitate peer mentoring (as described in the previous section) enabled participants to feel comfortable sharing on a range of topics that went beyond mentors' areas of expertise.

Finally, the reflective practice protocol designed to prompt mentors' attending to student experience impacted their interactions with each other. For example, in Year 2, mentors talked significantly more about youth engagement (47 occurrences) in the car rides after mentoring sessions, in comparison to Year 1 (15 occurrences). Mentors discussed finding out more about youths' interests ("Leah said that they both watch the same anime—'they started speaking anime, and I could no longer follow what was happening!'"—10/29/15 field note) and 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, leading them to reflect on their role while interacting with students during sessions, rather than on what youth could do differently.

Overall, reflections from the Year 2 mentors on their participation in the program were more positive than those of the Year 1 mentors. In contrast to themes in mentor post-interviews about student accountability and attendance in Year 1, mentors shared what they had learned about students and the connections that they made through building relationships. Denard, who participated in both years of STEM OUT, illustrates this shift. Rather than concentrating on specific tasks that youth did (or did not) accomplish outside their mentoring sessions, Denard shared how, in Year 2, he "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." 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 rather than setting his own goals for their success.

A main theme of youth participants' reflections from Year 2 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," whereas Kim, who discussed her immigration status with her mentor, shared how she felt "that I'm not alone" on her post-survey. Additionally, in contrast to wanting more opportunities to build rapport with mentors after Year 1, students' feedback described wanting more time to meet with mentors. This shift signifies how youth participants in Year 2 were more satisfied with the mentoring dynamics and relationships that they had developed.

Discussion

This study was concerned with 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 recommendations to inform the design of other scientist–youth partnership programs. The Findings section addresses the first question, detailing how distributing expertise and prioritizing relationship-building fostered less hierarchal relations. Through documenting the iterative changes to the STEM OUT program design, we portrayed how designed features contributed to these outcomes. Below, we situate these features in the broader conceptual framework, then describe principles of design that can be adapted for any setting for scientist–youth interactions, even those of short-term duration. Finally, we 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 relationship-building as a focal enterprise, we found that mentors and youth engaged more deeply on youths' research projects and shifted from mentors' external monitoring of youths' project work to an internal collaborative dynamic. We characterize these changes as being *in* students' projects together rather than shallow engagement via talking *about* their work. The findings suggest that emphasizing the dimensions of mutual expertise and social relationships facilitated their collaboration, rather than conversely assuming 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, 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 4). Similarly, when mentors reflected on how it felt to "fail" at designing an experiment or commiserated about the anxieties involved in public presentations, they validated students' analogous experiences as they carried out an independent research project. Relationship-building, in turn, directly contributed to and built on expertise being distributed within mentoring groups, by mentors discussing what they had in common with youth, or students' interests outside 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., engaging in scientist-led disciplinary activities in a lab or field setting;

Barab & Hay, 2001). However, discussing the social and affective dimensions of being a scientist illuminated how "authentic" scientific practices are conjoined with social processes. Rahm et al. (2003) described 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. 751). Authentic scientific practice, then, can be repositioned during scientist–youth interactions to encompass the many layers of coordinated social practices, navigating identity work, collaborative sensemaking, and evidence-based dissent, that take place in research contexts (Bang et al., 2012; Brickhouse, 2001; 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).

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 disciplinary practices of scientists, legitimating students' multifaceted tensions, struggles, and successes. If supported over time, these kinds of positioning moves could lead to more enduring identity work in the sciences (e.g., Bell, Tzou, 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 1 senior, Felicity, who shared interests with her mentor 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.

Although it is beyond the scope of this study to ascertain the impacts of STEM OUT participation as youth moved into college, getting to know a scientist through a mentoring relationship began to reframe their perceptions of future pathways.

More broadly, the analysis of 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 the students' research process was similar to their own. These perceptions, in turn, allowed youth to develop a sense of science as a social process that they were already undertaking. Finally, the positioning of seniors as mentors to younger students emphasized their expertise and multiple roles that they could take on, as opposed to being solely learners, as often occurs during adult–youth interactions (DiGiacomo & Gutiérrez, 2016).

Conclusion: 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, this study 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 demonstrated how design can disrupt these asymmetrical relations, and, as discussed below, contribute to broadening participation in STEM.

Limitations and Future Research

Limitations of this study mainly come from its focus on one instantiation of scientist–youth interactions. In line with the principles of design-based research, the iterative approach to designing STEM OUT was grounded in specific sociocultural constructs and broader research findings that informed the initial and subsequent designs. However, a fruitful direction for future research will employ these ideas in the design of other settings.

Similarly, it will be vital to test out the proposed design recommendations that follow this section for fostering relational equity between scientists and youth. Many scientist–youth programs are more limited in duration than STEM OUT, with perhaps only a single synchronous interaction or an intensive weeklong research experience. Although it may be challenging to understand outcomes that relate to distributing expertise and building relationships after a short-term interaction, designers of scientist–youth partnership programs should consider ways to adapt the principles of design proposed here for their local contexts and nature of participation for scientists and youth.

Finally, this study's findings are limited to the duration of the STEM OUT program. Opportunities to check in with participants over time would enable us to make stronger claims related to the durability of the outcomes, and to make claims regarding identity shifts that may have occurred for both youth and adults. Future research in this direction could be performed via a follow-up study to track participants across longer timescales and broader contexts as they moved on from high school and graduate school, respectively.

Recommendations for Scientist–Youth Program Design

Below are recommendations that follow from this study's findings, with accompanying suggestions for implementation in contexts involving scientist–youth interactions. In line with the design-based research framework used here, these recommendations are framed as design principles (e.g., Edelson, 2002).

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, et al., 2012; Bell, Tzou, et al., 2012; Stromholt & Bell, 2017; Van Horne & Bell, 2017). Designing for distributed expertise 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 youths' interests or connections to the activities at hand, or intentionally designing activities such that youth can develop and share expertise as they interact (such as a jigsaw structure).

Additionally, the STEM OUT mentors' status as early-career scientists may have enabled them to find parallels between students' research and their own, given their positioning 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 2 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. Although relationship-building will vary for a short-term rather than a prolonged mentoring experience, one starting place is an introductory "ice breaker" activity to mutually share about who participants are beyond being a scientist or student. Adult participants can then connect to outside interests and identities over the duration of the program. Another way to facilitate relationship-building is for scientists to connect back to their experiences and interests when they were the age of the students, 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 orient scientists to youths' school or community (especially if the program is in the scientists' context).

Design Principle 3: Design Tools to Scaffold Participant Structures for Relational Equity

Attending to *how* participants will interact is a key finding that follows from this study. As demonstrated by the evolving set of tools to scaffold participation structures in STEM OUT, encouraging collaboration between youth and scientists can be straightforward—for example, mentoring groups were prompted to talk about non-seniors' interests and expertise. For experiences involving collaborative scientific work, fostering relational equity between adult and youth participants could entail pausing to discuss what they are doing and make sense of what it means. For scientists working with groups of students, attending to who is talking and how much is important. A think-pair-share strategy may work well to encourage discourse between youth in large groups. Finally, building structures to elicit, share, and follow up on students' ideas is crucial to fostering relational equity.

Implications for Broadening STEM Participation on Multiple Dimensions

STEM OUT mentors' demographic backgrounds (Table 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 underrepresented backgrounds collaborating in an informal science learning environment, mentors "embodied the notion that individuals [from diverse backgrounds] can successfully complete such degrees" (Polman & Miller, 2010, p. 912). Such experiences can be incredibly valuable for youth from minoritized demographic backgrounds, especially when mentors and students also discuss issues of underrepresentation in the STEM fields (Hazari et al., 2013), which occurred on multiple occasions during STEM OUT mentoring sessions.

Reports on broadening participation often emphasize 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). Although such a shift is a vital goal, youth–scientist partnership programs provide opportunities to 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 mentors as full people enabled this second aspect of broadening participation. As described above, youth had the opportunity to understand science as a multidimensional 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 and transcended the limited repertoire of disciplinary practices 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, through interacting with youth, scientists can become aware of their 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). Recognizing this potential can have implications for youth that may be marginalized or uninterested in the vision of sciences as presented in classrooms, by broadening their perspectives on what counts as science. Lemke (2001) framed the implications for 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 and informed students' broader conceptions of the sciences. Beyond the implications for youth to pursue science, being positioned as already engaged in scientific activities is crucial to young people's ability to leverage 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 scientist–youth interactions can similarly have lasting impacts for all participants.

About the Authors

Elaine R. Klein *is a science educator at BSCS Science Learning.*

Philip Bell *is a professor of learning sciences in the College of Education at the University of Washington.*

References

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching, 47*(5), 564–582. https://doi.org/10.1002/tea.20353

Bang, M., Warren, B., Rosebery, A. S., & Medin, D. (2012). Desettling expectations in science education. *Human Development, 55*(5–6), 302–318. https://doi.org/10.1159/000345322

Banks, J. A., Au, K., Ball, A., Bell, P., Gordon, E., Gutiérrez, K., Heath, S. B., Lee, C. D., Lee, Y., Mahiri, J., Nasir, N. S., Valdés, G., & Zhou, M. (2007). *Learning in and out of school in diverse environments: Life-long, life-wide, life-deep*. The LIFE Center and the Center for Multicultural Education, University of Washington.

Barab, S. A., & Hay, K. E. (2001). Doing science at the elbows of experts: Issues related to the science apprenticeship camp. *Journal of Research in Science Teaching, 38*(1), 70–102. https://doi.org/10.1002/1098-2736(200101)38:1<70::AID-TEA5>3.0.CO;2-L

Barron, B., & Bell, P. (2015). Learning environments in and out of school. In L. Corno & E. Anderman (Eds.), *Handbook of educational psychology* (3rd ed., pp. 323–336). Routledge, Taylor & Francis.

Barron, B., Gomez, K., Pinkard, N., & Martin, C. K. (2014). *The Digital Youth Network: Cultivating digital media citizenship in urban communities*. MIT Press.

Basu, S. J., & Calabrese Barton, A. (2007). Developing a sustained interest in science among urban minority youth. *Journal of Research in Science Teaching, 44*(3), 466–489. https://doi.org/10.1002/tea.20143

Bell, P., Bricker, L. A., Reeve, S., Zimmerman, H. T., & Tzou, C. (2012). Discovering and supporting successful learning pathways of youth in and out of school: Accounting for the development of everyday expertise across settings. In B. Bevan, P. Bell, R. Stevens, & A. Razfar (Eds.), *Learning about Out of School Time (LOST) learning opportunities* (pp. 119–140). Springer.

Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (2009). *Learning science in informal environments: People, places, and pursuits*. National Academies Press.

Bell, P., Tzou, C., Bricker, L., & Baines, A. D. (2012). Learning in diversities of structures of social practice: Accounting for how, why and where people learn science. *Human Development, 55*(5–6), 269–284. https://doi.org/10.1159/000345315

Blomberg, J., Giacomi, J., Mosher, A., & Swenton-Hall, P. (1993). Ethnographic field methods and their relation to design. In D. Schuler (Ed.), *Participatory design: Principles and practices* (pp. 123–155). L. Erlbaum Associates.

Bransford, J. (2007). Preparing people for rapidly changing environments. *Journal of Engineering Education, 96*(1), 1–3. https://doi.org/10.1002/j.2168-9830.2007.tb00910.x

Bricker, L. A., & Bell, P. (2013). "What comes to mind when you think of science? The perfumery!": Documenting science-related cultural learning pathways across contexts and timescales. *Journal of Research in Science Teaching, 51*(3), 260–285. https://doi.org/10.1002/tea.21134

Brickhouse, N. W. (2001). Embodying science: A feminist perspective on learning. *Journal of Research in Science Teaching, 38*(3), 282–295. https://doi.org/10.1002/1098-2736(200103)38:3<282::AID-TEA1006>3.0.CO;2-0

Brown, A. L., Ash, D., Rutherford, M., Nakagawa, K., Gordon, A., & Campione, J. C. (1993). Distributed expertise in the classroom. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 188–228). Cambridge University Press.

Brown, B. A., & Spang, E. (2008). Double talk: Synthesizing everyday and science language in the classroom. *Science Education, 92*(4), 708–732. https://doi.org/10.1002/sce.20251

Calabrese Barton, A., Kang, H., Tan, E., O'Neill, T. B., Bautista-Guerra, J., & Brecklin, C. (2013). Crafting a future in science: Tracing middle school girls' identity work over time and space. *American Educational Research Journal, 50*(1), 37–75. https://doi.org/10.3102/0002831212458142

Calabrese Barton, A., & Yang, K. (2000). The culture of power and science education : Learning from Miguel. *Journal of Research in Science Teaching, 37*(8), 871–889. https://

doi.org/10.1002/1098-2736(200010)37:8<871::AID-TEA7>3.3.CO;2-0

Carlone, H. B. (2004). The cultural production of science in reform-based physics: Girls' access, participation, and resistance. *Journal of Research in Science Teaching, 41*(4), 392–414. https://doi.org/10.1002/tea.20006

Carlone, H. B., Benavides, A., Huffling, L. D., Matthews, C. E., Journell, W., & Tomasek, T. (2016). Field ecology: A modest, but imaginable, contestation of neoliberal science education. *Mind, Culture, and Activity, 23*(3), 199–211. https://doi.org/10.1080/10749039.2016.1194433

Carlone, H. B., Huffling, L. D., Tomasek, T., Hegedus, T. A., Matthews, C. E., Allen, M. H., & Ash, M. C. (2015). "Unthinkable" selves: Identity boundary work in a summer field ecology enrichment program for diverse youth. *International Journal of Science Education, 37*(10), 1524–1546. https://doi.org/10.1080/09500693.2015.1033776

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*(8), 1187–1218. https://doi.org/10.1002/tea.20237

Carlone, H. B., Johnson, A., & Eisenhart, M. (2014). Cultural perspectives in science education. In *Handbook of research on science education* (pp. 651–670). Routledge.

Carlone, H. B., Scott, C. M., & Lowder, C. (2014). Becoming (less) scientific: A longitudinal study of students' identity work from elementary to middle school science. *Journal of Research in Science Teaching, 51*(7), 836–869. https://doi.org/10.1002/tea.21150

Chávez, V., & Soep, E. (2005). Youth radio and the pedagogy of collegiality. *Harvard Educational Review, 75*(4), 409–434. https://doi.org/10.17763/haer.75.4.827u365446030386

Ching, D., Santo, R., Hoadley, C., & Peppler, K. (2015). *On-ramps, lane changes, detours and destinations: Building connected learning pathways in Hive NYC through brokering future learning opportunities*. Hive Research Lab. https://hiveresearchlab.org/2015/04/13/on-ramps-lane-changes-detours-and-destinations-new-community-developed-white-paper-on-supporting-pathways-through-brokering/

Ching, D., Santo, R., Hoadley, C., & Peppler, K. (2016). Not just a blip in someone's life: Integrating brokering practices into out-of-school programming as a means of supporting and expanding youth futures. *On the Horizon, 24*(3), 296–312. https://doi.org/10.1108/OTH-05-2016-0026

Cobb, P., Confrey, J., DiSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32*(1), 9–13. https://doi.org/10.3102/0013189X032001009

Collins, A., Brown, J., & Holum, A. (1991). Cognitive apprenticeship: Making thinking visible. *American Educator, 15*(3), 6–11.

Collins, H., & Shapin, S. (1986). Uncovering the nature of science. In J. Brown, A. Cooper, T. Horton, & D. Zeldin (Eds.), *Science in schools* (pp. 70–79). Open Univerity Press.

Cornelius, L. L., & Herrenkohl, L. R. (2004). Power in the Classroom: How the Classroom Environment Shapes Students' Relationships With Each Other and With Concepts. *Cognition and Instruction, 22*(4), 467–498. http://www.tandfonline.com/doi/abs/10.1207/s1532690Xci2204_4

Davies, B., & Harré, R. (1990). Positioning: The discursive production of selves. *Journal for the Theory of Social Behaviour, 20*(1), 43–63. https://doi.org/10.1111/j.1468-5914.1990.tb00174.x

Derry, S. J., Pea, R. D., Barron, B., Engle, R. A., Erickson, F., Goldman, R., Hall, R., Koschmann, T., Lemke, J. L., Sherin, M. G., & Sherin, B. L. (2010). Conducting video research in the learning sciences: Guidance on selection, analysis, technology, and ethics. *Journal of the Learning Sciences, 19*(1), 3–53. https://doi.org/10.1080/10508400903452884

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5–8. https://doi.org/10.3102/0013189X032001005

DiGiacomo, D. K., & Gutiérrez, K. D. (2016). Relational equity as a design tool within making and tinkering activities. *Mind, Culture, and Activity, 23*(2), 141–153. https://doi.org/10.1080/10749039.2015.1058398

Dweck, C. S. (1999). *Self-theories: Their role in motivation, personality, and development*. Psychology Press.

Edelson, D. C. (2002). Design research: What we learn when we engage in design. *The Journal of the Learning Sciences, 11*(1), 105–121. https://doi.org/10.1207/S15327809JLS1101_4

Emerson, R. M., Fretz, R. I., & Shaw, L. L. (2011). *Writing ethnographic fieldnotes* (2nd ed.). University of Chicago Press.

Erickson, F. (1986). Qualitative methods in research on teaching. In M. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 119–161). Macmillan.

Falloon, G. (2013). Forging school–scientist partnerships: A case of easier said than done? *Journal of Science Education and Technology, 22*(6), 858–876. https://doi.org/10.1007/s10956-013-9435-y

Fitzallen, N., & Brown, N. R. (2016). Outcomes for engineering students delivering a STEM education and outreach programme. *European Journal of Engineering Education, 42*(6), 632–643. https://doi.org/10.1080/03043797.2016.1210570

Gee, J. P. (2011). *How to do discourse analysis: A toolkit*. Routledge.

Gibbs, K. D., & Marsteller, P. (2016). Broadening participation in the life sciences: Current landscape and future directions. *CBE—Life Sciences Education, 15*(3), 1–3. https://doi.org/10.1187/cbe.16-06-0198

Goodwin, C., & Heritage, J. (1990). Conversation analysis. *Annual Review of Anthropology, 19*, 283–307. https://doi.org/10.1146/annurev.an.19.100190.001435

Halpern, R. (2005). Instrumental relationships: A potential relational model for inner-city youth programs. *Journal of Community Psychology, 33*(1), 11–20. https://doi.org/10.1002/jcop.20032

Harré, R., Moghaddam, F. M., Cairnie, T. P., Rothbart, D., & Sabat, S. R. (2009). Recent advances in positioning theory. *Theory & Psychology, 19*(1), 5–31. https://doi.org/10.1177/0959354308101417

Hazari, Z., Potvin, G., Lock, R. M., Lung, F., Sonnert, G., & Sadler, P. M. (2013). Factors that affect the physical science career interest of female students: Testing five common hypotheses. *Physical Review Special Topics—Physics Education Research, 9*(2), 1–8. https://doi.org/10.1103/PhysRevSTPER.9.020115

Heath, S. B. (2012). *Words at work and play: Three decades in family and community life*. Cambridge.

Heath, S. B., & Street, B. V. (2008). *On ethnography : Approaches to language and literacy research*. Teachers College Press.

Hinko, K., & Finkelstein, N. (2012). Impacting university physics students through participation in informal science. *AIP Conference Proceedings 1513*, Article 178. https://doi.org/10.1063/1.4789681

Holland, D., & Lave, J. (2009). Social practice theory and the historical production of persons. *Actio: An International Journal of Human Activity Theory, 2*, 1–15.

Kafai, Y. B., Desai, S., Peppler, K. A., Chiu, G. M., & Moya, J. (2008). Mentoring partnerships in a community technology centre: A constructionist approach for fostering equitable service learning. *Mentoring & Tutoring: Partnership in Learning, 16*(2), 191–205. https://doi.org/10.1080/13611260801916614

Klein, E. R. (2016, April 8–12). *Learning to engage: Scientists, engineers, educators, and youth in learning collaborations* [Paper presentation]. American Educational Research Association Meeting, Washington, DC.

Latour, B. (1987). *Science in action*. Harvard University Press.

Latour, B., & Woolgar, S. (1986). *Laboratory life: The construction of scientific facts*. Princeton University Press.

Lave, J. (1996). Teaching, as learning, in practice. *Mind, Culture, and Activity, 3*(3), 149–164.

https://doi.org/10.1207/s15327884mca0303_2

Lee, C. D. (2017). Expanding visions of how people learn: The centrality of identity repertoires. *Journal of the Learning Sciences, 26*(3), 517–524. https://doi.org/10.1080/10508406.2017.1336022

Lehrer, R., & Palincsar, A. S. (2004). Introduction to special issue: Investigating structures in the context of science instruction. *Cognition and Instruction, 22*(4), 389–392.

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching, 38*(3), 296–316. https://doi.org/10.1002/1098-2736(200103)38:3<296::AID-TEA1007>3.0.CO;2-R

Linn, M. C., Songer, N. B., & Eylon, B. S. (1996). Shifts and convergences in science learning and instruction. In R. Calfee & D. Berliner (Eds.), *Handbook of educational psychology* (pp. 438–490). Macmillan.

Luehmann, A. L. (2007). Identity development as a lens to science teacher preparation. *Science Education, 91*(5), 822–839. https://doi.org/10.1002/sce.20209

McDermott, R., & Webber, V. (1998). When is math or science? In J. G. Greeno & S. V. Goldman (Eds.), *Thinking practices in mathematics and science learning* (pp. 321–339). Erlbaum.

Miles, M. B., Huberman, A. M., & Saldana, J. (2013). Tactics for generating meaning. In *Qualitative data analysis: A methods sourcebook* (3rd ed., pp. 277–293). SAGE Publications.

Miranda, R. J., & Hermann, R. S. (2010). A critical analysis of faculty-developed urban K-12 science outreach programs. *Penn GSE Perspectives on Urban Education, 7*(1), 109–114. https://urbanedjournal.gse.upenn.edu/archive/volume-7-issue-1-summer-2010/critical-analysis-faculty-developed-urban-k-12-science-outreach

Nasir, N. S. (2012). *Racialized identities: Race and achievement among African American youth*. Stanford University Press.

Nasir, N. S., Rosebery, A. S., Warren, B., & Lee, C. D. (2006). Learning as a cultural process: Achieving equity through diversity. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 489–504). Cambridge University Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

National Research Council. (2015). *Identifying and supporting productive STEM programs in out-of-school settings*. National Academies Press.

National Science Foundation. (2008). *Broadening participation at the National Science Foundation: A framework for action*.

National Science Foundation. (2016). *Science & engineering indicators 2016*.

O'Connor, K., & Allen, A.-R. (2010). Learning as the organizing of social futures. *NSSE Yearbook, 109*(1), 160–175.

Patton, M. Q. (2002). *Qualitative research & evaluation methods*. Sage Publications.

Pea, R. D. (1993). The Collaborative Visualization Project. *Communications of the ACM, 36*(5), 60–63. https://doi.org/10.1117/12.139268

Penuel, W. R. (2016). Studying science and engineering learning in practice. *Cultural Studies of Science Education, 11*(1), 89–104. https://doi.org/10.1007/s11422-014-9632-x

Polman, J. L., & Miller, D. (2010). Changing stories: Trajectories of identification among African American youth in a science outreach apprenticeship. *American Educational Research Journal, 47*(4), 879–918. https://doi.org/10.3102/0002831210367513

Rahm, J. (2007). Youths' and scientists' authoring of and positioning within science and scientists' work. *Cultural Studies of Science Education, 1*(3), 517–544. https://doi.org/10.1007/s11422-006-9020-2

Rahm, J., Miller, H. C., Hartley, L., & Moore, J. C. (2003). The value of an emergent notion of authenticity: Examples from two student/teacher–scientist partnership programs. *Journal of Research in Science Teaching, 40*(8), 737–756. https://doi.org/10.1002/tea.10109

Rhodes, J. E., & DuBois, D. L. (2008). Mentoring relationships and programs for youth.

Current Directions in Psychological Science, 17(4), 254–258. https://doi.org/10.1111/j.1467-8721.2008.00585.x

Rosebery, A. S., Ogonowski, M., DiSchino, M., & Warren, B. (2010). "The coat traps all your body heat": Heterogeneity as fundamental to learning. *Journal of the Learning Sciences, 19*(3), 322–357. https://doi.org/10.1080/10508406.2010.491752

Rouse, J. (1996). *Engaging science: How to understand its practices philosophically*. Cornell University Press.

Sadler, K., Eilam, E., Bigger, S. W., & Barry, F. (2018). University-led STEM outreach programs: Purposes, impacts, stakeholder needs and institutional support at nine Australian universities. *Studies in Higher Education, 43*(3), 586–599. https://doi.org/10.1080/03075079.2016.1185775

Sadler, T. D., Burgin, S., McKinney, L., & Ponjuan, L. (2010). Learning science through research apprenticeships: A critical review of the literature. *Journal of Research in Science Teaching, 47*(3), 235–256. https://doi.org/10.1002/tea.20326

Sandoval, W. (2013). Conjecture mapping: An approach to systematic educational design research. *Journal of the Learning Sciences, 23*(1), 18–36. https://doi.org/10.1080/10508406.2013.778204

Stevens, R. (2013). Introduction: What counts as math and science? In B. Bevan, P. Bell, R. Stevens, & A. Razfar (Eds.), *LOST Opportunities: Learning in out-of-school time* (pp. 3–6). Springer Netherlands.

Strauss, A., & Corbin, J. (1990). *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. Sage Publications.

Stromholt, S., & Bell, P. (2017). Designing for expansive science learning and identification across settings. *Cultural Studies of Science Education, 13*, 1015–1047. https://doi.org/10.1007/s11422-017-9813-5

Tabak, I., & Baumgartner, E. (2004). The teacher as partner: Exploring participant structures, symmetry, and identity work in scaffolding. *Cognition and Instruction, 22*(4), 393–429. https://doi.org/10.1207/s1532690Xci2204_2

Tanner, K. (2000, April 29). *Evaluation of scientist–teacher partnerships: Benefits to scientist participants* [Paper presentation]. National Association for Research in Science Teaching (NARST) Annual Conference, New Orleans, LA.

Tenenbaum, L. S., Anderson, M. K., Jett, M., & Yourick, D. L. (2014). An innovative near-peer mentoring model for undergraduate and secondary students: STEM focus. *Innovative Higher Education, 39*(5), 375–385. https://doi.org/10.1007/s10755-014-9286-3

Thiry, H., Laursen, S. L., & Hunter, A.-B. (2011). What experiences help students become scientists?: A comparative study of research and other sources of personal and professional gains for STEM undergraduates. *The Journal of Higher Education, 82*(4), 357–388. https://doi.org/10.1080/00221546.2011.11777209

Tzou, C., & Bell, P. (2012). The role of borders in environmental education: Positioning, power and marginality. *Ethnography and Education,* 7(2), 265–282. https://doi.org/10.1080/17457823.2012.693697

van Es, E. A., & Sherin, M. G. (2002). Learning to notice: Scaffolding new teachers' interpretations of classroom interactions. *Journal of Technology and Teacher Education, 10*(4), 571–596. https://www.learntechlib.org/primary/p/9171/

Van Horne, K., & Bell, P. (2017). Youth disciplinary identification during participation in contemporary project-based science investigations in school. *Journal of the Learning Sciences, 26*(3), 437–476. https://doi.org/10.1080/10508406.2017.1330689

Vygotsky, L. (1978). *Mind in society*. Harvard University Press.

Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A. S., & Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching, 38*(5), 529–552. https://doi.org/10.1002/tea.1017

Woods-Townsend, K., Christodoulou, A., Rietdijk, W., Byrne, J., Griffiths, J. B., & Grace, M. M. (2016). Meet the scientist: The value of short interactions between scientists and students. *International Journal of Science Education, Part B, 6*(1), 89–113. https://doi.org/10.1080/21548455.2015.1016134

Wormstead, S. J., Becker, M. L., & Congalton, R. G. (2002). Tools for successful student–teacher–scientist partnerships. *Journal of Science Education and Technology, 11*(3), 277–287. https://doi.org/10.1023/A:1016076603759

Wortham, S. (2006). *Learning identity: The joint emergence of social identification and academic learning*. Cambridge University Press.

Wortham, S. (2008). The objectification of identity across events. *Linguistics and Education, 19*(3), 294–311. https://doi.org/10.1016/j.linged.2008.05.010