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"I Like That Girl Power": Informal/Formal Learning Ecosystems that Support Young Women's Engagement in STEM

Sarah Hug[1] and Suzanne Eyerman[2]

[1]Colorado Evaluation and Research Consulting
[2]Fairhaven Research and Evaluation
USA

ABSTRACT

At the heart of many STEM ecosystem models are cross-sector partnerships between formal K12 education and informal learning stakeholders. Informal/formal education cross-sector partnerships are considered effective models for enriching STEM education for youth underrepresented in the STEM disciplines. In this paper we identify benefits of a cross sector partnership from the point of view of the staff, youth participants, educators, and leadership engaged in the partnership. We focus on explicit, intended youth outcomes—engaging young women of color in engineering to support their career aspirations in the fields—as well as emergent themes, primarily noted by formal educators and formal education leadership, regarding the mechanisms by which partnership with a nonprofit has influenced students, teachers, and the school community. Evidence indicates the design of the partnership allowed each party to share practices, material, and human resources that minimized duplication of efforts of stakeholders. The study also shows how integrating an after-school program into the school community enabled Techbridge Girls to create opportunity for informal and formal settings to reinforce one another in ways that are less common in traditional, stand-alone informal STEM learning, benefitting the schools, the nonprofit organizations, and most importantly, the youth they serve.

KEYWORDS

informal/formal K12 education, cross-sector partnerships, STEM ecosystems, out-of-school-time learning

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The STEM disciplines, particularly engineering, have remained male dominated despite a multitude of programmatic efforts across the US to shift the numbers towards gender parity. Though a multitude of efforts across sectors and settings have been employed to improve gender representation in engineering via business, informal education, formal K12 and higher education, and community-based organizations, the efforts have not brought about greater representation of women in the fields. In recent years, collaborative models of affecting change have been promoted across multiple "intractable problems" (Kania & Kramer, 2015). The National Science Foundation's President, France Cordova, has named "NSF INCLUDES", (National Science Foundation, 2019) a collective impact model for diversifying STEM, one of the 10 "big ideas" of the foundation. As an example, Wells et al., (2019) described how their local collaborations moved the needle on the number of women applying to Ontario undergraduate engineering programs. Collective efforts blend the resources, knowledge, and skills of multiple entities to address gender parity in STEM.

Others have echoed the need to collaborate, in particular across sectors of STEM education and career-focused entities (Basham et al 2010; Chiu et al., 2015). According to Traphagan and Traill (2014), collaboration across sectors is vital to realizing supportive learning opportunities for youth in STEM. Bevan and colleagues describe the benefits of cross-sector partnerships, specifically those engaging formal and informal education organizations to offer rich experiences to youth and to create spaces for teachers and youth to develop new "practices, dispositions, and understandings" regarding STEM (2010, p. 57). At the same time, the report indicates there is a lack of evidence regarding the effectiveness of these formal/informal education partnerships for achieving their goals, specifically regarding the value of collaboration.

In this paper, qualitative methods were used to investigate the following research question: How do cross sector collaborations with Techbridge Girls support young women's engagement in science and engineering? The question was examined from multiple vantage points, emphasizing the impact of cross-sector collaborations on schools and school communities engaged in long-term partnerships with informal education nonprofit organizations.

Formal and informal education collaborations bring together professionals with different, though often complementary, funds of knowledge (Moll et al. 1992; Cook & Weiland, 2013). For example, informal educators may be adept at incorporating positive youth development practices into their interactions with youth, while formal educators bring their formal STEM curriculum understanding to the partnership. Cross-sector partnerships are often motivated by an understanding that each partner has resources that the other needs (Chen & Graddy, 2010; Russell, Knutson & Crowley, 2013). A cross-sector partnership brings different assets (students,

infrastructure, workspace, network of youth, knowledge, time, curriculum, youth development framework) together to advance the vision of the partners. Partnerships of different types of organizations are difficult (Bevan et al., 2010) in that they take added time to build trust across participants, negotiation of goals, norms of operating, and time to ensure the partners have the same vision. Evidence suggests, however, that cross-sector partnerships can increase STEM interest and content knowledge of target populations (Weinstein et al., 2014). Informal/formal education cross-sector partnerships are considered effective models for enriching STEM education for youth underrepresented in the STEM disciplines (National Research Council, 2009; Thiry et al., 2017). Studies that follow youth across formal and informal settings have noted that positive science identities do not always translate across settings (Bricker & Bell, 2014; Fields, 2010)—by making connections across these settings, youth have opportunities to bring the dispositions and practices of informal education opportunities into the academic sphere. Career trajectories in STEM are complex and relate to social interaction with multiple actors (e.g., peers, STEM professionals) as well as opportunities to expand youth opportunities to see the professional work of the field (Hughes & Molyneaux, 2016). Because of the complexities of STEM career trajectories, it is important to gather data from multiple sources and gain understanding of STEM youth identities from multiple perspectives.

In this paper we identify benefits of a cross sector partnership from the point of view of the staff, youth participants, educators, and leadership engaged in the partnership with Techbridge Girls. We focus on explicit, intended youth outcomes—engaging young women of color in engineering to support their career aspirations in the fields—as well as emergent themes, primarily noted by formal educators and formal education leadership, regarding the mechanisms by which partnership with a nonprofit has influence students, teachers, and the school community. We emphasize how the collaboration reshapes what it means to learn engineering and the roles formal and informal educators and young women have in the endeavor. This paper contributes empirical evidence lacking in the field (Bevan, Dillon, et al., 2010), showing that formal and informal educational partnerships can support resilient identities for young women in science. We provide a discussion of the findings, as well as recommendations for further study of collaborative efforts to engage young women in STEM.

CONTEXT OF THE STUDY: BACKGROUND OF THE ORGANIZATION

Techbridge Girls is a 20-year-old nonprofit organization with a focus on promoting girls' trajectories along SET career pathways, specifically engineering. Through national and regional summer camps, after-school programs, and professional development, the nonprofit seeks to improve the quality of STEM education in formal and informal settings with a particular emphasis on under-resourced girls and underserved communities in the United States. The organization has developed expertise in inclusive educational efforts that support all learners, particularly English language learners and learners experiencing poverty. Their mission statement reads:

> We strive to inspire girls in underserved communities to discover a passion for science, technology and engineering. We give them access to the hands-on learning and real-world exposure they need to pursue their dreams and careers. We also work with families, role models, school districts and partners to provide the guidance they need to support girls and set them on the path to success. We believe in the possibility of every girl having the power to change the world.
>
> (https://www.techbridgegirls.org/)

In 2013, Techbridge Girls received a National Science Foundation grant to scale out its operations and youth programming from two adjacent geographic areas to three additional cities across the United States. The grant supported social science research as well as evaluation of the process, outcomes, and impact of scaling out. Data collection was primarily focused on scale-out sites, with some attention to national headquarters, but no systematic analysis of legacy sites was completed. One of the scale-out sites is situated in a small school district in the outlying areas of a major metropolitan city. In this site, district involvement is strong, and school partnerships derive directly from the district office. For simplicity, this site will be referred to as "District Site." The other site, which began operations a year following District Site, involves a large metropolitan school district with a large charter and choice school culture. In this site, partnerships developed on a school-by-school basis, and the mix of partner schools is balanced among public schools and charter schools. Because of the nature of charter schools, agreements were made locally with their school-level leadership and occurred separately from the school district. For the purposes of this paper, the site is "Metro Site." Both sites have majority-minority populations, and 50–98% of the schools' students receive free and/or reduced school lunches, which is a proxy for low income.

The National Science Foundation grant provided the nonprofit organization (NPO) with funds for the hiring of new staff, capacity building at the new sites (e.g., procurement of physical office space, materials, staff, travel related to scaling out in new locations), consultancy to determine the viability of new sites, and funds to onboard new staff. The process to scale out to a new city involved hiring an executive director a year to six months prior to after-school program roll-out to lay the groundwork for partnership building in local schools, staffing, and infrastructure development (e.g., office space procurement, purchasing needed equipment).

The authors have expertise in the learning sciences and served as the principal researchers on the NSF grant. The first author worked with the organization in an evaluative and social science research capacity on multiple projects beginning in 2011 while the second author joined in a research capacity in 2013. Data collection occurred in collaboration with evaluators in the project. Each spring from 2015 through 2019, site visits occurred at both expansion sites. Two researchers (authors one and two) and two evaluators took part in the data collection each year. Each site visit lasted four to five days on average. Researchers also made fall site visits a part of their practice, emphasizing different elements of the research effort (e.g., focusing on one-on-one project-specific student interviews) to

maximize program observation, focus group, and interview opportunities in person. Instruments were co-developed to address evaluative and research-related questions in the same data point as an effort to ease partner, staff, and participant burden, as well as for efficiency in costs (e.g., travel to sites for observations and interviews, transcription costs). The first author also interacted with Techbridge Girls staff in her role as consultant on professional development projects with youth educators, providing feedback to staff on their professional development efforts. At the height of the project data collection, the first author spent approximately 15 days with Techbridge Girls staff and partners in one year.

RESEARCH METHOD

This paper stems from a multi-year, multi-site mixed methods research study of a nonprofit organization that partners with local schools. Through the partnership Techbridge Girls provided professional development to teachers as well as after-school programming for young women, with an emphasis on recruiting young women of color from the schools and school systems in which they are the majority of young women enrolled. This is the cross-sector partnership of interest in this study. The authors are social science researchers who have been funded by a National Science Foundation grant to study the impact of scale on a youth-serving nonprofit engaged in promoting science, engineering, and technology for youth. The research and evaluation team collaborated closely on data collection, yet analysis was separate and complementary. For this piece, the authors utilize their extensive knowledge of sociocultural learning theories to better understand how collaboration influences whether and how girls develop positive dispositions towards engineering, as well as whether and how the collaborators express the value of the partnership. This work is represented as a qualitative research study that spans multiple sites of programmatic practice.

Data Collection and Data Sources

As this study was part of the research and evaluation of a National Science Foundation grant, the evaluation and research teams collaborated on data collection from stakeholders. Techbridge Girls staff provided a list of teachers and principals who were partners with the informal education organization. The teachers and principals chose days and times that were convenient to them for the interviews, with in-person interviews occurring when possible during site visits to the two locations. Recruitment messaging for interviews followed Institution Review Board practices and approved documentation. The participation rates in interviews was relatively high for teachers and principals: approximately 80–90% agreed to participate in interviews each year. Both research and evaluation teams were included on the Institutional Research Board (IRB) protocols, and both teams had access to audio and transcript data for interviews and focus groups. Interview data from 2017 are prioritized in the results section, but the entire corpus of data are used to corroborate findings throughout the paper.

Interview questions, and the time allotted to each, were tailored to different stakeholders. Techbridge Girls staff interviews were held formally for approximately 60 minutes annually, and site visits provided opportunities for informal interviews to occur as well, for example, en route to program sites, and at meals following

program visits. Focus groups were handled differently at each site: some program coordinators asked for the researchers to talk with girls in small groups throughout the after-school session, while others provided time to speak with the whole group of students. Focus groups averaged 20 minutes and ranged from 2 to 15 participants. Teacher interviews typically lasted from 35 to 60 minutes and were scheduled, when possible, in person during teacher's planning time or following program activities. Some teachers were interviewed by phone due to scheduling difficulties. Many of the teachers interviewed in the target year were returning teachers, and so they often had multiple years of experience to speak about during interviews. Principal interviews were typically shorter in duration, usually 25–35 minutes, held during the school day.

Participant observation practices of the researchers differed across contexts, and focused on the tenets of participation observation imparted by Guest et. al., (2013) to emphasize being present whenever possible, building rapport with participants, and spending sufficient time with participants to answer research questions. During the logic model development meeting, the researcher who attended brought insight from previous work with the organization and participated from an "insider/ outsider" perspective (Dwyer & Buckle, 2009). In this case an insider/outsider is an individual with some inside knowledge of the practices of the organization from previous observations, data collection and analysis, yet not directly employed by the organization. The researcher took down notes following the meetings during the day to document impressions of the process and the product ultimately developed into a very detailed logic model that included the organizational theory of change as well as intended outcomes. The researcher took a similar approach during scale up and strategy meetings attended by phone. Staff onboarding and professional development participant observation were primarily opportunities to build rapport with staff and teachers, as well as to become aware of community norms and language practices.

Table 1 below details the sources that inform this study. While field trips were a key element of programming, they were not observed regularly because the timing of site visits did not always correspond with field trips. Thus, they were not a source of direct data or observation. Organizational artifacts and survey data were utilized as primary data sources to discover the structure of the partnerships and as secondary data sources for the remaining results sections, with the interviews and focus groups serving as primary data sources for developing themes, and survey data and documents used for triangulation.

Table 1: Table of Data Sources

Data type	**Source**	**Timing of Data Collection**
Organizational artifacts	Program coordinator manual, field trip manual	Upon development, 2014
	Curriculum documentation (e.g., lesson plans, handouts)	(2014–2019)

Data type	Source	Timing of Data Collection
	Techbridge Girls logic model	Upon collaborative development, 2014
	Professional development materials (e.g., slides, handouts)	(2014–2019)
Participant observation	Two-day logic model development workshop	Winter 2014
	Staff onboarding week	annually
	Strategy/scale-out coordination meetings	As held by the organization, early 2014–2015
	Professional development workshops with partner stakeholders	September 2016
Programmatic observation, including fieldnotes and analyses of practice	Dimensions of Success tool analysis (see https://www.thepearinstitute.org/dimensions-of-success)	Twice annually, 2014–2018
Surveys, interviews	School district leadership, scale-out sites	Annually, 2015–2018 (2 districts)
	Partner teachers, scale-out sites	Annually, 2015–2018
	Partner principals, scale-out sites	Annually, 2015–2018
	NPO Program staff, scale-out sites	Annually, 2015–2018
	NPO leadership, national and scale-out site	Annually, 2014–2018 (varied with staff reorganizations)
	Youth participant focus groups, scale-out sites	Approximately 8 held annually, 2015–2018

Data Analysis

In this paper, we emphasize interview data from school stakeholders and nonprofit staff. Interview transcripts were coded using domain analysis (Spradley, 1980). Researchers searched for units of meaning within the data, coding interview transcripts for examples of "cover terms" within broader "domains." Taxonomies were then constructed linking coded examples to domain categories through a semantic relationship such as "is a kind of" or "is a way of doing." Domains were generated both deductively, based on our research question and our conceptual

framework related to expressed youth outcomes and partnership value, and inductively, based on emergent themes from the data. Data were collected annually, and as the researchers reviewed data for multiple purposes (e.g., brief research memos for the program staff, conference papers regarding additional research questions) broad themes emerged regarding how the intentional collaborations with schools at the school administration and teacher levels served to expand outcomes beyond the participants in the after-school program. As the cover terms "organizational capacity", "social capital", and "expected participant outcomes" supportive of girls' SET career trajectories emerged from the data, the corpus of the data was reanalyzed with these at the forefront. The headers in the results sections mirror the final stage of codes. A list of final codes can be found in Appendix A.

The authors took note of the origins of the data to look for cross-site and cross-informant differences. Researchers examined and discussed their "tacit theories" regarding whether and how the partnership influenced participants' interest, knowledge, and opportunities for learning about engineering, searching for confirming and disconfirming evidence of these pre-conceived notions (LeCompte, 2000). Deductive and inductive coding occurred simultaneously in this study. For example, deductive domain categories from our analysis include: "Techbridge Girls builds youth technical skill" and "Techbridge Girls develops teaching capacity". Some inductive domain categories were "Techbridge Girls builds school capacity to provide STEM learning" and "Techbridge Girls leads to extension of school to support STEM in school practices".

RESULTS

The results section is divided into four sections that address the research question: *How do cross sector collaborations with Techbridge Girls support young women's engagement in science and engineering?* The first section details the structure of the partnerships between schools and Techbridge Girls. We find the details of the structure are important for understanding the partnership impacts for youth participants, partnering principals and teachers, schools, and for the organization and its staff. The remaining sections describe the Partnership *value.* The ways in which the partnership influenced stakeholders became clear from interviews with staff, youth participants, teacher collaborators, and principals partnering or benefiting from the organization that was under study. In section 2, we present data to support the supposition that girls in the program do indeed benefit from the after-school program in terms of their interest, knowledge and engagement with science and engineering, which is the goal of the partnership described in section 1. Sections 3 and 4 highlight secondary benefits of the collaborative efforts of Techbridge Girls and their school partners. Specifically, in section 3 we detail the way that the integration of the after-school program with a school community creates an opportunity for girls to be recognized as STEM-savvy young women at school. The fourth results section describes how the partnership builds capacity for schools to better serve their students regarding STEM knowledge and practices.

Results Section 1: The Structure of the Partnership

As stakeholders begin to take up the notion of STEM learning ecosystems, partners must define, communicate, and negotiate how organizations will participate in cross-sector efforts. Table 2 below describes how each party was engaged in the collaboration. These details are explicitly evident in agreements signed between Techbridge Girls and school administration and were corroborated by interview and survey data with staff, teachers, and school administration.

Table 2: Cross-Sector Partnership Roles and Responsibilities

Goal	**Task/Activity**	**Resource Needed**	**Responsible Party**
Recruit	General recruitment	Access to middle school girls in under-resourced communities	School/district administration, Teacher partner
	Engagement of girls in engineering activity at open house events, schoolwide engagement events	Supplies for engineering activities	Nonprofit staff
	Development of recruitment posters and media	Supplies for making posters and media; Time to make them	After-school program participants
	Selection of teacher partner	Meetings/communication between school/district administration and nonprofit staff	School/district administration, nonprofit staff
Retain	Record keeping, including attendance	Database/spreadsheet for record keeping	Nonprofit staff
	Communication with family members, guardians regarding attendance and performance at after-school program	Medium for communication: Email, text, flyers/papers	Nonprofit staff
	Continuous communication with participants to encourage attendance, continued engagement	Texts and phone calls between adults (staff, teachers) and students	Nonprofit staff, Teacher partner
Implement	Training of teachers on informal curriculum	Online and in-person training meetings	Nonprofit staff

Goal	Task/Activity	Resource Needed	Responsible Party
	Weekly reflection on implementation of after-school program, co-planning	Meetings and email communications	Nonprofit staff, Teacher partner
	Physical place of the program	Space to hold meetings with participants; Tables, chairs, technology such as overhead projectors, screens, teacher laptop; Curriculum and consumable materials for activities	School/district administration, nonprofit staff
	Implementation of curriculum at after-school program	Students as participants	Nonprofit staff is primary, teacher partner is secondary
Engage community	Coordination of "family night" or "community night" including logistics and planning	Email communication and meetings	Nonprofit staff
	Recruitment of audience, community members to attend	Communication with families: Texts, emails, flyers/papers sent home	Nonprofit staff

The partnership between informal and formal education organizations is vital to the functioning of Techbridge Girls in many ways. The after-school model involves district and/or school partnerships in which the NPO provides staff, materials, curriculum, and an informal education implementation philosophy and structure, described in detail in other work (Eyerman & Hug, 2020) [Schools host the programs within their buildings, and schools are chosen because of the demographics of the neighborhood (i.e., the population is under-served by STEM resources and demographics match those underrepresented in STEM fields). By recruiting participants within a school, the nonprofit creates a ready-made recruitment pool of young women who fit the organization's target demographic. Bringing high-quality curriculum and professional staff with dedicated time for planning and communicating to schools, girls, families, and teachers ensures a "value-add" for schools as well. That is, teachers who facilitate the program use their time to connect with students and collaborate with nonprofit staff, rather than having to spend their time planning and gathering materials for the after-school program. In turn, those educators can use what they learn in the program's professional development and in the curriculum provided in their formal school classrooms.

Results Section 2: Develop Youth Participants' Dispositions, Practices, and Understandings of STEM

Data from across sources indicate a benefit of the collaboration in building youth participants' dispositions, practices, and understandings of STEM. The informants describe changes in youth participants specifically, but not exclusively, in relation to STEM. Partners describe how youth in their schools are developing following their participation in the after-school program. They focus on interest and awareness regarding STEM careers and understanding and practice with the engineering design process. Table 3 below indicates each interview category, and the numbers and percentages of interviews that were coded with the theme at least once per category. Quotations used in this paper come directly from the coded documents referenced in Table 3 below.

Table 3: Student Pathways

		Youth develop interest in and awareness of SET careers		**Participants gain practice with engineering design thinking**		**Build youth participants' social capital along STEM trajectories**	
Data sources	**Total #**	# with this code	% with this code	# with this code	% with this code	# with this code	% with this code
Focus Groups	4	4	100%	4	100%	4	100%
Staff Interviews	2	1	50%	1	50%	1	50%
Principal Interviews	14	10	71%	7	50%	8	57%
Teacher Interviews	16	16	100%	14	88%	13	81%
District Interviews	2	1	50%	1	50%	0	0%

Youth Develop Interest in, and Awareness of, SET Careers

Every type of stakeholder—Techbridge Girls staff, teachers, principals, girls in the program—describe youth as more likely to have career awareness regarding STEM and describe increased interest in the fields because of their participation. Specifically, the code was found in 100% of the youth focus groups coded for this paper, 100% of the teacher interviews, 71% of the principal interviews, 50% of the staff interviews, and 50% of the district interviews. The school stakeholders who participated directly in the program, youth and teachers, all described how the partnership in youth informal learning creates interest and awareness in SET careers.

For example, a middle school girl in a focus group at the Metro Site described her changing impressions of engineering careers:

> The first thing that comes to mind when I hear engineering is lab coats, little glasses, and you always have your face down where sparks are flying and everything, building a robot or a car that could drive itself, a solar car. That's what I would normally think of when I thought of engineering at first, before I started Techbridge Girls, but now I know that engineering can be anything that involves building

> stuff. It could be building machines, building a game, it could be anything that you want to do, that all includes engineering.
>
> [Middle-school participant, Metro Site]

In her experiences at her after-school program, this participant experienced an increase in awareness of the opportunities in SET careers. A teacher also described the influence of a field trip on her students' awareness and interest in SET careers. Field trips are a common element of Techbridge Girls; participants complete a one-day field trip twice per year in the program, in which industry representatives engage girls in a hands-on activity, describe their work at the girls' level of understanding, and give the girls a sense of the workplace atmosphere. A teacher reflected on a field trip experience, and the influence it had on her elementary students:

> We went to [INDUSTRY PARTNER], and the offices were supercool. Everyone was thrilled to have a group of 20 fifth- and sixth-grade girls walking through the office, hands on everything. Everyone was super friendly, talking about different parts of their work and what they liked about it and how it was a really good place to work. They had the girls go out and do geocaching, with really cool role models. The role models were very accessible, all women doing different things in the company. All of my girls want to work there. All of them were like, 'We don't want to leave. We'll be back in 20 years' sort of thing. So that was cool. It was a really great opportunity for them.
>
> [Elementary school teacher, District Site]

Field trips to STEM workplaces and interactions with STEM role models create an opportunity for youth to envision possible selves (Markus & Nurius, 1986) in the fields of science, engineering, and technology. As a shared experience within the STEM after-school program, the group can reflect on the career with peers in an ongoing dialog of whom they might become in the future.

Participants Gain Practice with Engineering Design Thinking

Another specific code under the theme "student pathways" was the notion that girls who participate in the after-school program gain practice with design thinking practiced by expert engineers. This code was relevant in 100% of the youth focus groups, 88% of the teacher interviews, 50% of the staff interviews, 50% of the teacher interviews, and 50% of the district interviews. Similar to the previous student pathway code, those with the most direct contact with the program had the highest occurrences of the code, which seems to indicate that program activities fostered familiarity with engineering design thinking.

A nonprofit staff member who works directly with youth in the District Site described how she came to understand her participants' growing understanding of the engineering design process. The research team developed a process for collecting and analyzing videos of girls interviewing one another about their

engineering design projects. Girls describe their process for completing a specific project, including a more general description of the engineering design process. The nonprofit staff member describes how her review of that data made it clear she was meeting that goal with her participants:

> I just did (video interviews with participants) and I was just like, 'Yay!' You know, sometimes I don't know if I'm doing a great job with getting them to understand the engineering design process, but then when I see their videos afterwards, and they're like, 'First I identify the problem and then I brainstorm, then I draw it out,' (I realize) they're getting it. At the end of the day for me, it's good to see that and know that I'm actually doing something right, because I don't always know. That was something that I worked on this year, really trying to make sure they understand the engineering process.
>
> [Program coordinator, District Site].

The program coordinator noted that her focus for the academic year had been on being more intentional in ensuring the girls understood the engineering design process, and her formative assessment results showed her girls became more comfortable with the process of engineering design thinking. Similarly, in a focus group, girls collectively described the process they go through in working on a design project for Techbridge:

> Interviewer: You mentioned the engineering design process and so tell me what it is like to plan, design, and create projects. What steps do you take when you are working on a project?
> Inez: First, we brainstorm.
> Interviewer: Uh-huh.
> Iman: Then we build it.
> Gia: And we test it. Then we design and then we test it again, to see if it is good. It is really helpful because if you did something wrong, then you can test it and see if it breaks. If it still doesn't work, then you can try something else to make it better. It just keeps going.

In the exchange above, girls co-construct the engineering design process they have come to know through their work in Techbridge. Data from multiple sources show that girls gain skills and knowledge related to SET career awareness, build interest in these careers, and learn and practice the engineering design process in their work with Techbridge. These are expressed goals of the NPO, and are clear in their logic model, as well as outward-facing materials produced by the organization.

Result Section 3: Building Social Capital of Girls in SET Through Partnerships During and After School

A pattern has emerged in STEM interest data for middle school girls in the United States that is bleak: girls tend to lose interest in STEM careers at a faster rate than boys in the early teen years, yet research suggests students themselves have the power to change the culture of a school towards STEM learning (Chiu et al., 2014).

Techbridge Girls stakeholders outside of the organization (specifically teachers and principals) describe a social phenomenon in their schools in which girls build social capital, or as Bourdieu (1986) describes, "membership in a group … which provides each of its members with the backing of the collectivity and (establishes) a 'credential.'" (p. 246). The code for "social capital" was implemented across interview types. The theme was discovered in 100% of youth focus groups, 81% of teacher interviews, 57% of principal interviews, and 50% of staff interviews, while none of the district level interviews showed evidence of the "social capital for girls" theme. In the quotes below, we highlight how this code was visible in different interview types, specifically principal and teacher interviews.

The social capital derived from membership in a school-based after-school STEM program can support girls' STEM trajectories in a variety of ways. A group derived from participation in an activity that is counter to cultural norms (e.g., women in STEM) may serve to maintain interest, guard against isolation, and build member confidence. A middle school principal describes how she has seen a collective take hold in her school via the Techbridge Girls after-school program. She describes the ways in which the social network has implications for her students, primarily in positive ways:

> Anyone that leads a middle school knows the shift developmentally that we watch girls go through physically, socially, emotionally, and this is a program where I have watched the girl that has no friends matched with one of the popular eighth grade girls and that eighth-grade girl speaks to her in the hallway and completely gives her street cred. Because that eighth grader knows her and says 'Hi' to her and then the other kids are like, 'How do you know her?' I have witnessed this, and they have been like 'Oh, we are in Techbridge together.' It is this club, because middle school is already cliquey, and so I am fine for Techbridge to be a clique for my little girls to 'clique up' because of their likes around math and science.
>
> [Middle school principal, Metro Site]

Similarly, a science teacher who self-identifies as a woman of color described evidence of the organization's influence on youth networks, and how the social network built into the after-school program was influencing interactions in her science classes. In this way, benefits of the after-school program translate across contexts into the school day:

> I also notice they don't care who they work with, before girls liked to stay with their group, their friends who are in the program, and now (when we pair them with other girls) it's like, 'Okay, whatever.' Then they began kind of backing each other, validating each other, which they weren't really doing before, in Techbridge or in class, but now in class they're just like, 'Well, we did that in Techbridge.' I like that part. I like that girl power. You need that. Oftentimes there are students who like to make those comments, about other students, like, 'Why is

> she reading (out loud in class)?' and then another girl from Techbridge would say, 'Leave her,' kind of shutting that (bullying behavior) down, and that wasn't something that they were doing before. I think it's one, maybe working in Techbridge, but also two, having that camaraderie with each other, which we need. You need people just supporting you, backing you.
> [Middle school teacher, Metro Site]

The teacher indicated that women, especially the young women of color who account for most of her program participants, need a support network to succeed in the STEM fields, which are dominated by white males. This informal education program was building social networks that would be advantageous for girls pursuing STEM academically; these networks were embedded in their academic learning environment and did not exist only in informal settings.

Building on this evidence of organizational influence at the school level, the author sought confirming and disconfirming evidence from other data sources to triangulate the finding (Patton, 1999). While NPO staff did not explore how girls may be developing an advantageous social network, they did describe some intentional practices, evident from program participation, that may enrich the social capital, such as intentional social and communicative skill development within the program. A program coordinator describes the ways in which the intentional design of the youth development program influences the burgeoning social network:

> Every week they have to work within a team for the most part; even in small groups there's some semblance of teamwork there. You kind of see in the icebreakers and activities how leadership arises and how certain girls were more prone to take the lead than others, but then you're always made aware because the girl who is not the leader comes up to you and tells you her ideas aren't being valued, in other words. You kind of help them figure out how to work as a team and how to be a leader but also acknowledge other ideas and stuff like that. There's a lot of that facilitation going on as well. That age group just needs a lot of help with their social interactions .... It's constant in [PROG NAME], these roles of teamwork and leadership and how those apply to the projects they're working on.
>
> [Nonprofit staff, District Site]

The social engineering involved in informal education program facilitation is evident in the quote above and is a hallmark of quality informal education practice focused on youth development (Mahoney et al., 2005).

Results Section 4: Building Organizational Capacity to Influence Girls' STEM Trajectories

Highlighting illustrative data from partners, below, shows how the collaboration was identified by partners as influential in building capacity at the classroom, teacher, and school levels. A teacher at the elementary school level described how the

experiences her students have at Techbridge Girls prepare them for activities they encounter during the school day:

> We have a little graphic diagram that shows [the engineering design process]. We were very explicit initially when we'd go through the steps of calling it out. Like this thing that you just did is this part of the design process so the girls could start to make it more of a conscious effort. I think it also helped with persevering. 'This is what real engineers do. You mess up and then you redesign based on what you learned from your mistake.' Again, I bring it up in class. When we were doing our science unit on magnets and motors, I was connecting a lot with what we'd been talking about in Techbridge Girls, just to kind of help them scaffold that even more. I would ask the girls who participate in the program to describe engineering design to the class. They've gotten really good at being able to name the different steps in the process.
>
> [Elementary teacher, District Site]

In the passage above, a teacher describes the way in which her students' participation in the after-school program she co-facilitates enriches the corpus of experiences her class can reference in their academic work. The teacher was speaking about this as it specifically relates to the engineering design process, which youth practice extensively in Techbridge Girls. The teacher incorporates these shared experiences into her teaching and highlights her students' knowledge in this area during the school day. In this way, the teacher draws attention to the girls in her classroom having expertise relevant to academic STEM activity while teaching in a mixed-gender academic setting. This is an example of one way the cross-sector partnership has built the capacity of her class to engage in engineering inquiry.

Enhancing teachers' skills in inquiry-based pedagogy

Informal education organizations can assist formal educators with developing inquiry-based teaching practices that are prevalent in the informal STEM learning settings in which NPOs have expertise. This pedagogical practice can be leveraged in public schools to transform students' impressions of STEM from considering the fields as a static body of knowledge to a new understanding of STEM as principles and ways of thinking. In interviews, this theme came up only with nonprofit staff and with teachers themselves. It is possible that district level staff, youth, and principals were not aware of which elements of professional development supported teacher learning.

Two teachers spoke in interviews specifically about how the professional development they received to co-facilitate the after-school program influenced their teaching during the school day. One teacher emphasized a workshop provided by the nonprofit organization on questioning techniques that she uses regularly in her facilitation with youth:

> We have trainings before we started, like a big, all-day training explaining the new expectations, how we can help the girls in very specific ways: instead of giving the answer, setting her up to find the answer. The training was very helpful. Then, when implementing the program with the girls, I found asking questions was the strategy most helpful for me with the girls. Like, 'How did we get this?' or 'Why do you think it's not working?' I ask for them to go back and think. I think that's the most helpful for me. I think [that through] the questioning about what they're doing or what they're thinking or explaining they got there. That was the most successful.
>
> [Elementary school teacher, District Site]

The partnership across formal and informal education organizations influences teaching beyond the after-school setting—the teachers who engage in new pedagogical practices enhance learning opportunities for students beyond those engaged in the informal program and may influence the quality of SET education more broadly in partner schools.

A second teacher described how the professional development provided by the nonprofit organization has influenced her teaching practice during the school day:

> The training prepared me because it gets me to think about things in [sic] which I don't normally think about, depending on the topic, and it supports me because it enhances what I'm already teaching, because I am a physical science teacher. I can filter those items in with the lessons that I'm already teaching. Specifically, I think it was where we did building bridges, where I incorporated some content into the school day curriculum—talking about the forces, and things of that nature.
>
> [Middle school teacher, Metro Site]

As teachers improve their practices within the less-formal and highly engaging after-school endeavors, their facilitation practices are shifting within their time with their formal education students. In this way, a school's partnership with Techbridge Girls enhances a school's capacity to educate students along STEM career pathways.

Extending schools' abilities to support student growth in STEM

In some interview responses, the collaboration with Techbridge Girls was put into context with school- and district-wide initiatives, providing understanding of how the collaboration fitted within other efforts to improve SET learning in K12. This code was most common among district staff (100%) and principal interviews (93%). One of the two staff interviews (50%), a few teachers (31%), and some youth (25%) interviews indicated connections to the school context and how the collaboration extended school reach. Principals described how their partnership with Techbridge Girls elevated their efforts to support youth learning in STEM. One

principal described how the invitation to partner with the organization came at a time when the school was ramping up science learning during the school day:

> Last year we were looking at how to be able to increase the amount of science instruction in the building and making sure that it's a meaningful experience for the students. Through a scheduled adjustment, we were able to double the time of students receiving science instruction in sixth and seventh grade and also have a ninety-minute science block in fifth grade for students every single day. Again, with that in mind of looking for something additional to be able to expose students to the STEM field, we were approached via email by Techbridge Girls. Hearing her little bit about the program we were excited that someone on our staff was able to work along with her, which we thought was really important.
>
> [Middle school principal, Metro Site]

Another principal noted the ways in which the program enriched students' experiences:

> Right now, this is our only math- or science-related after-school program, so it's really important for girls. Within the school day they have math and science every day. We also have math intervention, and before school we do math tutoring, but this is the only one that's for, I think, more creatively getting girls excited about STEM and engaging in projects. It's unique and that's why I was so excited to have it here and I want to expand it. ... It provides an opportunity for a lot of kids who wouldn't have access to that kind of program. So many of our kids who would be interested in careers in science I think wouldn't even know unless they have an opportunity like this, so it's providing them that access that's so important.
>
> [Elementary school principal, District Site]

Techbridge Girls builds the capacity of their partners, in this case, elementary and middle schools, to support girls along scientific and technical learning trajectories. Having students who have expertise in the engineering design process can elevate classroom learning, as students learn from their peers about STEM. Stakeholders themselves indicate that professional development was transformative to practice, as techniques learned and modeled via Techbridge's explicit instruction and participation integrated with school-day classroom practices. Schools considered the partnership with Techbridge Girls as an extension of their own efforts to educate youth, and highlighted how the partnership was particularly meaningful because of social inequity. Family resources are not sufficient in the communities in which the NPO operates to provide enrichment activities such as Techbridge Girls at cost to girls or to schools. The partnership with Techbridge Girls differentiates itself from other SET informal NPOs by providing professional development and

opportunities for learning that shift beyond the informal education setting, with implications for school-day teaching and learning.

Data from interviews indicate Techbridge Girls is involved in building partnering schools' capacity to support girls along scientific and technical career trajectories. Table 4 below shows the ways the data support the idea that organizational capacity is developed at the school level when partnerships between informal and formal education entities are successful. The trend in this data show "higher level" support for the concepts of organizational capacity building, with district level staff and principals showing more instances of the codes than youth and teachers, for example. Specifically, 100% of principals, 100% of nonprofit staff, 100% of district level staff, 75% of teachers, and only 25% of youth interviews indicated this theme.

Table 4: Organizational Capacity Building

		Build organizational capacity to influence girls' STEM trajectories		**Enhancing teachers' skills in inquiry-based pedagogy**		**Extending schools' abilities to support student growth in STEM**	
Data Sources, 2017	**Total #**	# with this code	% with this code	# with this code	% with this code	# with this code	% with this code
Focus Groups	4	1	25%	0	0%	1	25%
Staff Interviews	2	2	100%	1	50%	1	50%
Principal Interviews	14	14	100%	0	0%	13	93%
Teacher Interviews	16	12	75%	8	50%	5	31%
District Interviews	2	2	100%	0	0%	2	100%

In summary, individual outcomes related to participants and teachers were delineated in the organization's formulation of its theory of change, while collective and systemic outcomes were not addressed. This pattern was also evident in interviews with organization staff: there was little to no discussion of school level or other collective outcomes when speaking with program coordinators or executive directors, while teachers and principals were very likely to bring up these benefits. The ways in which Techbridge documentation focused attention on individualistic outcomes may be, to some extent, an artifact of evaluation practice focused on efficient measurement. Yet the ways in which partners experience their interactions with the NPO are valuable for reimagining purposes and the value of cross-sector collaboration.

DISCUSSION

> A STEM learning ecosystem encompasses schools, community settings such as after-school and summer programs, science centers and museums, and informal experiences at home and in a variety of environments that together constitute a rich array of learning opportunities for young people. … Designed pathways enable young people to become engaged, knowledgeable, and

> skilled in the STEM disciplines as they progress through childhood into adolescence and early adulthood.
>
> (Traphagen & Trail, 2014, p.2).

This qualitative effort sought to highlight how a collaboration between formal K12 schools and an informal learning nonprofit organization were supportive of young women's engagement in STEM. Evidence indicates the design of the partnership allowed for each party to share practices, material, and human resources that minimized duplication of efforts and harnessed unique contributions of stakeholders, precisely as is hypothesized in the STEM learning ecosystem model described above. The study and related past work (Fitzhugh, et al. 2017) indicates that the collaborative implementation of an after-school program for young women in STEM can be effective in broadening youth engagement in STEM, with engineering design thinking in particular, and familiarizing youth with STEM career trajectories.

We have now addressed the research question "*How do cross sector collaborations with Techbridge Girls support young women's engagement in science and engineering?"* and found that youth interests and engagement with science and engineering was one direct benefit of the collaboration between schools and the informal education organization. **The study also shows that, by integrating an after-school program into the school community, Techbridge Girls created opportunities for informal and formal settings to reinforce one another in ways that are less common in traditional, stand-alone informal STEM learning**. The integration in the case of Techbridge Girls created some opportunities for youth to be recognized by teachers and peers as competent in science and engineering, for youth to be positioned as "experts" in follow-on activities teachers bring to the formal K12 curriculum, and for integrating developed social networks of girls in STEM that permeated school and after-school settings. Receiving recognition, opportunities to perform in STEM, being positioned as competent in the fields, and developing social support networks are all viewed as vital to young women developing STEM identities (Carlone & Smithenry, 2014; Carlone & Johnson, 2007; Holland et al 1998; Hurtado et al, 2011; National Research Council, 2009).

We hypothesize that other informal education organizations can develop the capacity of schools to engage in high-quality, inquiry-driven curriculum, as is evidenced in this paper. We note that in the case of our study, the collaboration with schools, and particularly with teachers, was accompanied by the informal learning organization providing lesson plans, professional development training, coaching, and co-teaching opportunities with informal organization staff who have dedicated time in their job descriptions to support teacher learning and development. This organizational resource allocation by the informal education organization is difficult to scale. We found that the co-teaching element of the collaboration across learning settings can provide opportunities for professional reflection and feedback, both of which are necessary to support active inquiry-based science in K12 formal classrooms (Zeichner & Liston, 2013).

We acknowledge limitations in our study. For example, the qualitative emphasis makes generalizability of findings a subjective process, and the emphasis on the direct stakeholders may obfuscate how the collaboration influences those beyond direct participants (e.g., Techbridge Girls staff with indirect connections to schools, students who do not participate after school). However, we believe the findings illustrated in this paper have merit despite these limitations.

The concept of STEM learning ecosystems is pervasive and has potential for improving the representation of young women and other marginalized groups in STEM. In this study we aimed to understand how a cross-sector collaboration influenced young women's engagement in STEM. We found primary benefits that related to girls' increased interest and understanding of STEM, as well as secondary benefits that related to the integration of informal and formal K12 content, curriculum, peer groups, and educators. These initial findings suggest a need to look beyond youth outcomes when measuring impact and consider the benefits of collaboration for schools and school communities. Understanding the mechanisms by which collaborations can improve and sustain young women's engagement in STEM is vital to the design of robust STEM learning ecosystems—and this study suggests rich collaboration among K12 schools and informal learning organizations may be one method of strengthening STEM learning ecosystems.

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APPENDIX A: LIST OF CODES

Level 1 Develop youth participants' cultural capital to succeed in SET trajectories
    Subcode 1 Participants gain practice with engineering design thinking
Subcode 2 Youth develop interest in and awareness of SET careers
Level 1 Build youth participants' social capital along STEM trajectories
Level 1 Build organizational capacity to influence girls' STEM trajectories
    Subcode 1 Enhancing teachers' skills in inquiry-based pedagogy
Subcode 2 Extending schools' abilities to support student growth in STEM
Subcode 3 Hiring program staff who are a good fit for Techbridge
Subcode 4 Partnering with teachers who are a good fit for Techbridge