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STEM Guides: professional brokers in rural STEM ecosystems

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ABSTRACT

We describe the research and development of an NSF-funded, five-year experimental program to strengthen informal (out-of-school) STEM learning by youth in five rural communities. The central component of the model was a cadre of community members known as 'STEM Guides' who were hired to work as brokers between youth and the STEM learning resources potentially available to them. These STEM Guides were respected adults with credible connections to youth, flexible schedules, the ability to travel within the community, and enthusiasm for identifying local STEM resources. The Guides were trained and supported by the project staff of an educational research and development non-profit, whose researchers studied the Guides' experiences over several years as they reflected on the ways they could support youth to pursue STEM outside of school. This project was unusual in developing embedded rural residents to take a professional brokering role with youth aged 10–18 throughout a region of several neighbouring towns, instead of relying on parents or teachers to provide such connections opportunistically and only for their own youth. Taking an ecosystems perspective, this article highlights some of the opportunities and challenges these STEM brokers faced as they tried to catalyze connections for youth in their communities.

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learning ecosystems; brokering; rural education; community engagement

Overview

In this article we describe the nature and development of an innovative educational program and our efforts to understand the program's impacts. We begin by framing the work within an ecosystem perspective on learning, and motivating the need for community-level brokers whose explicit role is to connect youth with locally available STEM resources. We then describe the implementation of this approach in five rural regions of Maine, before moving on to address several research questions about the model and its impacts.

Introduction: learning ecosystems

Increasingly, learning theorists in out-of-school settings are using an ecological metaphor to describe the broad variety of learning opportunities available to young STEM learners (Crowley, Barron, Knutson, & Martin, 2015; National Research Council, 2015; Penuel, Clark, & Bevan, 2016; Traphagen & Trail, 2014). It is the foundational metaphor for the recent National Research Council report on productive STEM programs in out-of-school settings (National Research Council, 2015, p. 6), as

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well as the central construct on which the STEM Funders' Network has built a set of 84 STEM Learning Ecosystems across the world (STEM Learning Ecosystems, n.d.). Cross-sector 'STEM Hubs' of various sizes are appearing in cities and states across the U.S., and STEM ecosystems are a recurrent theme in the latest federal plan for STEM Education (National Science and Technology Council, 2018).

While including schools is one component, these ecological models take a much broader approach to identifying learning settings, including informal and home-based opportunities for youth to engage with a range of STEM knowledge, practices, and dispositions. Ecosystems may include K-16 education partners, business and industry, afterschool and out-of-school partners, and a variety of other stakeholders interested in supporting STEM learning and career pipelines.

Most of these researchers situate the STEM Guides concept broadly within the Bronfenbrenner model of child development (Bronfenbrenner, 1977,1986). This model has the child at the centre, with circles of influence from direct interactions such as family members and school to broader contexts such as community values and history. Such ecological models of learning have two key features that make them strong for the current study: First, they adopt an inherently asset-based model of learning, rather than one based on deficits. This draws from theoretical frameworks such as Funds of Knowledge (González, Moll, & Amanti, 2006) and related work (Civil, 2006; Lloyd, 2010), which honours the expertise that community members bring to informal STEM education. Second, by putting the individual youth at the centre, ecological models readily represent personal learning choices, making them particularly appropriate for studies that emphasize informal learning. This idea of building cumulative learning paths through a space of ideas and resources draws from the 'islands of expertise' concept of Crowley and Jacobs (2002) as well as 'lines of practice' (Azevedo, 2011) and the 'learning progressions' of the world of schools (Corcoran, Mosher, & Rogat, 2009).

Brokering

Among the key challenges of any learning ecosystem are ensuring that youth and families are aware of the larger system that surrounds them and supporting them to interact personally with available STEM-related learning opportunities of interest. Such activities fall under the construct of 'brokering' (e.g. Penuel, Lee, & Bevan, 2014; Van Horne, Allen, DiGiacomo, Chang-Order, & Van Steenis, 2016). In our work we adopt Ching, Santo, Hoadley, and Peppler's (2016) definition of 'practices that connect youth to events, programs, internships, individuals and institutions related to their interests to support them beyond the window of a specific program or event' (p. 296). We also adopt their list of what may be brokered: a wide variety of opportunities and resources that include experiences (programs, one-day events, classes, internships and fellowships); social connections (mentors, institutional gatekeepers and collaborative peers); institutions (colleges, companies and organizations); and information sources (websites, books and how-to guides) (Ching et al., 2016, p. 301). Projects such as Hive, with locations in New York, Pittsburgh, and Chicago (Hive, 2018a, 2018b, 2018c, 2018d), bring together learning organizations such as museums, libraries, and afterschool programs, and some have used human 'brokers' to help break out of institutional isolation and create a more integrated system for learners to navigate.

Education researchers are increasingly recognizing the importance of this brokering role per se, and recognizing its value to youth as they build interest-driven pathways (Penuel et al., 2016), identify potential careers, and build social capital (Ching et al., 2016). For example, Archer, Dawson, DeWitt, Seakins, and Wong (2015) define 'science capital' as scientific forms of cultural capital, practices, and social capital such as knowing people with science-related jobs or talking to others about science. They show that such science capital was correlated with students' desires to go into science-related careers later in their lives. Clearly, then, an important and under-studied mechanism for broadening participation in STEM is the equitable building of youth awareness of, and connections to, existing locally available STEM opportunities.

Professional STEM brokers

Ching et al. (2016) point out that a variety of people can step into the role of STEM brokers for youth: parents, teachers, and other community members. Our work takes the next step in recognizing brokering as an intentional practice by defining a new genre of professionals whose *primary* responsibility is brokering.

Over the last five years, our team of researchers and practitioners has worked to create and study cohorts of such STEM professionals – dedicated ecosystem brokers – who focus specifically on the brokering activities that can help to make ecosystem opportunities more accessible and equitable. To avoid the class-related financial metaphors inherent in the term 'brokering,' we call these professionals 'STEM Guides.' We have deliberately hired Guides from within each target community, thereby increasing the chances that they would already be well-known and trusted adults, familiar with community youth and their range of needs and interests.

Our specific project goal was to establish active Guides in five rural regions of Maine. Most ecosystem research has been situated either in metropolitan areas like New York and Chicago (Hive, 2018a, 2018b, 2018c, 2018d) or in regions surrounding large urban centres such as the greater Los Angeles, and Washington DC areas (STEM Ecosystems, n.d.). By contrast, our goal was to explore how brokering might work in a group of small-scale rural regions where populations tend to be more stable and relationships among residents, families, and local organizations tend to be longer-lasting.

Diagrammatic summary of theoretical framework

Figure 1 shows our conception of the role of the STEM Guides within a Bronfenbrenner-style learning ecosystem. At the centre we place the ultimate target audience (youth aged 10-18). In the same circle we place their parents/guardians, because we saw them as joint decision-makers in the youth's informal STEM activities. Around this inner circle are concentric circles of increasingly indirect and large-scale influence. For this research we consider only the inner rings because that is where the brokering work is focused: the youth and families, the microsystem (of people and places that have direct contact with the youth, such as school or the library), and the mesosystem of informal STEM resources and opportunities that do not, as yet, have any direct connections with youth. We assume the larger rings of exosystem and macrosystem (including industry, social services, cultural attitudes and ideologies) are relatively constant as the largest-scale context of youths' lives.

Overlaid on this model, we represent with dotted arrows the primary work of our professional human brokers (STEM Guides), viz. moving STEM resources, people, and organizations from being part of the local community context (STEM mesosystem) to being in direct contact with the youth and their parents (STEM microsystem), where they can experience them and engage further with those of most interest. This role of connection catalyst might involve the Guide talking with a youth about her interests and making relevant suggestions; putting out physical posters or social media announcements of upcoming STEM events in the region; encountering a youth by chance somewhere in the community and offering to introduce her to a local STEM professional for a shadowing experience; or any other form of letting youth know about available STEM assets that seem relevant to their interests.

The Guides had a second brokering role, which was building relationships and making connections among members of the mesosystem. Research has shown (Akiva, Kehoe, & Schunn, 2017) that informal STEM organizations in a regional ecosystem tend to advocate and connect youth exclusively with their own program and resources, thereby reinforcing silos. To counter this, the Guides were encouraged to meet with individuals and organizations in the STEM mesosystem and to find opportunities to connect them to each other through sharing of information and joint activities. This might involve, for example, the Guide talking to a local 4-H club leader about an upcoming opportunity for professional development at a different organization; meeting with a retired scientist about participating in a science café; showing local librarians a national database of hands-on experiences

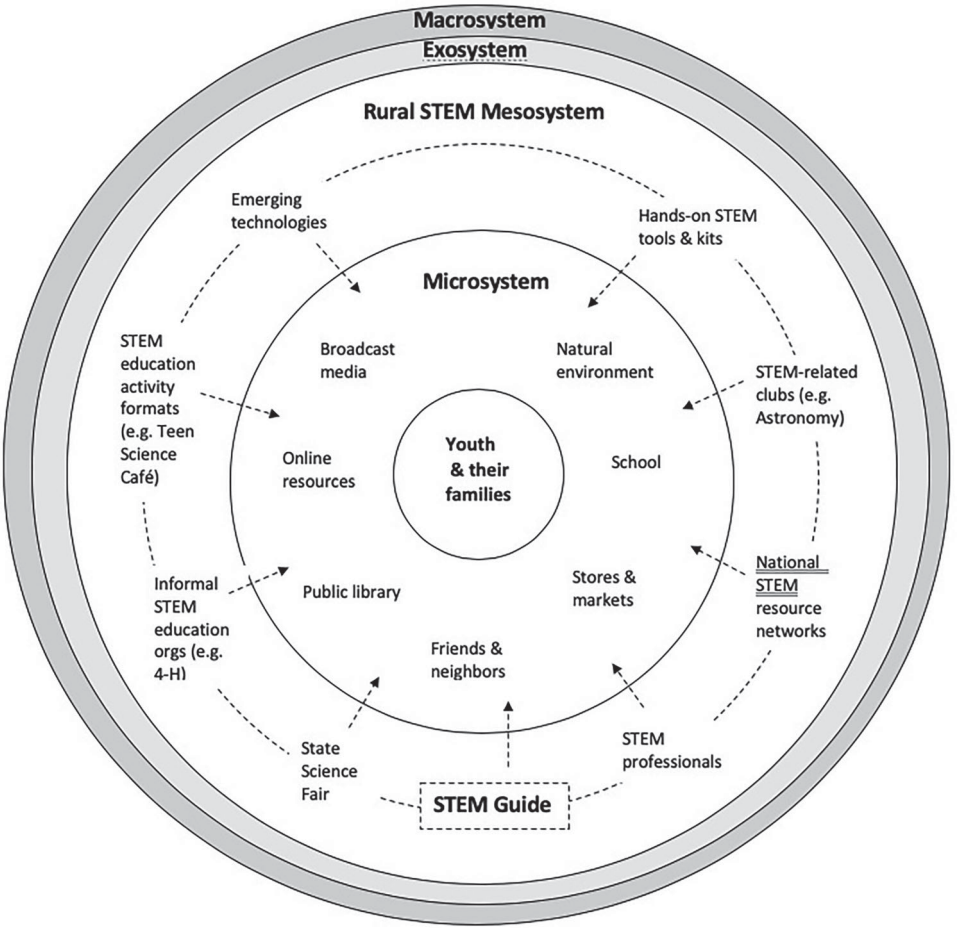


Figure 1. Adaptation of Bronfenbrenner's ecosystem model to show a rural STEM learning ecosystem with STEM Guides as brokers (dashed lines). Their actions serve to strengthen connections (i) among STEM entities within the surrounding mesosystem, and (ii) between such STEM entities and the families of the rural youth.

for a library program; or any other form of making members of the mesosystem aware of potential synergies with each other that might be useful. This work, making mesosystem connections, is represented in Figure 1 by the dotted circle linking elements in the STEM mesosystem.

Not shown in the diagram are several prerequisites that underlie both types of brokering activities. One is the existence of a basic level of trusting relationship between the broker (STEM Guide) and the youth they serve. Another is a knowledge of an array of current STEM opportunities and resources in the community that are both appropriate (in terms of age and interest) and accessible (logistically and financially) to youth. These are further elaborated in the Results section of the paper, to follow.

Program setup

Selection of STEM Hubs in a rural state

Rural areas are particularly appropriate settings to develop and study the above model of STEM learning ecosystems with their professional brokers. Many are characterized by multi-generational communities where long-standing human relationships shape discourse, action, and life expectations (Monk, 2007). Despite the lack of large-scale informal STEM institutions such as science

centres, rural places do have a broad range of STEM assets that can be leveraged to create learning opportunities (Mokros, 2012). Often these assets are interwoven, with people and places filling multiple roles. Facilities such as schools and libraries also serve as STEM centres where those facilitating out-of-school STEM experiences may also be teachers, engineers, or librarians. Rural areas are rich in natural phenomena within easy reach of home, and may support a range of STEM-related lifestyles and professions: hiking, logging, farming, fishing, etc. Rural areas may also include retired or remotely working STEM professionals wishing to escape the stress of urban life. Lastly, rural states host many well-established youth-development organizations such as 4-H, Boys and Girls Clubs of America, and Girl Scouts of the U.S.A., all of which have increasingly embraced STEM as a core programming area over the last decade (e.g. Imagine Science, 2018; Modi, Schoenberg, & Salmond, 2012).

For the STEM Guides project, we chose five Hubs with populations of approximately 15,000 (typically consisting of about 5–10 small towns or 1–2 school districts) in different geographical regions of Maine, the most rural state in the U.S. (U.S. Census Bureau, 2012). Our criteria for choosing these small regions included: their populations were mostly middle- to low-income; the communities had some easily-identifiable STEM assets (such as an active 4-H club, STEM-related program, or active environmental organization); there were at least some community leaders interested in growing STEM interest among the youth; and early conversations suggested it would be feasible to hire one or more Guides from within. We also gave priority to our principal state-based partner, University of Maine Office of Extension, and tried to work in areas with a strong 4-H presence. All of the Hubs were located in low-income rural areas of Maine. Their final locations are shown in Figure 2.

Recruitment and support of STEM Guides

While we had originally hoped to engage many part-time volunteer Guides in each Hub, in practice we found that community members were only willing to volunteer 10–20 h of time over the course of an entire year. As a result, we moved to a salaried model, paying STEM Guides a rate comparable with other community workers, afterschool providers, or school coaches. Guides were hired as employees of the primary grant-funded organization (Maine Mathematics and Science Alliance, an education research and development non-profit) or one of the partner organizations in the mesosystem (e.g. 4-H or a business partner). A key consideration was liability: a person working closely with individual children needed to have an umbrella organization, background checks, and appropriate training. One implication of this was that we could not, as a result, hire youth as STEM Guides.

Once hired, new Guides received one-on-one mentorship from both the project manager at MMSA and the lead STEM Guide in their Hub. Quarterly in-person meetings were convened for the first two years of the project, so that Guides could get together in person and share strategies and experiences. Later, due to difficulties with travel, videoconference meetings were convened with the same aim. These trainings focused on topics such as: how to identify and keep track of the evolving STEM assets in the Hub, how to build community relationships by offering services at a variety of local events, how to encourage parents and other residents to share their own forms of STEM expertise, and how to lead youth through experiences with high-quality resources such as national 4-H kits or activities from HowtoSmile.org. They also had access to a shared Dropbox account which contained templates of flyers, photos, and program documents to assist them in establishing their role as the community 'go-to' person for informal STEM. Guides were encouraged to reach out to a variety of youth and local community-based organizations, with emphasis on equity in terms of gender and socio-economic status.

The Guides were employed part-time, to make the model more potentially scalable. Many of them had a background in teaching or youth development and were also employed part-time with other organizations when they accepted the position. While this seemed a good model at first, Guides were

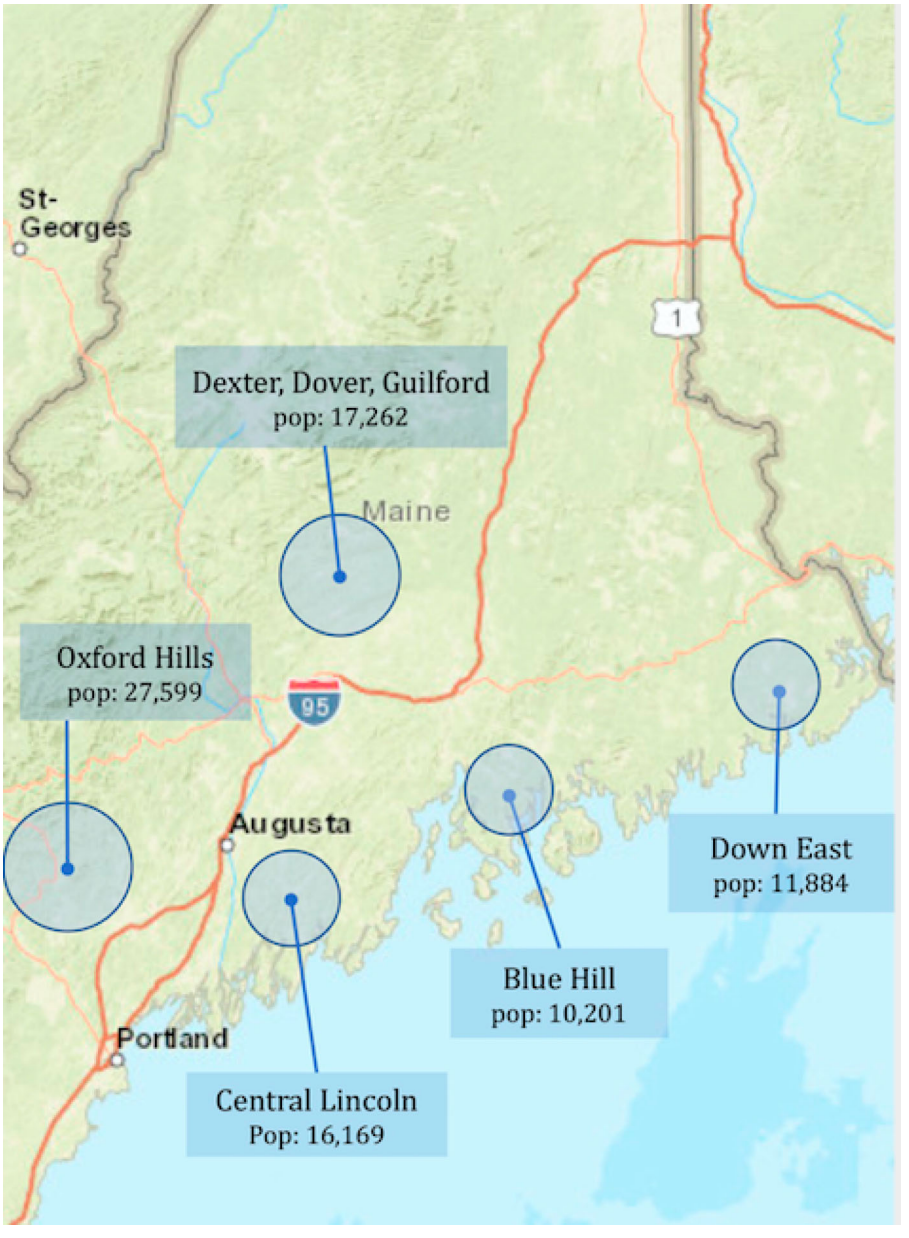


Figure 2. Map of Maine showing the approximate size and location of STEM Hubs.

challenging to recruit and retain. The work called for flexible, opportunistic relationship-building at all hours (e.g. discussing an upcoming science fair project with a parent while in a grocery store), and did not provide the consistency of full-timework with fixed hours. While the Guides expressed sustained enthusiasm for working with youth, many moved or took on other positions over the course of the project.

Each Hub had a lifetime of approximately three years of support for its Guides, falling in a sequence over the five years of the project. Over the project's five years, we recruited a total of 22 Guides across the five Hubs.

Research questions

Having outlined the creation of the STEM Guides program and its implementation in five rural Hubs, we move on to focus on the three main research questions that were systematically studied:

1 How did STEM Guides act as professional brokers in these rural communities?
2 What factors did STEM Guides find most challenging in their brokering work?
3 What were they able to achieve through their community brokering?

Research methods

The most direct and systematic feedback for this study came from the Guides themselves, as they reflected on their brokering work and shared their challenges and successes. Research associates conducted individual semi-structured interviews with every Guide in every Hub at intervals of four to six weeks, over the entire period of approximately three years that characterized the lifetime of each Hub. The questions were intentionally broad, allowing Guides substantial opportunity to talk about their work in relation to the various components of brokering. The main categories of questions were:

- Activities over the last month (e.g. 'What are some of the main questions or challenges you find yourself grappling with or thinking about at this point?')
- Specific aspects of brokering (e.g. 'How has it been going in terms of connecting youth/families to other STEM resources, either online or unplugged?')
- Self-growth (e.g. 'What are you getting more skilled at, as you go along?')
- Motivational factors (e.g. 'What's been giving you positive motivation to work on the project?')
- Desires and recommendations (e.g. 'What do you wish you could do more of, and why?')

We coded the interviews, using NVivo software, by hub, interviewee, and question. Next, as coding continued and common themes emerged, researchers created codes based on topics that came up most frequently. For example, many responses to 'main questions and challenges' were related to the theme of transportation, either their own challenges in reaching youth, or youth having difficulties reaching the Guides.

In addition to the STEM Guide interviews, we asked the Guides to record their work in 'activity logs' that captured the people, organizations, and specific activities in Guides engaged with daily. While it proved extremely challenging to find a format detailed enough to allow systematic analysis, yet efficient enough for Guides to comply without resentment, we did glean enough examples to reveal a 'typical day' in the life of a Guide.

Finally, we attempted to quantify the outcomes of the Guides' activities by recording youth participation in a variety of STEM opportunities within each Hub. Specifically, we recorded participation in every activity that afforded the opportunity for youth to sign in as individuals. These were then categorized by type of opportunity and aggregated to give a lower bound on the number of successful brokering events catalyzed by the Guides.

Results

Using these data, we answered our research questions as follows:

How did STEM Guides act as professional brokers in these rural communities?

We describe the activities of the Guides in terms of their key roles in the ecosystem: building trust with youth and families, looking for STEM learning opportunities among members of the surrounding mesosystem, and actively connecting youth with such opportunities.

Building trust, credibility, and coming to understand youth's needs and interests

Guides began by talking with youth they already knew and built on these connections opportunistically whenever possible. Many of the Guides were already serving educator roles in their communities: as ex-teachers, teaching assistants, and afterschool providers. Several had school-aged children and knew their friends. One was the director of the high school musical, and over the years had come to know many youth and families in her Hub through that role. She also had knowledge of their interests and social-emotional characteristics, mostly as a result of getting to know them in this 'third place' outside of both home and school (Oldenburg & Brissett, 1982). The Guides characterized youth in multiple interconnected ways, both as individuals and in their family and social groups:

> One boy definitely struggled in other groups, and I know he struggles in school. He couldn't help but fool around, spray water, cause trouble etc. But when he did a hands-on activity like solar cars, he really shined. He concentrated the whole time without any issues – it was unreal. There were a few kids like that.

> At the library we get the home-schoolers – it's where they go for socializing that's not basketball. A few kids with special needs that aren't as identified as such, like they would be in public school, are really having positive experiences with the SPIN club model … It's a good thing for kids that don't have a whole social network, a safe place to try new things. One kid who comes all the time is quiet engaged with the kid next to him and is now learning scratch coding.

> We've had a girl who has been attending the TSC (Teen Science Cafe) regularly. [She's] kind of immature but very interested, and really engaged with our speakers. She's the neighbour of a YLT (Youth Leadership Team) member, and definitely wants to be involved. Transportation will be an issue for her. Her family doesn't take her anywhere, but she's open and forward about getting rides. I see a lot of potential, but I am not quite sure how we can help her. I want to be able to engage her, but her current ride is graduating, and I can't rely on her neighbour to get here next year. I don't want her to disappear.

Learning about and building connections within the mesosystem

In all the Hubs, Guides were encouraged to gather STEM-interested local leaders in a 'Partners' Council' that met periodically to share information about resources and opportunities. However, over the long-term, Guides found that such meetings were difficult to sustain, partly due to the logistical challenges of bringing multiple partners together simultaneously. Instead, Guides often engaged in one-on-one meetings with STEM-interested people or organizations, either in person or by phone. They also sought networking opportunities where mesosystem members were likely to be present, such as fairs, festivals or community gatherings.

> I went to the Healthy Maine Partnership meeting and talked to everyone there: 15–18 non-profits. I talked about STEM Guides and gave them a program about it. <My partner STEM Guide> went to a meeting with five local libraries. We also hosted a non-profit fair at the high school, where 28 non-profits came in and networked with kids and teachers about community service and other opportunities we could be doing as a community overall.

> The Salmon Federation has been doing a fin-clipping activity where they need lots of volunteers, so I sent it out to all my teacher colleagues, and they are signing up kids to go and assist with that after school. That was a direct partnership with a new STEM Guide.

> Maine Robotics is coming to train educators and families to start a club. It's supposed to cost $30 per person, but they offered to do it for free! We have to think about demographics: We have people from Calais and Princeton, and educators from all over. It will be a nice batch of people coming. I think it will help lead to more STEM and robotics clubs and more materials.

Guides learned about new resources from familiar people and organizations (a snowball approach) and were supported by the project leads to dig more deeply into readily available resources such as 4-H activities and Teen Science Cafés which could be adapted to follow youth interests. As STEM Guides uncovered more STEM resources in their community's mesosystem, they needed ways to keep track of their evolving relationships with partners and promising contacts. We created a

database with templates, but they found it more efficient to build their own personal data management systems by extending functional technologies already in their lives. For example:

> I have a spreadsheet. To be honest, I don't update it as much as I should. I do have names in a composition book, and I also have a cork board with business cards.
>
> I print out all my emails so they're sequential, so I have dates and contacts. I have a rolodex, and a list in my computer …
>
> I have them bookmarked in a Google folder called 'STEMY organizations.' I've bookmarked all their websites. Once I have a meeting with them, then they go into my phone, but until then they're a bookmark.
>
> I use Google tools for everything academic. I have a system of tools that's very efficient for me. If someone needs a name or number, I can quickly get it. During our weekly meetings, I pass it on to <partner STEM Guide>.

Making the connections to youth and families

Most of the Guides' time was spent in the quintessential brokering activity: making connections between community youth and emerging STEM mesosystem resources, such as events, opportunities, people, and organizations. Figure 3 shows an excerpt of a Guide's activity log showing this aspect of their work.

We characterized such connections as falling into three main types, based on the degree of human mediation provided by the Guides to the youth as they connected them to the STEM resource:

Shallow brokering: 'Pointing' to a STEM resource

In many cases, a Guide simply informed youth or their caregiver about the existence of an available resource that might be of interest. Guides did this through various media, including direct conversation, written materials, e-mail, and social media. The following are sample quotes from different STEM Guides, describing how they pointed youth to resources such as hands-on activities, a solar car engineering challenge, and a rocket event at a nearby observatory. The last quote shows a STEM Guide engaging in detailed matching of resources to different individual youth:

> Kids who had downtime, I let them use my laptop and navigate 'How-to-Smile' [an online clearinghouse of STEM activities] to find something they wanted to do at home or for next club. Kids found stuff that they would not have thought of doing, like mummifying fish.
>
> Junior Solar Sprint was another big one … I suggested kids could do that … Also a few other things, like Twitchell Observatory – since we were doing rockets, space is a cool thing – it's not far, ten minutes away, if they wanted to do that. Simple things they could do if they have internet, like go online and go to NASA's website, that has a lot of fun games where they can learn about space.
>
> There's a home-school network going on. I have special education providers calling me at the office looking for help matching kids up with appropriate activities.

Intermediate brokering: 'Supporting' a youth to engage with a STEM resource

Going beyond simply pointing, Guides were sometimes able to provide more substantive assistance by removing obstacles or encouraging youth as they attempted to engage with a STEM asset (e.g. helping with forms, arranging transport, providing letters of recommendation, offsetting the costs of a camp with scholarships, reaching out to a potential mentor). Also included in this category were occasions when Guides attended an event along with youth, rather than merely informing the youth about it.

> <Youth> is participating in the Maine State Science Fair through <her local High School>. She's looking to do a project in the neuroscience arena and was looking for some guidance. I contacted <neuroscience professor at university an hour away> and asked if she might be willing to mentor a student participating in the Science Fair, and she was! I sent an intro email to <youth> and cc'd <professor >.
>
> <A fellow STEM Guide> and I took 23 kids to the Science Festival and that was awesome. The kids were super stoked, and many will sign up for our STEM class if they can get in the schedule.

Event	Connection Via	Online	Connection Action	#Youth Reached
	Email and social media	Facebook	Sent emails to parents who had expressed interest in SeDo summer sci programs to find out if still interested. Posted on fb.	
SeDo Summer Lunch Program	Personal Contact		Met w/ 3 adults, 5 youth to inform about SeDo Summer Sci Club. Left apps & fliers at Summer Lunch Program.	5
NASA 3D Space Container Challenge	Email		Received complimentary email from parent following event	2
NASA 3D Space Container Challenge	Personal Contact		Informed participants about Matt McEntee, at the University of Maine's Innovative Media Research and Commercialization Center (IMRC), who offered to give them a tour. Talked to parents at pick-up re: NASA Challenge & next steps.	6
RVCS Symmer Science Club	Personal Contact	Howtosmile.org, STEM Guides DDG FB page	Spoke w/ 4 moms re: SG Project & online resources	0

Figure 3. Excerpt from a STEM Guide's activity log.

> <Youth> is interested in engineering, he agreed to join the TSC Youth Leadership Team and helped to determine our first speaker, a design engineer. During the first youth interview with him we uncovered an engineering summer camp at <university an hour away> for juniors, and when he was old enough, he asked me for a letter of recommendation to attend. He was accepted and LOVED it.

> <Youth> is a seventeen-year old high school student at <local school>, who's been involved with the TSC Youth Leadership Team for a year and a half, she's interested in biology/medicine/science in general. I made her aware of a Maine Humanities Council program on Darwin and she really wanted to go. We both went and had fantastic in-depth conversations about evolution and natural selection among other things. She is still exploring what she might be interested in pursuing for a college major.

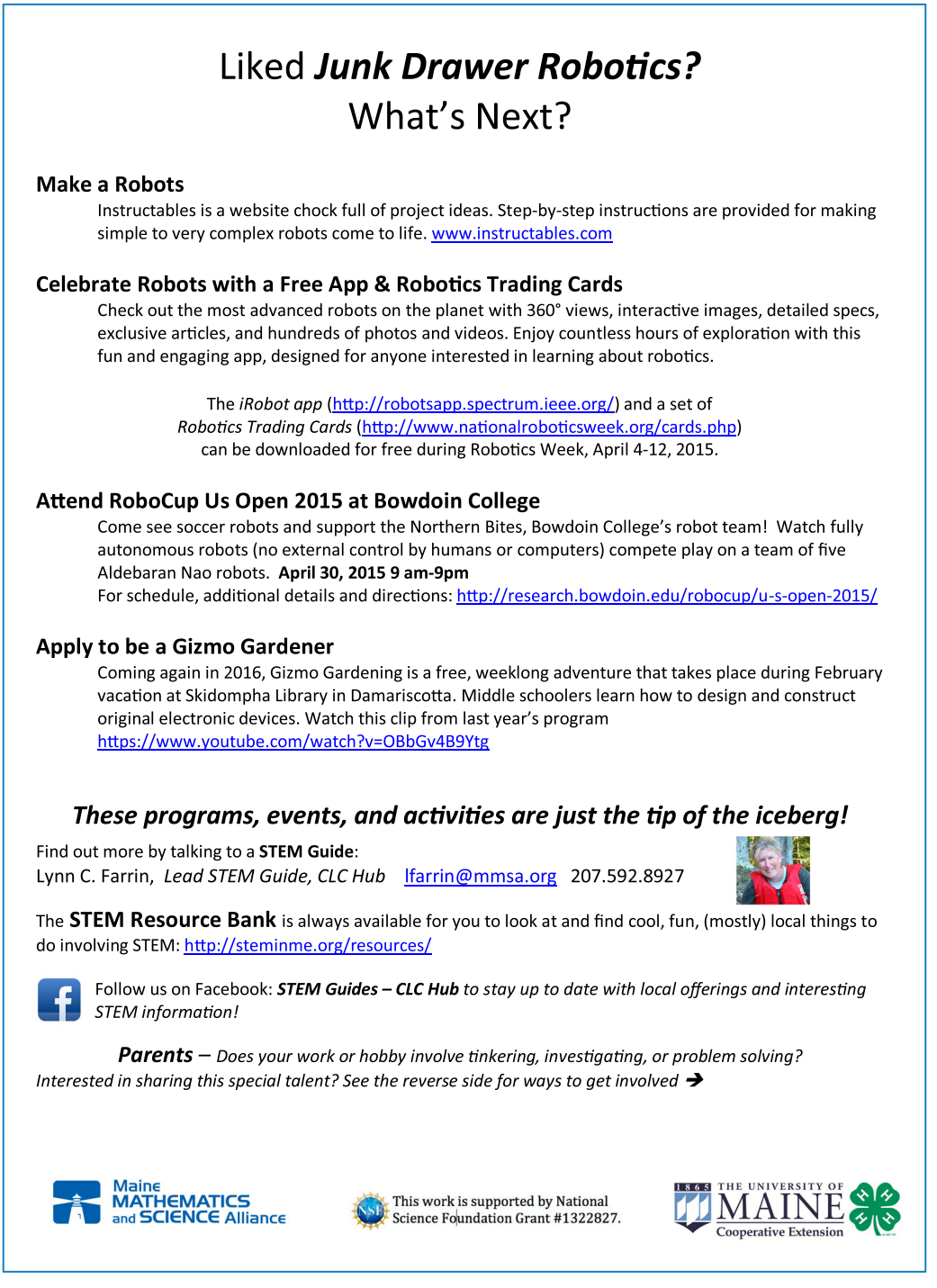
What these reports have in common is that the Guide lowered the barriers to participation by students as they explored next steps in their learning.

Deep brokering: 'Leading' youth through the experience of a STEM resource

The most deeply mediated form of connection was when a Guide actually led an experience, going through it with the youth to share with them a STEM asset in detail. This deepest level of involvement gave the Guides significant access to youth beyond their immediate circle, and also allowed them to build greater credibility with youth and their parents. To qualify as an acceptable activity for Guides to *lead* within the project's scope, we insisted (i) that the activities were well-established, high-quality, inexpensive and broadly accessible mesosystem resources, and (ii) that the Guides explicitly provided additional examples of *pointing* or *supporting* so that participating youth were shown how to build on their experiences by taking small 'next steps' related to the topic or type of activity.

For example, in every Hub the Guides were encouraged to *lead* at least one Science Club for preteen youth. This involved taking the youth through activities selected from a high-quality source (such as www.howtosmile.org) and then providing them with multiple pointers for possible next steps. Figure 4 shows the way such next steps were typically presented to youth and caregivers.

For the older youth, Guides were encouraged to *lead* a series of Teen Science Cafés (Mayhew & Hall, 2012). This involved gathering a group of teens into a 'Youth Leadership Team' to create and host a series of events on topics they found interesting and featured a local STEM professional. This allowed participating youth, and especially the Youth Leadership Team, to make multiple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Attend RoboCup Us Open 2015 at Bowdoin College

Come see soccer robots and support the Northern Bites, Bowdoin College's robot team! Watch fully autonomous robots (no external control by humans or computers) compete play on a team of five Aldebaran Nao robots. **April 30, 2015 9 am-9pm**
For schedule, additional details and directions: http://research.bowdoin.edu/robocup/u-s-open-2015/

Apply to be a Gizmo Gardener

Coming again in 2016, Gizmo Gardening is a free, weeklong adventure that takes place during February vacation at Skidompha Library in Damariscotta. Middle schoolers learn how to design and construct original electronic devices. Watch this clip from last year's program
https://www.youtube.com/watch?v=OBbGv4B9Ytg

These programs, events, and activities are just the tip of the iceberg!

Find out more by talking to a **STEM Guide**:
Lynn C. Farrin, *Lead STEM Guide, CLC Hub* lfarrin@mmsa.org 207.592.8927

The **STEM Resource Bank** is always available for you to look at and find cool, fun, (mostly) local things to do involving STEM: http://steminme.org/resources/

Follow us on Facebook: ***STEM Guides – CLC Hub*** *to stay up to date with local offerings and interesting STEM information!*

Parents *– Does your work or hobby involve tinkering, investigating, or problem solving? Interested in sharing this special talent? See the reverse side for ways to get involved* ➔

Maine MATHEMATICS and SCIENCE Alliance

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THE UNIVERSITY OF MAINE Cooperative Extension

Figure 4. Example of a flyer emphasizing 'next steps' to youth and their caregivers.

connections with people, organizations, and materials in their STEM mesosystem. In addition, every invited STEM professional was asked to share three additional pointers to STEM resources that youth could follow up with if they were interested to learn more.

Encouraging families to take agency

Ching et al. (2016) make the point that part of a successful brokering in an ecosystem is that children and their families themselves see value in exploring next steps to learning (p. 305). To contribute to this 'help-seeking orientation' (Stanton-Salazar, 2001), the Guides made themselves available to any youth or family who approached them in search of resources or opportunities, but they also encouraged youth and their caregivers to take agency in finding next steps for themselves.

> I always encourage kids to reach out: go to conferences, lectures, volunteer, or do internships. It's those connections that are going to help them learn what's really out there and may help them get into a better college.

> I found out from <Name's> mom that she was interested in space and considering becoming an astronaut or doing something related to space exploration. I had a few conversations with <Name> about it and suggested the MERITS program. She is a good student but very quiet, so we hadn't had the opportunity to talk much about stuff other than schoolwork. I now talk with her more regularly about this sort of thing and I actively encourage her to get more experiences under her belt.

> <Boy's> mom is one of these moms who comes in a lot. He's one of these kids who we'll be involved with in the next few years. He's interested in STEM, very inquisitive, and off-the-charts-bright. He has social struggles, and his mom is very much his advocate … We've had a positive relationship. He's only a 4th grader, so a relationship is just starting, but I'd love to follow up. She's very willing to participate.

> One girl in particular was super excited. She spent most of the day and we put together a robot and programmed it. I gave her my info and my number, and told her to have her parents call me if they wanted more info. They called before I got out of the parking lot, they said she enjoyed it and wanted to get more connected. I will call them this week to let them know about November robotics in <nearby town>.

To help youth see connections among their activities, one Guide created 'brag boards' where youth were encouraged to recognize and share examples of follow-up activities as well as new STEM experiences they had engaged in since the previous meeting. Figure 5 shows an example of a brag board, with columns for S, T, E, and M, and sticky notes where youth 'bragged about their STEM-y awesomeness.' Their notes included statements such as 'I can unicycle', 'Investigated animal tracks and scat,' 'I made a cardboard robot,' 'I made a map,' and 'I wired my sister's phone so the next time she opens something she gets a scary surprise.'

What factors did STEM Guides find most challenging in their brokering work?

In their regular interviews, Guides were asked about their most pressing challenges. Across all Hubs and all years, the most frequently reported of these fell into the categories of: access barriers, cultural barriers, and competing interests of the youth.

Access barriers

Maine has few public transportation options, and nearly none in rural areas. Some of our hubs, like Down East, are so large, and towns so spread apart that it can take hours to drive back and forth between towns. Coupled with a high poverty rate and working parents, it was often difficult for youth to participate in opportunities even within their own town.

> Transportation is a huge issue here. Now I'm trying to figure out how to get the bus, and if it's not a school or 4-H sanctioned thing, how do you deal with liability, even recruitment?

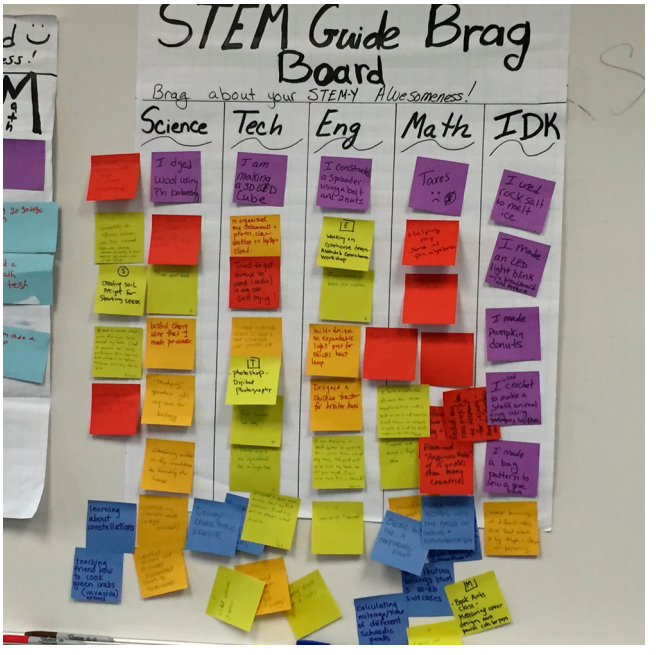

Figure 5. Example of a 'brag board' created by STEM Guide Alicia Millette.

> When I asked <girl> she said that she'd like to be involved in the Youth Leadership Team but she has a major transport issue. No help from parents on this – they can't make it to <town>.
>
> There are so many needs. A simple one is transportation. For any event that's open to public, a free and open transportation system would greatly increase numbers. Or have something that goes directly to their home. Gas cards don't always work because sometimes there's no reliable vehicle or licensed driver. Churches did it for years. Businesses do it. Jackson Lab has a shuttlebus that takes people every day from <town> and back. Everybody is realizing reliable transportation is a barrier.
>
> The biggest problem of all is the transportation issue. The Science Fair is really terrific; we're spreading word as we can, through Facebook, etc., but I would love to have a bus to pick up kids and go – there's no other way we can do it. And we can't bring them. And there are no resources to rent a minivan. It's one tiny example of what we face. There are limits to how much parents can do.

Online participation was also quite constrained: While schools and libraries in Maine have high-speed internet, homes are far less likely to have reliable connections to facilitate youth learning outside school.

> There's a huge digital divide – internet is horrific in some places. Kids either don't have it at home or aren't allowed to use it because it costs money. Schools are divided: Some are tied in and some aren't. So there seems to be a huge digital divide; hopefully it'll be addressed soon.

Cultural barriers

A number of STEM Guides saw themselves as coming up against community beliefs about STEM or education.

> I think there's a lot of stigma around STEM. They hear STEM or technology and don't think they're smart enough. I'm hoping to bring things to this area – make them say I didn't realize that was part of STEM, that's cool. Get that spark. Then you hook them, and then we've got them. And they can do it.
>
> It's given me a slightly different perspective on community where I grew up. We live in an area that is quite impoverished. 15% may be educated and have money to encourage kids to do out of school STEM activities and the other 85% have resistance to education and are actively keeping kids from doing anything to do

> with academic education. These parents devalue it. In large part it comes from not wanting their kids to be better than they are, and they don't want to lose kids out of the community.

> Kids here don't dream enough. 'Maybe I'll work at McDonald's' is a really big job here. It's wacky. There are great opportunities for internships for the summer, but they don't want it. They all really want to work at McDonalds or Hannaford (a regional grocery chain).

> Some parents feel threatened and uncomfortable with folks who have higher education level then they do. They see education as threat to their communities and way of life, so unfortunate.

Time

Lastly, Guides learned that they needed the time and attention of youth to engage them in STEM connection-making (particularly *leading* connections, which were heavy with programmatic components). Often, sports were the biggest competition for the youths' limited time:

> It's more challenging to get to kids than we initially thought. Not that kids are lazy and don't want to do anything, but there's so much else going on and taking their time, the priorities and stresses of the lives they're leading.

> We were trying to find two more dates for TSC before end of year, and it was almost impossible, between drivers' ed, lacrosse, and AP exams. It's amazing how limited out-of-school time is … It's hard because there are only so many kids. Is it ok if there are only five kids? People are pulled in a million directions. There's competition with school events, sports, afterschool events … The reality is that interested kids are busy kids.

> We'd have more kids if not for sports events. We need to find ways to not be in competition and build synergy with other activities. How do we bring STEM to basketball games?

What were STEM Guides able to achieve through their community brokering?

Over the five years of the project and across the five STEM Hubs, STEM Guides documented (through activity logs and/or interviews) a total of 6,484 connections with 1,768 individual youth meeting our demographic profile of 10–18 years of age. Given that the total population of each Hub is in the neighbourhood of 15,000, we consider this a successful output for a project so deeply situated in low-density areas of the state. Table 1 shows these totals, along with a gender split (f = 42%, m = 51%) that reflects many of the Guides' attempts to actively recruit females in particular. Also encouraging is the mean number of connections to STEM opportunities that these youth were documented to make: a mean of 3.67 over all Hubs and all years.

At the same time, this is a very broad distribution: approximately half of the youth (49%) engaged in only one STEM opportunity initiated by a Guide, and a small number engaged in a great many – the top 1% engaging in 24 or more documented events. Figure 6 shows the histogram summarizing these results.

To give a sense of the broad range of these STEM opportunities, Table 2 breaks them out by format type, from single events to multi-day camps and work experiences. The Guides were encouraged to begin where they felt most comfortable, and to expand their work from there. At the same time, their choices were guided by their cohort trainings, which mostly took the form of having them experience a range of STEM resources for themselves. The most frequently suggested types of events during these training sessions were Science Clubs (for the elementary and middle-schoolers), and Teen Science Cafes (for the high schoolers). These two formats account for two of the largest contributions in Table 2 (viz. STEM Program Multi-Session and STEM Event.) The reasons for them

Table 1. Total number of youth engaging in STEM opportunities through STEM guides.

Individual Count	1768
Females	42%
Males	51%
Unspecified	75
Number of Connections:	6484
Opportunities per Individual (mean)	3.67

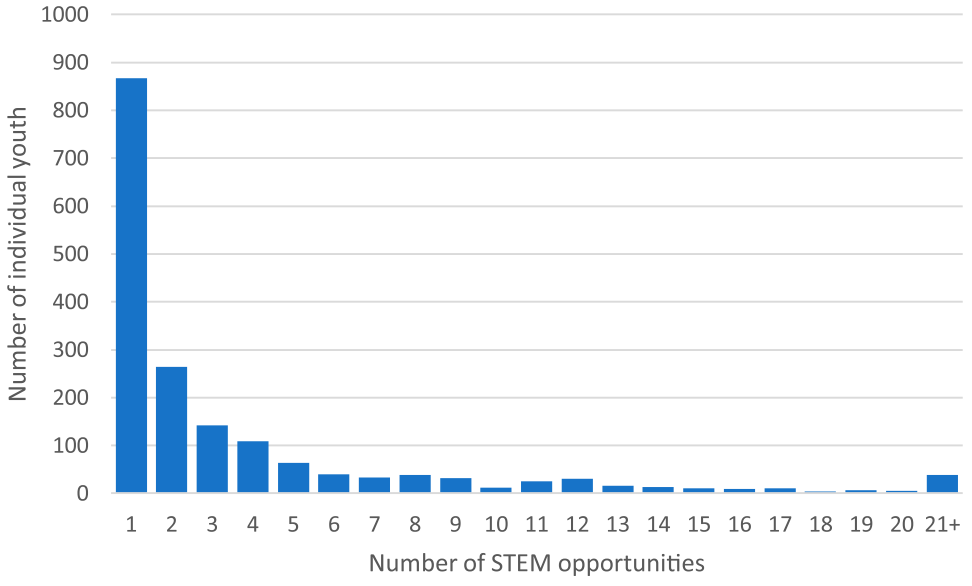

Figure 6. Histogram of youth engaging in multiple STEM opportunities through STEM Guides.

being explicitly encouraged are described in the next section. We note that the table has been substantially consolidated into broad categories: in all, there were ten different formats of STEM opportunities, that took place in schools, after school spaces, libraries or other community spaces. This variety reflects the broad range of contextualized opportunities available in the different regions and shows the STEM Guides' willingness to explore many approaches to brokering between youth and available STEM opportunities.

The number of connections recorded in Table 2 is without doubt a lower limit. All the sign-in events shown in Table 2 are of *leading* connections of this deeper type, since *pointing* and *supporting* connections were often difficult to document, being informal, briefer and/or directed at groups of youth rather than named individuals.

Despite myriad challenges, almost all of the Guides were consistently enthusiastic about their work throughout their tenures as paid professionals. Looking back, many believed they had made positive impacts on their communities. Among the rewarding aspects they listed were: working closely with youth, getting to know and engage parents, working with other adults and organizations, and learning about STEM themselves.

> It was rewarding working with the kids, in all the different ways and the programming. And it was really positive having the STEM Guides, a niche and cohort of adults that were together by common interests, even though we're totally different.

Table 2. Breakdown of 'Sign-In' STEM opportunities by Format Type.

Type of STEM Opportunity	Hub1	Hub 2	Hub 3	Hub 4	Hub 5	Total
STEM Activity	42	32	21	226	155	476
STEM Camp Multi-Day		1	2	103	742	848
STEM Competition Team			20			20
STEM Event	161	82	215	167	124	749
STEM Field Trip				22		22
STEM Presentation				135	10	145
STEM Program Multi-Session	57	196	1299	618	1736	3906
STEM Research Experience			18			18
STEM Work Experience					12	12
STEM Youth Group	80	30	120	58		6484
Total	340	341	1695	1329	2779	6484

> Most rewarding was finding and increasing the resources my area has for STEM, which was mostly me learning about resources and then distributing them to people here.

> Nothing was easy, but it was very rewarding, seeing the connections that the students are making, and providing opportunities at 5,6, and 7th grade that is NOT sports. It's something different that there wasn't there before.

> I think we have had an impact on some students who feel like they don't fit anywhere. This has provided a community for them where it's okay to geek out a little and have conversations that in most circumstances you wouldn't have with other teenagers. Parents have said this is the best opportunity because their kid is shy or doesn't participate much. Some kids don't have stable adults in their lives, so it's just having pizza and a safe place to hang out. It's the basics: food and shelter and someone who cares.

> We had a huge culture change, which was my objective: to have academics be something kids want to do, that they excel at and have pride in. For example, during this year's high school assembly we gave out awards for STEM-related things kids had done – kids at the Maine State Science Fair, or the Science Festival. Not only awards for sports, but also academic acknowledgement of STEM-related events.

Discussion

Research on brokering in STEM learning ecosystems is a young but emerging area of interest in the education research literature, and the Bronfenbrenner framework (1977, 1986) is becoming widespread. We see our work as contributing to both theory and practice in this growing area.

On the practice side, studies have suggested that a common obstacle to brokering is that education program staff tend to be self-referential, encouraging youth to enrol only in further opportunities within their own programs and institutions (Akiva et al., 2017). Our project addressed this structural challenge by creating a new genre of salaried and semi-autonomous professionals (the STEM Guides), whose allegiance was not to any particular program, but whose explicit role was to broker between youth in their own communities and a broad range of STEM opportunities that were readily available but unfamiliar to them. The Guides also attempted to make the notion of exploring 'next steps' in STEM interest trajectories more salient to youth and families through a combination of providing pointers and encouraging families to take agency in finding their own. Whether STEM pathways are characterized as building islands of expertise (2002), participating in lines of practice (Azavedo, 2011; Renninger & Su, 2012), following career pathways, or simply going from situated interest to individual interest they rely ultimately on some form of intentional search by the learner for new elements in their accessible mesosystem, along with an epistemology that includes aggregation of learning experiences.

On the theory side, we have introduced a typology of brokering moves, based on the catalytic nature of the brokering itself rather than the STEM opportunities or the youth. Specifically, we use '*pointing*,' '*supporting*,' and '*leading*' describe three levels of involvement that STEM Guides engaged in as they tried to encourage youth to explore their STEM interests. Secondly, we have focused some attention on the STEM learning mesosystem, consisting of STEM people, organizations, resources, and opportunities that are not yet directly intersection with youth and their families. We argue that an important and often overlooked aspect of brokering involves building connections with and among members of the mesosystem that may have little or no regular interaction with each other.

From an ecosystem perspective, we discovered that this kind of opportunistic localized brokering is much more challenging than we had expected. STEM Guides had to frequently explain to puzzled community members what they were doing, and why it was slightly different from just 'running programs.' Our interviews with families revealed that even frequent participants and friends of STEM Guides found it difficult to talk about their (or their children's) interests in terms of trajectories or next steps; in fact, we abandoned these interviews entirely when we began to fear that our periodic phone calls were making parents feel guilty or distressed if they had nothing to tell us. Often, community members interpreted 'out of school STEM' as meaning formal programs for groups of youth and did not see STEM in daily activities or in the natural resources around them. Many mesosystem

members were reluctant to invest the time and resources to even meet together, let alone create a larger vision for their communities' youth. Overall, it seemed that the perspective shift from institutional programming to a true ecosystem mentality was a major conceptual change for all parties, and three years (the life of one of our Hubs) felt far too short for this kind of systemic mind-shift to take root.

That said, we found it intriguing that in one of our earliest STEM Hubs, our head STEM Guide, Alicia Millette, has continued to champion the brokering work well beyond the project's funding, and in doing so has gradually built relationships with the school, town, and local library. Since the project ended, she has successfully galvanized parents to insist on school funding of a continuation of her middle school science club and the various opportunities that she continues to broker via *pointing* and *supporting*. Perhaps, despite the challenges, this kind of community-based investment may have a longer tail of impact than is typical for short-term STEM education projects. As a 4-H partner reported:

> I still go places and people think SG is still going. Last night I went to vote and people still think of me as a STEM Guide. And they said oh, the kits! It brings new life to kits that 4-H has for Maine residents. And now it's not an elitist thing, we just let people in <low-income town> borrow a kit. I think this helped change how 4-H is perceived in the community.

Looking forward, we would make several suggestions for adaptations of the model that might ameliorate some of its challenges. Perhaps the most obvious is to consider whether the role of a STEM Guide could be taken by someone in the community who is already salaried and has regular access to youth. This could be a teacher, youth developer, or other respected adult in an educational role. Such a person would need to embrace a much broader view of their responsibilities than the narrow role of guiding youth through a set curriculum on a set topic. They would need to take a broader view of where STEM might be embedded in a range of community activities, and be ready to follow student interests. They would also need to embrace the inherently entrepreneurial and boundary-crossing nature of brokering, which includes not only the familiar and appealing aspects of working directly with youth, but also a role negotiating with organizations and individuals toward a larger vision, much like a community organizer. This may be unrealistic for most educators, especially given their lack of time and resources and the multi-dimensional performance issues they often face. However, one advantage is that a broker may not necessarily need the formal STEM credentials of a classroom teacher, and might be someone like an aide, ed tech, or other position. In particular, someone who is uncomfortable taking a *leading* role with youth might still contribute to STEM learning through *pointing* and *supporting*.

For an ecosystem perspective to truly take root in a community, brokering needs to be elevated as a respected part of an educator's professional identity, training, and expectations. A welcome side-effect of such a perspective could be a gradual shift in the sense of competition that is common among many informal STEM organizations, toward a recognition that they all benefit if youth are building interest across multiple engaging experiences.

This research has obvious methodological limitations. Throughout the project we struggled to find ways to consistently track the impacts of the STEM Guides' work across the myriad opportunities they created to contribute to their communities. We tried STEM Guide activity logs, school-administered surveys, family interviews, observations, and several other approaches, before settling on the more modest goals of characterizing youth participation at sign-in events led by STEM Guides, and characterizing the reflections of the Guides themselves through periodic interviews. This is clearly an area where innovative and low-cost measures of community-level impact are much needed.

In summary, other researchers (e.g. Ching et al., 2016) have suggested that brokering is not only the purview of teacher and parents but can be embraced by anyone in a community. The STEM Guides project explored an extension of this view, by investing in community-embedded professionals across several small regions of rural Maine. In doing so, we learned that professional brokering is an extremely challenging but rewarding role for those community members who readily embrace a brokering mindset.

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