Design for Success: Developing a STEM Ecosystem

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Executive Summary

As humans, we regularly interact with Science, Technology, Engineering, and Mathematics (STEM) concepts in our daily lives, but often STEM education does not include experiences that make connections to life outside of classroom walls. One approach to bridge STEM learning across settings and sectors is called STEM Learning Ecosystems. According to a recent report on the approach "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".[1]

The STEM Learning Ecosystems approach promises to have broad impact, but there is much that we do not understand regarding how best to successfully organize, manage and promote it. Indeed, even the underlying elements of ecosystem efficacy warrant further research. This study begins to address such lack of understanding by asking, *how do partners building and running a STEM learning ecosystem define the parameters of an "effective" ecosystem?*

To answer this question, we studied the first cohort of 27 ecosystems in the national STEM Learning Ecosystems Initiative. Leaders of the Initiative describe it as "a collection of like-minded partners preparing every child to thrive through high-quality science, technology, engineering and math (STEM) education…By relying on coordination between unlikely partners—such as school districts, teachers, parents, higher education institutions and informal STEM programs, to name a few—each ecosystem can transform the local infrastructure for ensuring more students, particularly underserved and underrepresented students, develop the knowledge and skills they need to succeed." In the inaugural year of the Initiative, community partners from 27 ecosystems participated, reflecting a diversity in terms of age, size, and location.

This study centers on two rounds of interviews with partners from a total of 24 ecosystems. We supplement these interviews with direct observations of five ecosystems and analytic review of key documents, including initial applications to become part of the Initiative and ecosystem self-assessments.

Overview of Key Findings

Results highlight how foundational funding is to the sustainability of an ecosystem. For partners, funding is particularly needed for financing leadership positions and operating costs. Partners also see funding as a means to sustain their local

[1] Traphagen, K., & Traill, S. (2014). How cross-sector collaborations are advancing STEM learning. Los Altos, CA: Noyce Foundation.

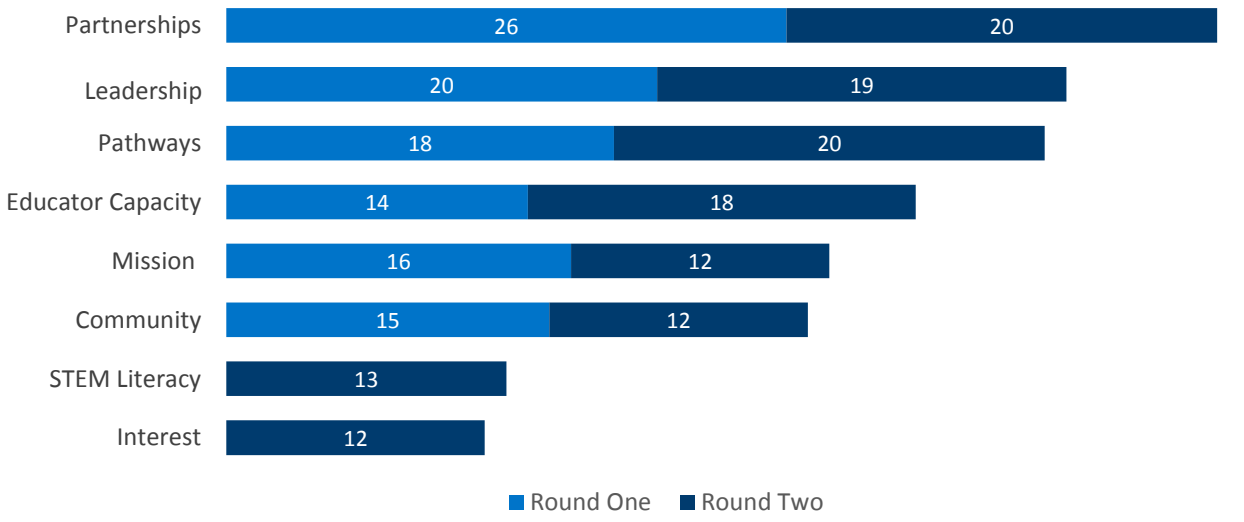
ecosystems. One of the ecosystem partners discussed the importance of long-term funding in order to develop the capacity of the local ecosystem: *"Yes, sustainability is a challenge in all of our worlds. I think people love to fund things for a limited amount of time and then say okay, you guys are on your own. But I think this capacity building work is some of the most important work of our future and it's going to take… targeted and I would say, long term, so not two years of funding*.''

As a foundational factor, funding can impede or bolster the critical factors, described below, for a STEM ecosystem. Furthermore, partners view funding as essential for sustainability. Two strategies that partners use to attract funding are emphasizing the collaborative nature of the ecosystem and diversifying their funding portfolios.

The findings also illuminate eight "critical factors" that are essential to the development of a STEM earning ecosystem. These eight factors signify the most prevalent ecosystems elements discussed by partners in their interviews.
As shown in Figure 1, which delineates the number of ecosystem partners that viewed each factor as important, *partnerships* emerged as the most commonly cited critical factor, followed by *leadership* and *pathways*. A similar number of partners mentioned *educator capacity*, *mission*, and *community* as important for a local ecosystem to be successful. *Interest* and *STEM literacy* emerged as well, although they were not as prevalent as other critical factors. Analysis of critical factors provides keen insight into efficacy, which is noted as a research need above. The key findings about each critical factor follow in order of implied importance or criticality.

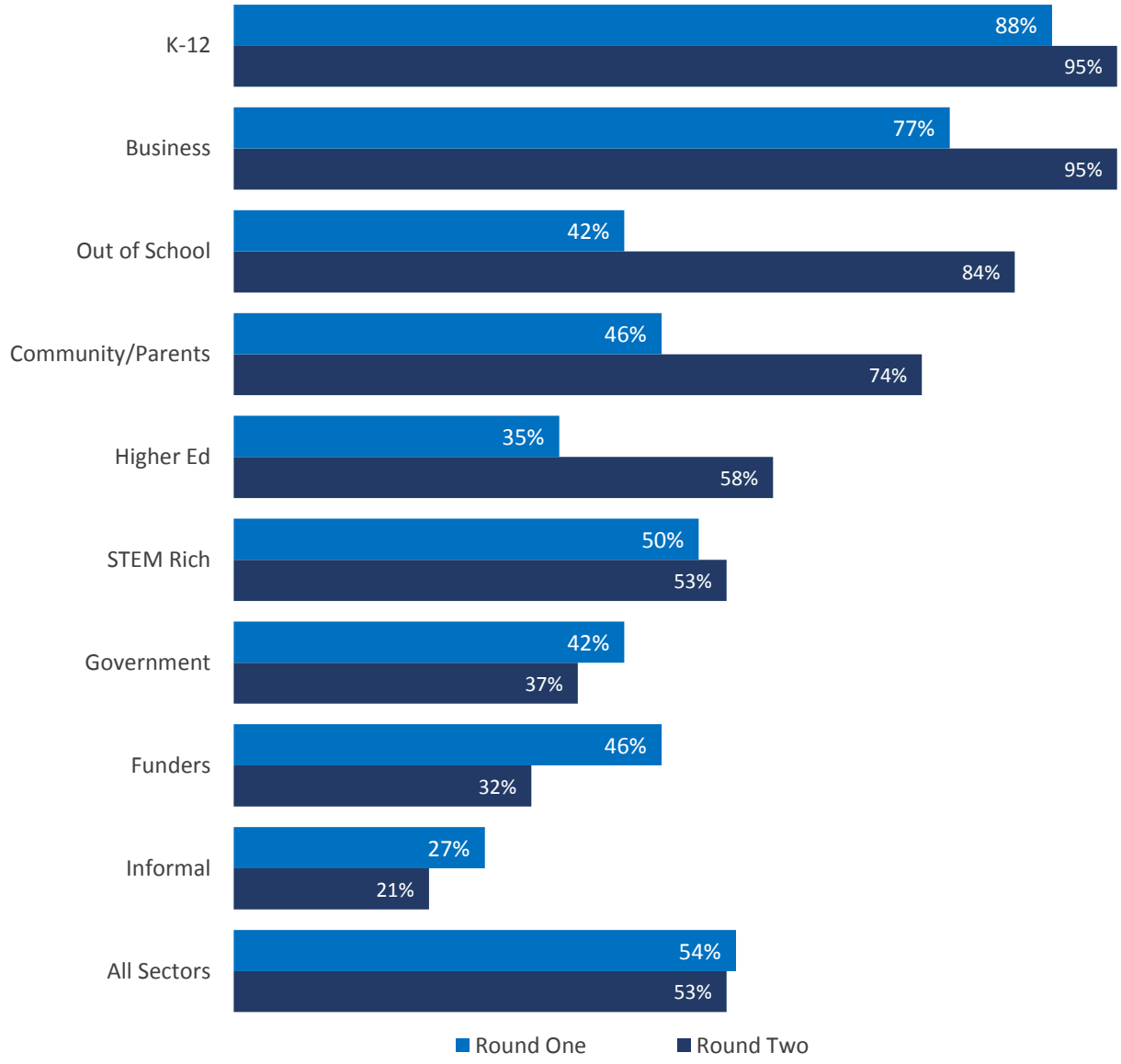
Partnerships - While K-12 and business were consistently perceived as the most important sectors for doing ecosystem work in both rounds one and two, the out-of-school time (OST) and higher education sectors moved up considerably in the rankings between the two rounds, indicating a shift in partners' perceptions of the sectors that they need to bring to the table in their ecosystems (see Figure 2).

Figure 1: Partnerships were the most frequently mentioned critical factor



Source: Round one interviews, N=30; Round two interviews, N=21

Figure 2: Partners viewed the K-12 and business sectors as most important for performing local ecosystem work



Sources: Round one interviews, N=30; Round two interviews, N=21

Leadership – In first round interviews, partners reported having designated lead personnel or organizations in place, and described their primary responsibilities as managing, connecting, organizing, and seeking funding. In the second round interviews, ecosystem partners described one additional responsibility: evaluating the effectiveness of programs and initiatives.

Pathways – In round one interviews, partners focused on the link between the business and K-12 sectors to promote pathways. However, in round two, ecosystem partners described collaboration

with partners from the business, higher education, and OST sectors to develop and implement pathways programs and initiatives that target specific groups of students such as girls.

Partners emphasized the need for workforce development in STEM fields when promoting pathways. One partner described the role of programming in inspiring students towards STEM topics and careers: "*A few years ago we started moving into youth programming and more intentionally moving into STEM programming and we really saw, we see the influence of STEM in terms of, sparking interest in the STEM subjects…[and], students getting interested in STEM careers, and ultimately for work force development effort because we want to make sure that the companies in the region need STEM workers have STEM workers to choose from*."

Educator Capacity – In round one and round two interviews, partners viewed building educator capacity as a method to improve the quality of STEM learning opportunities. In round one interviews, partners expressed a need for developing educator capacity and some stated that district policy and restrictions on school curricula interfered with their professional development plans. At the time of round two interviews, partners had begun to provide professional development for educators. Jointly hosting training for educators with other ecosystem partners and using a peer-to-peer model in training are some of the successful strategies used by partners.

Mission – In round one and round two interviews, ecosystem partners viewed the mission as guiding their work and believed that developing the mission was a collaborative endeavor that entailed making explicit the connections between partner's areas of expertise and the shared ecosystem mission. In round one interviews, partners emphasized the need to intentionally cultivate buy-in among collaborators. By round two interviews, partners had begun to establish shared goals and engage in coordinated, mission-centric work.

Community – Community involvement seemed to become increasingly more important to ecosystem partners over the course of the year. The initial ecosystem applications suggested limited involvement from community and parent organizations, while round one interviews showed that ecosystem partners recognized the value of including the community with an emphasis on parents, specifically. In round one and round two interviews, partners strived to communicate the importance of STEM to parents and students and raise their awareness of available STEM opportunities. In round two interviews, a few partners articulated some unique strengths and needs of their communities. This increased emphasis on community strengths and needs suggests that ecosystem partners had deeper knowledge of the community as it relates to STEM education.

STEM Literacy – STEM literacy did not emerge as a critical factor in round one interviews, indicating that ecosystem partners may have shifted their focus towards STEM literacy towards the end of the inaugural year of the Initiative. In second round interviews, most partners reported that their ecosystems used in-

school and OST settings to advance STEM literacy.

Interest – Interest only emerged as a critical factor in round two interviews. Ecosystem partners discussed the need to clarify and align their ecosystems' goals with the goals of their respective organizations. Some partners noted that aligning their organizations' efforts with the efforts of the local ecosystem may ultimately impact more students and they have begun to capitalize on ecosystem resources to do so. One partner described the need for a shared vision: "*I think our original goal was to have an understanding of who is working in the STEM learning space…then developing…a shared vision...*"

Recommendations

The findings support important recommendations for current and future ecosystems:

- Given that funding is a foundational factor, ensure ecosystem partners have a sustainability plan that is sensitive to the need for short- and long-term operating costs.

- Considering the centrality of partnerships to ecosystems, strategically cultivate partners who can meet the needs of the local ecosystem. For example, if an ecosystem is interested in expanding STEM programming, the leadership may focus on building partnerships with OST organizations. The findings indicate that K-12, business, and OST may be the most important sectors to engage first.

- A more targeted focus on involving students and parents as ecosystem designers is needed, as these stakeholders are the focus of many ecosystems efforts, and they will likely have valuable insights to offer from their experiences.

- A connection with the ecosystem benefited partnering organizations by connecting them to additional resources. Ecosystem leaders should highlight this benefit to promote buy-in from potential partners. As ecosystems move to evaluating their efforts, they should explore how they can adequately document how pooled resources benefit partnering organizations and the populations they serve. This will help to accurately capture the full impact of the ecosystem.

- According to partners, leaders have five core responsibilities including managing, connecting, organizing, funding, and evaluating. Provide leaders with resources and training to help them perform these responsibilities effectively.

- Very few ecosystems are evaluating the critical factors. As ecosystems progress they may need guidance on the appropriate ways to evaluate their use of the critical factors. Likewise, more research is needed to better understand the benefits of having these factors in place when developing a STEM ecosystem.

Introduction

A Need for Integrated STEM Learning

As humans, we regularly interact with Science, Technology, Engineering, and Mathematics (STEM) concepts in our daily lives, but often STEM education does not include experiences that make connections to life outside of classroom walls. Forging experiences across educational settings has the potential to deepen students' interest in and understanding of STEM topics.[2] There is only limited integration of STEM experiences across settings and sectors,[3,4] which can negatively affect students' ability to consistently engage in scientific and engineering practices.[5] According to the National Research Council, "the use of problem-, project-, or design-based tasks to engage students in addressing complex contexts that reflect real-world situations"[6] can be accomplished through integrated approaches to STEM education.

Furthermore, integrating STEM education across settings and sectors has the potential to equip students with the knowledge and skills to be successful when they enter the workforce[2].

One approach to bridge STEM learning across settings and sectors is called STEM Learning Ecosystems. According to a recent report on the approach, "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".[3, 7] The STEM Learning Ecosystems Initiative represents a prominent example of how an ecosystem can develop, the characteristics and efficacy of which we address through this study.

Study Overview

The STEM Learning Ecosystems Initiative provides space and support for partners from different sectors to collaborate with the goal of affording youth access to STEM-rich learning opportunities. As stated by leaders of the Initiative, "The STEM Learning Ecosystems Initiative is a collection of like-minded partners preparing every child to thrive through high-quality

[2] Fenichel, M., & Schweingruber, H. A. (2010). *Surrounded by science: Learning science in informal environments*. National Academies Press.
[3] Olson, S., & Labov, J. (2014). *STEM learning is everywhere: Summary of a convocation on building learning systems*. National Academies Press.
[4] Traphagen, K., & Traill, S. (2014). *How cross-sector collaborations are advancing STEM learning.* Los Altos, CA: Noyce Foundation. Quote on p. 3.
[5] Quinn, H., Schweingruber, H., & Keller, T. (Eds.). (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.
[6] Honey, M., Pearson, G., & Schweingruber, H. (Eds.). (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. National Academies Press. Quote on p. 51.

[7] The work done by Traghagen and Traill provided the initial framework that guided the development of the STEM Learning Ecosystems Initiative.

science, technology, engineering and math (STEM) education…This effort addresses the decided lack of coordination within the field, a challenge that has stalled progress in closing equity gaps and dramatically improving students' STEM literacy. By relying on coordination between unlikely partners—such as school districts, teachers, parents, higher education institutions and informal STEM programs, to name a few—each ecosystem can transform the local infrastructure for ensuring more students, particularly underserved and underrepresented students, develop the knowledge and skills they need to succeed."

In 2015 – 2016, the inaugural year of the Initiative, community partners from 27 ecosystems participated, reflecting a diversity in terms of age, size, and location. While nine ecosystems began at the same time as the Initiative, nine others had already been operating for five or more years, and the remaining ecosystems had operated for one to four years. On their applications, leaders from 10 ecosystems reported they had 1-4 partners, nine ecosystems reported they had 5-8 partners, and eight ecosystems reported they had 9-12 partners, illustrating considerable range in the number of community partners involved in various ecosystems. Ecosystems are dispersed throughout the country, and their reaches vary; some focus efforts on cities, while others focus on the region or state.

The STEM Learning Ecosystems approach promises to have broad impact, but there is much that we do not understand regarding how best to successfully organize, manage and promote it. Indeed, even the underlying elements of ecosystem efficacy warrants further research. This study begins to address such lack of understanding by pursuing a critical research question: *How do partners building and running a STEM learning ecosystem define the parameters of an "effective" ecosystem?*

This study centers on two rounds of interviews with partners from a total of 24 ecosystems from November 2015 through August 2016. More specifically, to answer the research question, we draw on 30 first round interviews with ecosystem partners from 20 ecosystems and 21 second round interviews with ecosystem partners from 21 ecosystems. As seen in Table 1, most participating ecosystem partners are from STEM-rich institutions and PK – 12. We supplement these interviews with direct observations of five ecosystems and analytic review of key documents, including initial applications to become part of the Initiative and ecosystem self-assessments. In particular, we use key documents to provide partners' perspectives at the beginning of the Initiative and we use observations of ecosystem activities hosted by five different ecosystems to provide illustrative examples of the study findings in short vignettes. The detailed methodology section further explains data collection.

Table 1: Interviews Analyzed by Sector

Sector	First Round Interviews	Second Round Interviews
Community	0	0
Higher Education	3	4
Out-of-School Time	4	3
Business	5	0
PK-12	8	4
STEM-Rich Institution	10	10
Total	**30**	**21**

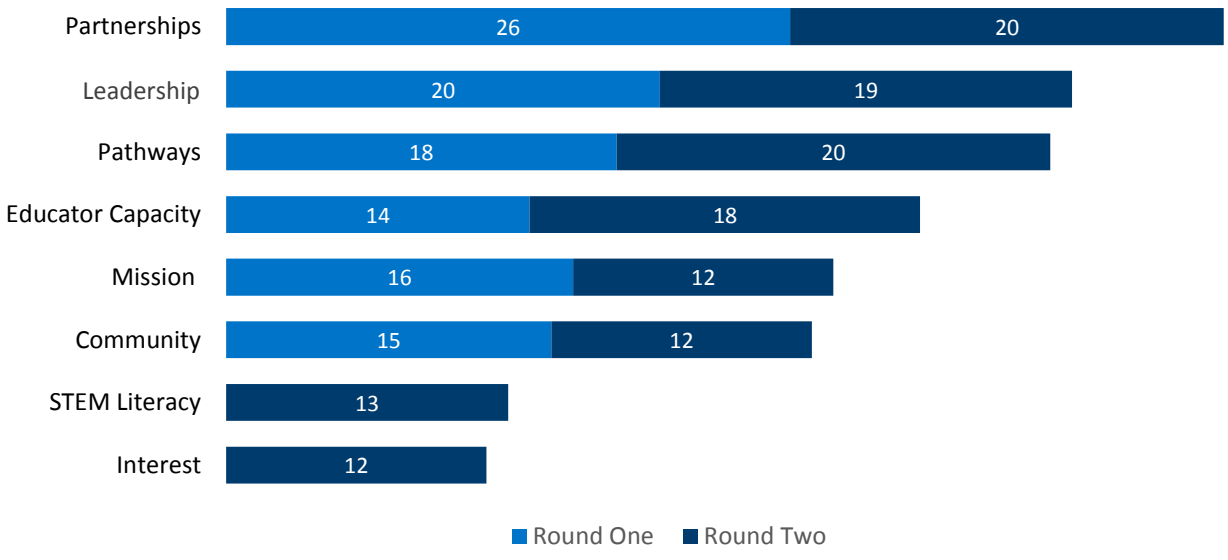
Eight factors emerged from our analysis of the interviews with ecosystem partners (See Figure 1) as being essential to the development and implementation of a STEM learning ecosystem.

The findings explore dimensions of the factors and explain the reasons why partners believed that the factors contributed to an effective ecosystem. The detailed methodology section explains how we examined the interviews to identify and describe these eights factors. Throughout this report we refer to these factors as 'critical factors' to emphasize their perceived importance to the STEM Learning Ecosystems approach.

Critical Factors for Ecosystem Development

The eight critical factors represent partners' perceptions of key elements of a successful local ecosystem. The eight factors signify the most prevalent elements discussed by partners in their interviews. As shown in Figure 1, which delineates the number of ecosystem partners that viewed each factor as important, *partnerships* emerged as the most commonly cited critical factor, followed by *leadership* and *pathways*. A similar number of partners mentioned *educator capacity*, *mission*, and *community* as important for a local ecosystem to be successful. *Interest* and *STEM literacy* emerged as well, although they were not as

Figure 1: Partnerships were the most frequently mentioned critical factor



Source: Round one interviews, N=30; Round two interviews, N=21

prevalent as other critical factors. Analysis of critical factors provides keen insight into efficacy, which is noted as a research need above. Definitions of each critical factor follow in order of implied importance or criticality.

Partnerships – Collaboration between any two sectors, including in school (PK-12), afterschool and out-of-school (OST), higher education, business, and government.

Leadership –A person or organization that directs the work of the ecosystem and contributes to the development of the ecosystem.

Pathways – Promoting children and youths' interest and knowledge in STEM concepts and/or STEM careers.

Educator Capacity – Developing well-trained and/or skilled educators in any/all sectors (e.g., in and OST, post-secondary/higher education, and business sectors) work to increase the quality of STEM education for students.

Mission – A clear, "shared vision for change"[8] that directs the work of the ecosystem.

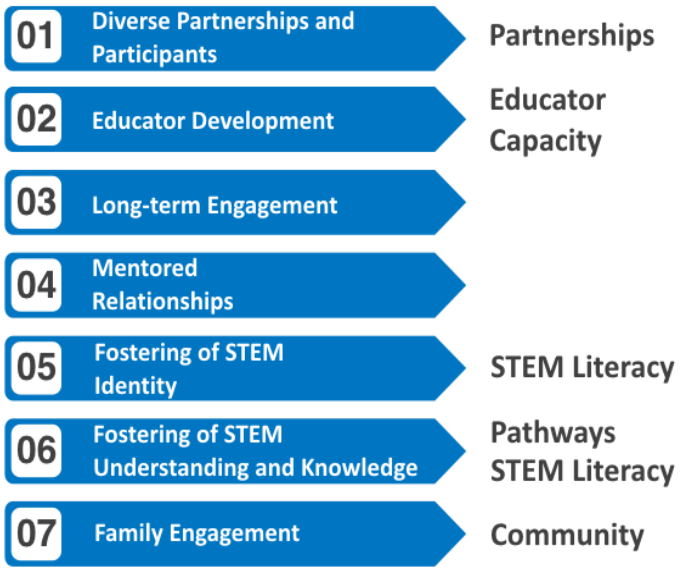
Community – The community, writ large, is actively engaged in raising the awareness and quality of STEM learning opportunities and increasing access to these learning experiences. This may include community events, parent education, and STEM advisory councils.

STEM Literacy – Plans, programs, or services designed to foster STEM literacy in students.

Interest – The goals, programs, and resources of the ecosystem uniquely contribute to the mission, goals or programs of the partnering organization(s).

The development of the STEM Learning Ecosystems Initiative was informed by seven core elements drawn from the literature on STEM education. Some of our critical factors map onto these elements, while others do not. The alignment of our findings with the core elements is shown in Figure 2. As displayed in the figure, the critical factors of partnerships, educator capacity, pathways, and community align with the core elements. Partners rarely referenced the remaining elements.

Figure 2: Four critical factors match proposed "core elements"



[8] Kania, J., & Kramer, M. (2011). Collective impact. *Stanford Social Innovation Review, 36-41.* Quote on p. 39.

Stages of Critical Factors

We developed four stages to assess the level at which the critical factor mentioned by partners was being implemented. Identifying the stages for the critical factors illustrates the maturity, in thinking and practice, of the critical factor. The four stages are:

1. Commentary – Ecosystem partners discussed the importance of a critical factor in the local ecosystem, but had yet to develop a plan or implement strategies around the critical factor.

2. Developing – Partners mentioned the development of a plan around a critical factor in the local ecosystem and/or started building the infrastructure to support the implementation of the critical factor.

3. Implementing – Partners described the implementation of a critical factor. This could include specific strategies or tools that the partner or other partners used to move the work forward in the local ecosystem. This could also include services or programs in place that benefited the target population(s) that the local ecosystem serves.

4. Evaluating – Partners provided a plan on how to evaluate the implementation of a critical factor and/or stated specific outcomes of the local ecosystem's work.

For each critical factor, we present the number of quotes that are classified in each of the four stages. The numbers of quotes are presented in blue at the top of the findings page and are organized in order of prevalence. For instance, if most quotes described the commentary stage, then the number of commentary quotes is presented first.

Often the majority of quotes indicated that ecosystem partners were at the commentary or implementation stage for the critical factor. A limited number of quotes described critical factors as being in the evaluating stage. While partners discussed the critical factors as being at different stages, the analysis of four of the critical factors – mission, pathways, STEM Literacy, and educator capacity – revealed key distinctions about the stages that were beyond a description of the level of maturity. These distinctions are discussed in the findings pages for these factors. For the remaining critical factors, we point to the most prominent stage(s).

Funding as a Foundational Factor

It is well known that funding is a key part of any initiative. Underscoring this point, 28 of 30 partners in round one (93% of interviews) and 18 of 21 partners in round two (86% of interviews) mentioned the need for funding in interviews. Given the centrality of funding to any initiative, we consider it a "foundational factor", or a resource that enables the use of other critical factors. For partners, funding is particularly needed for financing leadership positions and operating costs. Partners also saw funding as a means to sustain their local ecosystems. One of the ecosystem partners discussed the importance of long-term funding in order to develop the capacity of the local ecosystem:

"Yes, sustainability is a challenge in all of our worlds. I think people love to fund things for a limited amount of

time and then say okay, you guys are on your own. But I think this capacity building work is some of the most important work of our future and it's going to take… targeted and I would say, long term, so not two years of funding.''

The research on collaborative partnerships supports the link between funding and sustainability described by ecosystem partners. Authors of a thorough literature review concluded that having ample funding is tied to a partnership's sustainability, stating that "the ability of a partnership to secure financial resources for the work (e.g., donations and in-kind support, competent staff, daily expenses, and technical assistance) may predict its sustainability and indicate its capacity to influence community-level outcomes".[9]

Notably, as partners seek to maintain current funding and attract additional funders many are focusing on broadening or diversifying their funding portfolios. Given the explicit and implicit cost of collaboration, one might expect that ecosystems with more partners would have larger budgets. Developing and maintaining partnerships requires engaging and coordinating with partners and adequate funding is needed to support the costs associated with the infrastructure and time needed to carry out these responsibilities. All of these duties tend to be in addition to existing work duties[10]. As shown in Figure 3 most ecosystems had limited budgets regardless of the number of partnerships they had established.

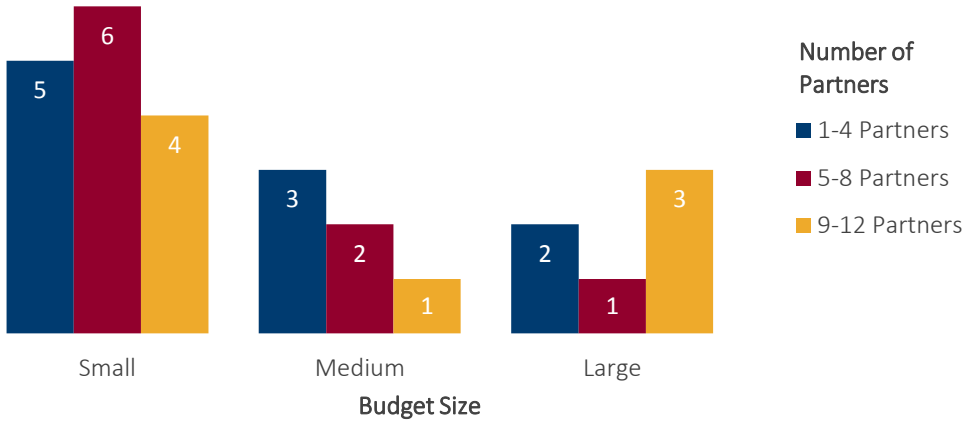
A few partners also shared how collaboration was viewed as a strength when raising funds. According to partners, funders value the collaborative and non-competitive nature of their partnerships, which gave partners the impression that funders may be more responsive once they witnessed the harmonious structure of their ecosystems. One partner shared this perspective:

"The action orientation of what the ecosystem wants to move forward will get supported by the fundraising around those projects or programs. And so, that's what we hope to seed out and I think the funding community is very excited about that because they like the idea of having the collaborative partners who are working on things together. They like the idea of kind of having the strategic framework around moving the STEM learning forward and so are probably more likely to fund those types of efforts than if groups were coming to them not having been part of a planning discussion."

[9] Roussos, S. T., & Fawcett, S. B. (2000). A review of collaborative partnerships as a strategy for improving community health. *Annual review of public health, 21*(1), 369-402. Quote on p. 387.

[10] Penuel, W. R., Allen, A. R., Coburn, C. E., & Farrell, C. (2015). Conceptualizing research–practice partnerships as joint work at boundaries. *Journal of Education for Students Placed at Risk (JESPAR)*, *20*(1-2), 182-197.

Figure 3: Ecosystems have relatively small budgets despite partnership sizes



**Small=< $99k Medium=$100-999k Large=>$1m*
Source: Ecosystem Applications, N=27

As a foundational factor, funding can impede or bolster the critical factors for a STEM ecosystem, and partners view funding as essential for sustainability. Two strategies that partners use to attract funding are emphasizing the collaborative nature of the ecosystem and diversifying their funding portfolios.

Organization of the Findings for Each Critical Factor

Throughout this document we report the findings related to each of the eight critical factors in its own section. These sections are presented according to the prevalence of the critical factor (most to least prevalent). We use several elements in each to organize the findings. We first present the findings from round one and then present findings from round two, incorporating comparisons to round one as necessary. The name and definition of the critical factor are at the top of each page. Under the definition, the number of quotes that coincide with the four stages (commentary, developing, implementing, evaluating) are listed in order of prevalence. A narrative explaining the findings related to the critical factor follows. Illustrative quotes and relevant tables or graphs accompany each narrative. Additionally, near the end of each section there is a vignette, which provides a practical example of the critical factor. The vignettes are derived from observations of an ecosystem activity collected from a sample of five ecosystems.

Partnerships

Collaboration between any two sectors, including in school (PK-12), afterschool and OST, higher education, business, and government.

Round One

28	24	20	1
Developing	Commentary	Implementing	Evaluating

In all, 26 partners (87% of interviews) perceived cross-sector partnerships as important for doing ecosystem work. The results, shown in Figure 4, reveal that 88% of partners think K-12 partnerships are important, while 77% perceive business partnerships as necessary for moving their ecosystems' work forward. In contrast, only 35% of partners believe partnerships with higher education institutions are needed, and 27% identify informal education organizations as important. Fifty-four percent of partners emphasized the importance of all sectors being involved in their ecosystems. Partnerships had a fairly equal representation across three of the stages: developing, commentary, and implementing. The highest incidence of developing and commentary suggest that ecosystems are still in the early stages of promoting collaboration among sectors.

One partner viewed all sectors, and the different roles they have, as important for the ecosystem.

"I think that [collaboration] is key. Getting everyone in our community to understand that the roles that we all play, and they're very different roles, but they're all equally as valuable."

We also explored the reasons *why* partners viewed connections between specific sectors as being important. Not all partners shared why specific cross-sector partnerships were important, but those that did emphasized that these connections offered learning experiences and programming to students and provided resources to specific groups of students like those from low-income families.

Ecosystem partners perceived the partnership between business and K-12 as being mutually beneficial. STEM professionals were regarded as important for their participation in school activities, as well as for their provision of career learning opportunities for schools. In turn, businesses stand to benefit from their interactions with schools through the development of STEM literacy. The partnership of these two sectors was also discussed as contributing to the larger goal of workforce development. For example, some partners said it was necessary for both K-12 and business leaders to work together to help achieve regional economic viability. In terms of STEM mentorship programs, a partner discussed the link

between the business and K-12 sectors this way:

"We are heavily focusing on STEM mentorship in 2016, so I think that will bring companies to the table in a way that makes them feel engaged. I think it will bring real world relevance and resources to educators and students, in a way that may inspire them and support them and it will allow for us to tell a story that's compelling."

Some ecosystem partners expressed the importance of providing everyone in a community access to STEM resources. For example, the link between OST and STEM-rich institutions was thought to be important because of the different affordances of these sectors – that is, OST is skilled in relating to youth, and STEM-rich institutions have programming designed for youth. By creating partnerships between these two sectors, students can see the relevance of and have access to STEM activities. One partner summed this up stating:

"There's a difference between what non-profit [OST] organizations can do and let's say for example a museum. A museum struggles to have programming that is culturally relevant, a non-profit may be more likely to be able to engage, you know, young people at a different level. But then how do you create the connection so that the young person who does live in a poor community and doesn't feel going to the museum is fun or even knows that they can get there. How do you start to bridge that connection and that gap?"

In sum, ecosystem partners viewed the business and K-12 sectors as being most important for carrying out their work. Reasons given for why cross-sector collaborations are crucial include the provision of learning opportunities and STEM programming, and access to resources for specific student populations.

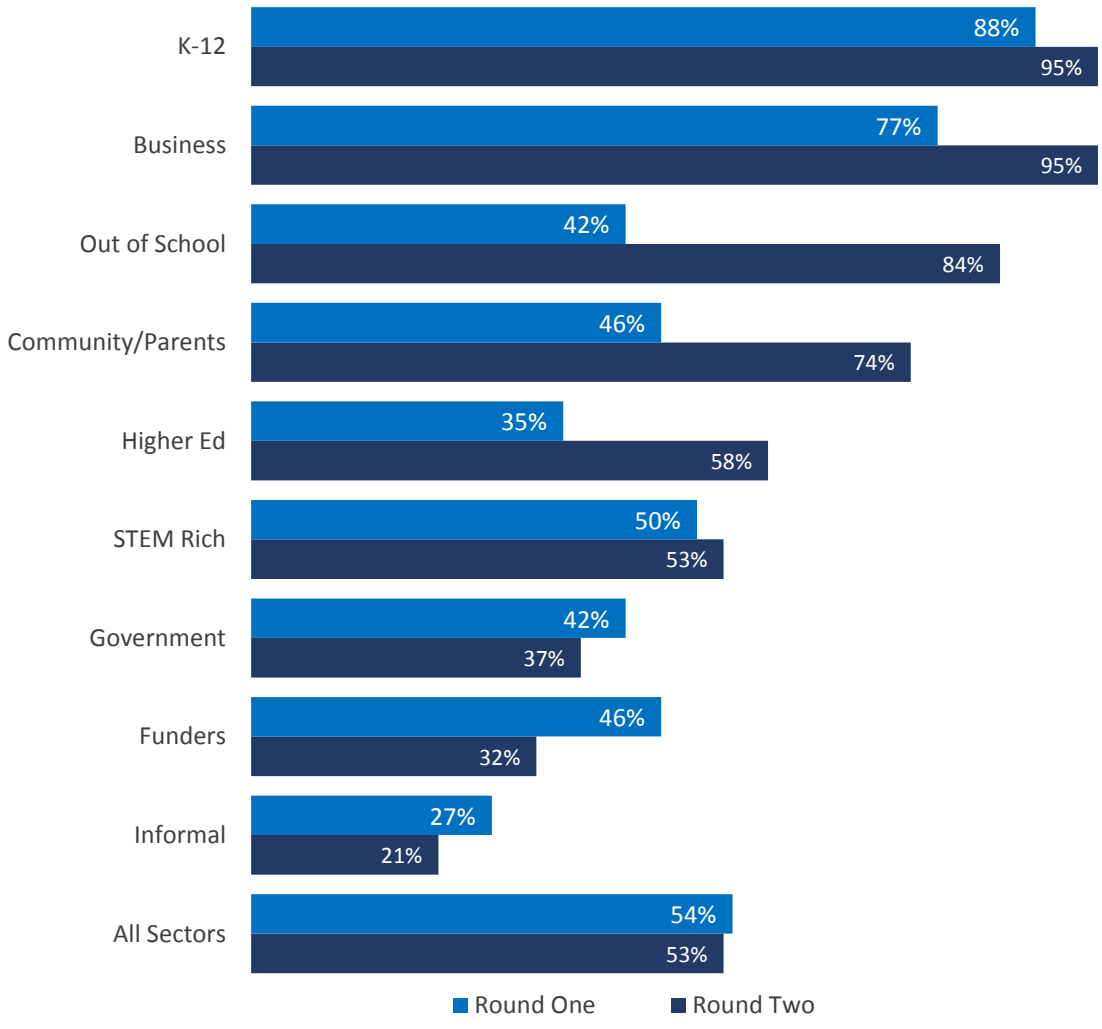
Round Two

43	19	9	2
Implementing	Commentary	Developing	Evaluating

In all, 19 partners perceived cross-sector partnerships as important for doing ecosystem work in the round two interviews. These 19 partners represented 19 different ecosystems. The results, shown in Figure 4, reveal that 95% of partners think K-12 and business partnerships are important. These findings are consistent with the round one interviews. However, the OST and higher education sectors moved up considerably from round one to round two, from 42% to 84% of partners who advocated for OST's ecosystem participation and from 35% to 58% of partners who discussed the

importance of higher education in their ecosystems. In contrast, the funders sector moved down, from 46% of partners who emphasized partnerships with funders to 32% who identified funders as important for doing their work. This decline is noteworthy given that funding is a foundational factor. Ecosystems should consider inviting more funders to be ecosystem partners. This may increase the visibility of the ecosystem and attract additional funding. Fifty-three percent of partners discussed the importance of all sectors being involved in their ecosystems, which was nearly identical to partners' responses from round one.

Figure 4: Partners viewed K-12 and business' presence as most important to carry out local ecosystem work



Sources: Round one interviews, N=30; Round two interviews, N=21

Partnerships had a substantial increase in the implementing (from 20 to 43 quotes) stage and decreases in the developing (from 28 to 9 quotes) and commentary (from 24 to 19 quotes) stages from the round one to round two interviews. The higher incidence of implementing suggests that ecosystems are now largely doing the work of promoting collaboration across sectors.

As in round one, we explored the reasons *why* partners viewed connections between specific sectors as being important. Since OST and higher education moved up in the percentage of partners that cited these sectors as important for their ecosystems, this warranted a deep dive into the relationships described between OST, higher education, and other sectors.

OST Partnerships

According to partners, there is no one reason why connecting with OST is important. Instead they offer a multitude of examples illustrating the varied roles that this sector plays in the ecosystems.

Partners reported that connections between OST and other sectors are used to:

- Provide PD, resources, and programming to K-12.
- Coordinate efforts between educational providers (K-12 and OST).
- Facilitate community groups' work with students through a summer intensive program and in the afterschool space.
- Provide low-cost or free membership to STEM-rich organizations for OST programs.

Ecosystem Vignette: Committed K-12 & Business Partners

One ecosystem exhibits a strong connection between the K-12 and business sectors. The leadership team is solely comprised of partners from each of these two sectors, and they are uniquely committed to the economic development of the region. Each member shows their commitment by contributing an annual membership fee, actively participating in quarterly meetings, and sharing resources with the full group. In the observed meeting of the leadership team, a business partner informed the group of a mobile fabrication lab, previously used for training employees, which his company would bring to interested schools so that students could launch design activities. By using this lab, students would be working with the same materials as STEM professionals and potentially experiencing similar design challenges.

Partner's Perspective

"The sustainability plan is to grow our base of public schools and community members on the [leadership team]. [One new business member] is real big, it's a new employer in [a local county], but it's a pretty high-tech employer that have good paying jobs. You know, develop those relationships…"

- Connect OST programs with corporate partners to introduce students to STEM careers.

According to the National Research Council, productive STEM OST programs leverage community resources and partnerships and provide additional STEM learning opportunities for students.[10] The findings above illustrate how OST partners are making these contributions to local ecosystems. In addition, some partners expressed the value of asking OST for input in their ecosystems' development. Thus, the OST sector is seen as important not only for its connections with other sectors, but also to inform the ecosystem work as a whole.

Partnership Between OST & K-12

According to 16 (76% of) partners, ecosystems have connections between in-school and OST entities in place, and some partners are beginning to evaluate the effectiveness of the collaborations. The emergence of the evaluation theme suggests that a few of the connections between the two entities are well-established enough for partners to measure effectiveness.

When describing links between in-school and OST entities, nine (43% of) partners emphasized the importance of aligning curricula and activities. The purpose for alignment varied, but some reasons cited include increasing the quality of OST programs through educator collaboration, to reinforcing learning for young people, and supporting a unified vision. One partner described how the connection between in-school and OST learning is essential to the ecosystem work:

"I think in the future for our planning is the connectedness [between in-school and OST] and through the ecosystem work we [have] become more enlightened and aware of the importance of aligning our afterschool, our summer school and our commitment to other types of learning extension beyond school work."

Another partner emphasized the importance of academic integrity within OST programs:

"And it's developing community partnerships to support learning and also working with our informal institutions to ensure, you know, the academic integrity of what they're doing and connecting this back to the school district."

It is clear that the purpose of connecting in-school and OST experiences is to ensure touch points with students are maximized; however, ecosystems have different approaches and desired outcomes for making those connections.

[10] National Research Council. (2015). *Identifying and Supporting Productive STEM Programs in Out-of-School Settings.* Committee on Successful Out-of-School STEM Learning. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Higher Education Partnerships

For the higher education sector, partners also talked about collaborations with different sectors. For example, partners discussed the collaboration with K-12 for STEM programming and mentorship. Specifically, partners described the importance of:

- Higher education and K-12 teaming up on how to create Makerspaces in every school.
- STEM camps as a collaboration between school districts and community colleges.
- Higher education engineering majors engaging in STEM programming and mentoring middle school students.
- College students mentoring middle and high school students who are interested in a STEM pathway.

In addition, partners mentioned relationships between higher education and the business sectors as important for bringing internships/scholarships to college students and for providing professional development to teachers. The link between higher education and families was described as well in order to connect families to resources.

Partners also talked about barriers to getting higher education involved in the ecosystem, as well as the value of having an ecosystem member whose sole job is outreach to bring in underrepresented sectors, like higher education.

Partnership Between Higher Education & OST

Both OST and higher education were mentioned as connected to each other and sometimes with other sectors in the partners' round two interviews. Partners provided these examples of the OST and higher education sectors working with one another:

- Higher education and business working with students in summer camps.
- Higher education students helping out with afterschool programs.
- Masters students receiving PD so they can teach in future summer STEM camps.

In conclusion, OST and higher education were discussed by a much higher percentage of partners from the round one to the round two interviews. Partners perceived these sectors as having vital roles in the ecosystems overall. Results indicate that OST and higher education play a variety of roles within the ecosystems – collaborating across many different sectors and with each other.

Leadership

A person or organization that directs the work of the ecosystem and contributes to the development of an ecosystem.

Round One

35	5	4	0
Implementing	Commentary	Developing	Evaluating

According to ecosystem partners in 16 (or 62% of) interviews, strong leadership is important for moving the work forward in their ecosystems. These partners represent 16 (or 62% of) ecosystems. In 35 quotes, partners reported having a lead person or organization that contributes to the development of the ecosystem, while partners mentioned developing ecosystem leads in four quotes. In five quotes, partners spoke about leadership rhetorically, mostly in ways that described strong leadership as a need. Ecosystems were required to identify a leader in their initial applications to be part of the national effort and this may have contributed to the prominence of leadership. Perhaps most notable is the absence of quotes in the evaluating stage; no ecosystem partners reported they are evaluating the effectiveness of their leader(s). While it is clear that partners view leadership as important, partners from only three ecosystems identified leadership as a strength in their applications, indicating there is room for leaders to grow.

Leadership Responsibilities

Research suggests leaders of collaborative partnerships play a substantial role in organizing and managing activities, which aligns with our findings.[11] When describing leaders, community partners highlighted the following responsibilities:

- Connecting – convening partners and fostering relationships
- Managing – giving direction and employing strategies to attain goals and the larger vision
- Organizing – structuring meetings including setting agendas
- Funding – obtaining fiscal resources

Figure 5 displays how often each responsibility was described in ecosystem partner interviews.

[11] Roussos, S. T., & Fawcett, S. B. (2000). A review of collaborative partnerships as a strategy for improving community health. Annual review of public health, 21(1), 369-402.

The most frequently reported responsibilities of leaders by ecosystem partners are connecting and managing (See Figure 5). This may indicate that ecosystem partners appreciate a point person or organization responsible for providing direction. A clear direction allows others to better understand how they can support the ecosystem.

Leadership in Practice

In one ecosystem, the leader demonstrated the role of building connections by organizing a local convening. In another ecosystem, the lead organization demonstrated management by creating subgroups responsible for overseeing the ecosystems' focus areas (e.g., building educator capacity, connecting businesses and schools).

One community partner described a leader as someone who ensures work progresses, which falls under managing:

"[A leader is] someone who can herd the cats, keep the agenda moving, review progress, chide us when we're not making progress if things are slowing down."

Another community partner and ecosystem lead described the many facets of their role, including convening, managing, and funding:

"I see my role as nurturing relationships between the partners, documenting the work that we've done, and I also have to write grants or work with others to partner in writing grants to ensure that we grow our ecosystem."

According to partners, lead personnel and organizations have four core responsibilities. To ensure the work of the ecosystem progresses, it may be beneficial for ecosystems to provide funding for a designated person to serve as the leader.

Round Two

42	3	2	0
Implementing	Rhetoric	Developing	Evaluating

In round two interviews, 18 (86% of) partners mentioned leadership as important. Similar to round one interviews, partners who participated in second round interviews reported they have a leader in place. In the 42 quotes in the implementing stage, 17 (81% of) partners described the current responsibilities of their leaders.

Also, similar to findings from round one interviews, no partners mentioned they were evaluating the effectiveness of their leaders.

Leadership Responsibilities

In round one interviews, partners reported the most prevalent responsibilities of their leaders include connecting and managing. While those responsibilities were still the most prevalent according to partners in round two interviews, the prevalence of the responsibilities of organizing and funding increased. Additionally, a new theme emerged: evaluating. According to five partners, it is the leader's responsibility to evaluate the effectiveness of their ecosystems' programs and initiatives. Figure 5 illustrates leaders' responsibilities mentioned by partners.

The emergence of the evaluating theme may be a result of ecosystems' interest in understanding their own progress. Also, as mentioned above, funding is important to most ecosystems partners. Because funders often desire evidence of program effectiveness to make funding decisions, leaders may be striving to gather that evidence in order to attract their attention.

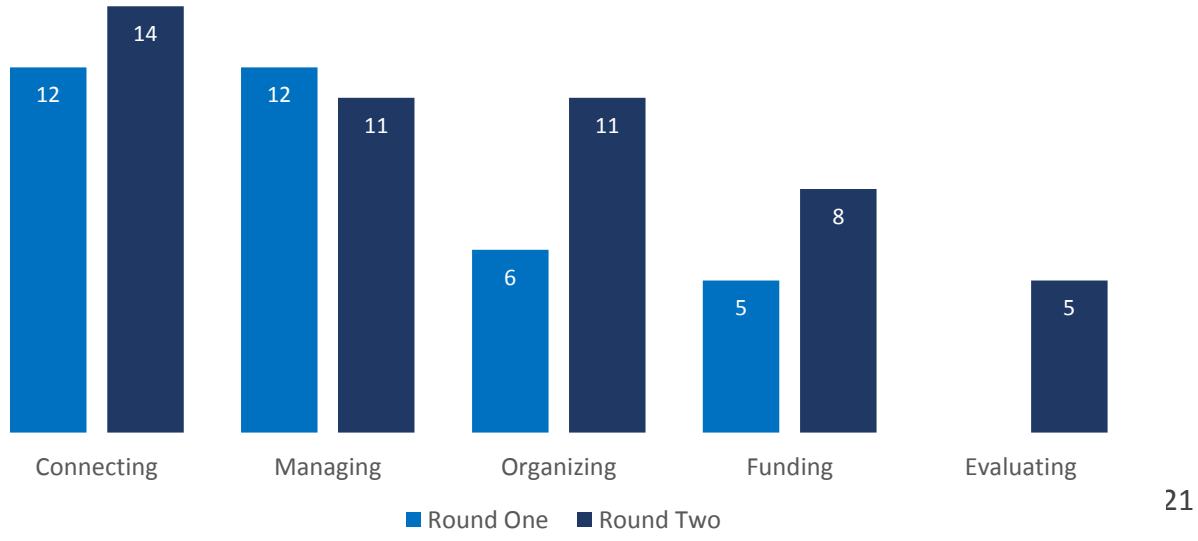
Ecosystem Vignette: Passionate Leadership

One ecosystem has developed a structure with a designated, passionate leader who has engaged foundational partners and sponsors. The partners and sponsors pool resources to generate programs based on their collective priorities. The leader's role is to connect and convene people that will take up the work.

Partner's Perspective

"[The leader] builds a connection in the ecosystem, he starts conversations, he provides support, he checks in to see if we have questions, he attends meetings periodically to provide input, to keep us motivated and stuff, offer his perspective, he creates opportunities for collaboration by hosting events."

Figure 5: Partners view the primary roles of leaders as connecting partners, managing collective work, and organizing logistics



Sources: Round one interviews, N=30; Round two interviews, N=21

Leadership in Practice

In the second round interviews, as compared to the first round interviews, partners spoke about connecting in more detail. Rather than building relationships to recruit new ecosystem partners, partners described how they make connections with purpose and across larger geographical areas. One partner shared how they intentionally connect current ecosystem partners to others at the regional, state, and national levels:

"We have a vast array of partners that we can easily connect different organizations to that might not know one another. So, we have an understanding that it's not only our local STEM community but also throughout our region, our state and nationally because our organization connects to national opportunities. So, we are able to connect other partners who don't have the opportunity to get some of those national meetings, we bring back that information and share that broadly."

In the first round of interviews, the responsibility of managing the ecosystem was primarily described as developing systems and plans. In the second round, partners described how systems are in place, but the architecture is being refined. One partner described how they consistently reflect and grow:

"What we're doing is developing systems and structures for sustainability…We do a lot of reflecting on our work and what did we build or design over the last year and how do we now imbed it for sustainability. How do we continue to cultivate leadership in each of the areas that we're designing and growing in for that sustainability so that we can continue to pass the torch and I think part of it is the fact that we have identified sets of goals, vision, mission and so this is not shelf art, it's actually a living, breathing part of who we are."

Lastly, leaders have started to evaluate effectiveness of programs and initiatives. One partner mentioned evidence of effectiveness helps keep people at the table:

"Data, I think it's my job to make sure that we measure the impact of what we do and communicate it effectively to all of our audiences which would include funders, government, education, parents, students, you know they all need to know what the results are and sometimes they need to know it in a little bit different format but the basic need to know if what we're doing and how it's working is really important to keep [partners] at the table."

Based on findings from the implementation stage, ecosystem leaders continue to have a wide range of responsibilities, but partners described responsibilities of their

leaders in more targeted ways. This may mean that structures and partners are in place, and leaders are now striving to think more strategically to broaden the impact of the ecosystem.

Pathways

Promoting children's and youths' interest and knowledge in STEM concepts and/or STEM careers.

Round One

15	11	3	2
Commentary	Implementing	Developing	Evaluating

Eighteen out of 30 (or 60% of) ecosystem partners discussed fostering students' interest in and understanding of STEM topics and/or occupations in the interviews. Partners represented 14 local ecosystems. In addition, 56% of ecosystem leaders referenced STEM pathways in their purpose statement included in the ecosystem applications.

The interview findings reveal that across multiple stages, there was some consistency in the way that partners discussed student engagement, student mentorship in STEM, and STEM partnerships and programs. However, there were some key differences, particularly between the commentary and implementing stages. Partners who discussed pathways as commentary emphasized the importance of pathways for workforce development and increasing student engagement to develop a STEM pipeline. In comparison, partners who mentioned pathways implementation in their ecosystems spoke about engaging youth in STEM programming for workforce development and promoting pathways through partnerships between business and K-12.

Commentary Stage

Under commentary, ecosystem partners provided examples of the *importance of workforce development efforts* at both a global and local scale. One partner raised the concern of the need to compete globally:

"As a country we are and should be concerned about our status in the global economy and certainly STEM is a part of what we need to increase in terms of achievement in our students and also to really keep competitive globally."

Another partner brought the issue of workforce development to the region and discussed training local students for local jobs. This partner described a local need in the ecosystem to fill positions in the high-tech industry. The partner commented that companies bring in workers from other countries since the local university does not produce enough graduates in the tech field.

Implementing Stage

In contrast, ecosystem partners already engaged in implementation efforts discussed *running programs* and *developing partnerships* as a means to foster STEM pathways. One partner described the role of programming as being influential in driving student interest in STEM:

"A few years ago we started moving into youth programming and more intentionally moving into STEM programming and we really saw, we see the influence of STEM in terms of, sparking interest in the STEM subjects…[and], students getting interested in STEM careers, and ultimately for work force development effort because we want to make sure that the companies in the region need STEM workers have STEM workers to choose from."

Several partners also made the specific connection between *schools and companies* to further this goal. As discussed above in the partnership critical factors section, partners viewed the link between the business and K-12 sectors as important for doing ecosystem work. A partner described the active role of businesses in schools:

"We've had students obviously shadow, we do that all the time, we've been doing that for a long time. But that exposure is brief and it's a first step. We've had our folks in the classroom as knowledge experts or working with teams either in developing projects, training students on say Google Sketch Up."

Ecosystem Vignette: Student Engagement with STEM Careers

One ecosystem has a strong focus on workforce development. The stated mission of the ecosystem is to raise a local, skilled STEM workforce. To support the mission, the ecosystem created a three-phase STEM workforce process for students that leverages school and community resources to expose students to STEM careers, provide mentorship to students, and offer students certifications, internships, and fellowships.

Partner's Perspective

"So the, the idea is that we're trying to work inside the school day initially, that's what we've been at. Up until now, that's all we've done, is we've gone in and we're trying to put in exploratory STEM education back into upper middle school, even down to sixth grade and begin the engaging process of the career pathway."

In conclusion, the ecosystem partners recognized STEM pathways as being important to the work that they do, regardless of the stage of implementation of this critical factor. Running programs and developing partnerships, particularly between the K-12 and business sectors, are approaches that ecosystem partners use to develop pathways for children and youth.

Round Two

29	21	9	4
Implementing	Commentary	Evaluating	Developing

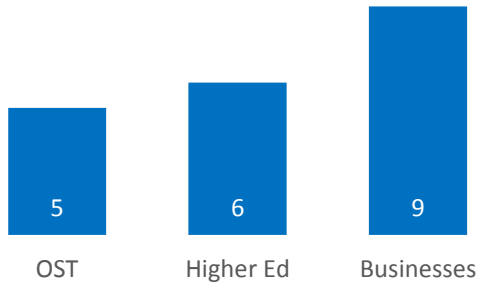
In second round interviews, 19 (90% of) partners mentioned the development of career pathways as important. Twelve (57% of) ecosystem partners described implementing pathways 29 times in round two interviews. A larger percentage of partners discussed pathways in round two than in round one interviews. This may indicate there is more of a push to establish career pathway programs or initiatives. In nine quotes ecosystem partners described their efforts to evaluate those programs in second round interviews; evaluation was only mentioned in two quotes in first round interviews. This may mean their ecosystem partners have started to evaluate pathways programs and initiatives.

Pathways Partnerships

In general, ecosystem partners understand that creating pathways programs and initiatives must be a cross-sector effort, which is a strategy supported by prior research on STEM Learning Ecosystems.[12] In describing sectors involved in carrying out pathways programs and initiatives, nine (43% of) partners mentioned business, six (29% of) partners mentioned higher education, and five (24%) mentioned OST sectors. Figure 6 displays the number of partners that described the sectors as important.

In the first round of interviews, five (17% of) partners mentioned the importance of businesses partnering with the K-12 sector to implement pathways programs. In the second round of interviews, that number grew to nine (30% of partners). Both the number of partners who emphasized business as partnering with the K-12 sector to create pathways and the number of partners who emphasized businesses partnerships in general increased in the second round. This may mean partners have focused their efforts on using pathways programs and initiatives to engage more business partners.

Figure 6: Partners engage with businesses, higher education, and OST entities to create pathways programs



Source: Round two interviews, N=21

[12] Traphagen, K., & Traill, S. (2014). How cross-sector collaborations are advancing STEM learning. Los Altos, CA: Noyce Foundation.

Target Groups

Eleven (53% of) partners reported they strive to develop career pathways for certain target groups defined by race, socio-economic status, gender, or grade level. One partner explained how a mentor program targets girls:

"We found eighty mentors for girls in our schools, which we ended up mentoring over four-hundred girls this year for twenty hours a piece around the importance of succeeding in STEM, pursuing careers in STEM, etcetera. And so that was a result of the ecosystem work as well."

Another partner emphasized the importance of engaging middle school students in STEM:

"We do [a banquet] which is a 7th grade banquet honoring students who've shown promise or interest in STEM and we invite STEM professionals…because we want them to see at that…critical age that we have identified them as having 'it'– the STEM 'it' and…that we aren't going to take our eyes off of them."

Other partners emphasized the importance of engaging students living in poverty. Although the target groups differ across ecosystems, partners clearly focus their efforts on reaching students who are members of specific underrepresented groups and grade levels.

Overall, partners are collaborating with businesses, higher education representatives, and OST providers to develop and implement pathways programs and initiatives.

Educator Capacity

Developing well-trained and/or skilled educators in any/all sectors (e.g., in and OST, post-secondary/higher education, and business sectors) work to increase the quality of STEM education for students.

Round One

10	9	8	2
Implementing	Commentary	Developing	Evaluating

Fourteen partners from 11 ecosystems mentioned building the capacity of educators in some/all sectors as a factor that contributes to the success of their ecosystems. In ecosystem applications, seven ecosystems identified training educators as a need of their ecosystems. Additionally, in applications, 33% of ecosystems identified "equipping educators" as a strategy they planned to focus on in the first year of the Initiative. Although one third of ecosystems claimed they would prioritize this critical factor at the onset of the Initiative, at the time of interviews, partners did not show very significant progress toward achieving these goals.

In round one interviews, partners discussed the notion that high-quality STEM education was achieved through well trained educators (K-12 and/or OST). Providing resources and professional training in the form of professional development (PD) programs was the most commonly discussed strategy. Seven of 14 partners saw a need for PD in their ecosystems (whether for specific sectors or in general), while eight partners identified PD programs that were already being developed or implemented in their ecosystems. Research suggests educators can better help students to navigate STEM learning opportunities when they are attuned to what other educators are doing.[13] Aligned with the research, one PD strategy valued by two partners from different ecosystems was peer-to-peer learning, in which teachers learn from other teachers with expertise and training in STEM subjects. One partner said about their peer learning PD program:

"Everything is all taught by teachers that we call master teachers who have been in the classroom a long time, love it, enjoy science, and or whatever path they have chosen I guess. And so, they're proven, quality teachers that know how to engage students and so they teach their class like they're teaching kids so they're demonstrating the best skills and how

[13] Brevan, B. (2016). STEM learning ecologies: Relevant, Responsive, and Connected.

to do it and the various activities to get across at a particular point of science or math or engineering or technology that meet the students' need."

Even though PD was viewed as an important part of building educator capacity, five out of 14 partners mentioned that PD is either wasted or not provided due to policy or curriculum barriers, (i.e., teachers do not know how to integrate STEM experiences into already set curricula or standards based curricula do not support creative teaching). One partner described this issue:

"So we might say why don't we teach more engineering in schools, that might be a problem. That's a problem of practice or something that we identify. Root causes could be a teacher's professional knowledge, could be not enough time in the school day you know, but really when you dig down deeper and deeper we might find out that it's really district policy [that] is the driving force or the root cause behind all of these other superficial causes that we see and that's really where change then needs to be instituted."

Initial applications indicated partners viewed educator capacity as a need and interviews showed that partners *tried* to build the capacity of educators to teach STEM. Existing and developing professional development programs show promise, however many partners had not yet developed a plan for achieving high-quality STEM education through well-trained educators.

Round Two

25	6	4	2
Implementing	Commentary	Developing	Evaluating

Eighteen partners from 18 ecosystems continued to see educator capacity as a factor that contributes to the success of their ecosystems (up from 14 in round one). In the first round of interviews, many partners indicated they needed to build educator capacity in their ecosystems, but few described strategies or existing programs to support these goals. In second round interviews, partners revealed that they had gained significant traction on their goals of increasing and expanding professional development (PD) programs in their ecosystems.

Ecosystem partners continued to view high-quality STEM learning as a function of high-quality instruction, but the transition from identifying goals around PD, to implementing and expanding upon a variety of PD programs was the most revealing finding. With regards to stages, educator capacity had a substantial increase in the implementing stage (from 10 to 25 quotes) and slight decreases in commentary (from 9 to 6 quotes) and developing (from 8 to 4 quotes) stages from round one to round two interviews. The higher occurrence of the implementing stage in round two suggests that ecosystems are significantly increasing resources and access to PD for educators across sectors.

The discussion of the round two findings is a deep dive into the commentary through implementing stages, as there were clear trends associated with these stages. Very few partners in round two, as in round one, discussed the evaluating stage. When they did, partners described plans for evaluation not results.

Commentary Stage

At this stage, partners primarily discussed goals and barriers to building educator capacity. Whether it be time or resources, the barriers described by partners constrained their ability to make progress towards their goals. Compared to round one, fewer quotes were included in this stage, which shows a transition from placing value on PD and identifying goals, to putting plans into action.

Developing Stage

Partners continued to describe goals and barriers to educator capacity at this stage, but three partners also identified plans to implement PD programs in their ecosystems. One partner described an exciting program that is in its "infancy":

"A cool thing that we just started, it's in its infancy, it's providing all virtual and real resources for teachers to do a better job with STEM education and one of the things that we're really excited about are STEM carts. And so,

Ecosystem Vignette: Professional Learning Opportunities for Educators

Conference
In August 2016, three leaders from one ecosystem facilitated a 5-day conference for teachers across nineteen districts in the region. Participants actively engaged in inquiry-based learning and reflection. The conference focused on building knowledge of STEM topics and strengthening educator collaboration, with the ultimate goal of exposing more students to STEM.

Externships
Another ecosystem has a variety of programs designed to build educator capacity. One program uses externships that allow teachers to experience the work of a STEM professional first-hand. The goal is to expose participating teachers to the real-world demands of a STEM job so that they can help students to build the types of skills needed to excel in STEM positions.

these will be actual, physical carts that will be placed in elementary school libraries and they'll have 10 STEM lessons on them with everything it takes to do the lesson and a well-written lesson that will provide YouTube for the teachers of what's on there… [Teachers] can go right down the hall to their own library and grab the STEM cart and know that… [they] have everything that's needed to do that lesson on the cart and that it's aligned to their State Standards and it's synced up to their paging calendar, then we have a really good shot at increasing access for all students to STEM education. So, that's a thing that we're really excited about."

Implementing Stage

Fourteen partners from 14 ecosystems identified PD programs that are currently operating in their ecosystems (up from 8 in round one). There were several note-worthy aspects of these programs. Seven partners described cross-sector collaborations as components to their PD programs. This meant that educators from two or more different sectors were collaborating to receive or provide PD programs, a strategy identified as effective for building educator capacity.[14] In one ecosystem, for example, businesses are providing externships for teachers to learn from current STEM professionals and offering ways for teachers to bring what they learned back to their classrooms:

"Teachers go out and do externships [or] they [have] internship[s] with companies and employers…we're actually the largest pilot program the state [has]… And we get the teachers out in the summer, out with companies. […] We've got different levels. Some we have individual grants where professors go out with [STEM professionals] and then [the teachers and professionals] go out and visit a site and come back and write lesson plans in the afternoon. […] What we started with the governor's office this year, is we do five days, but we require [teachers] to get [certification] from a community college, which is a partner. And then they go back and they do their five days and they write lessons plans, and then they go back to our department with instruction to be kind of put into a consortium that can be shared out to the state."

Peer-to-peer learning continued to be a strategy five partners utilized to provide PD to their educators. Finally, four partners identified "foci" of their PD programs. For example, three partners expressed a value for providing training on inquiry-based learning for their educators.

In sum, it is evident that at the time of the second round of interviews partners were improving access to PD programs and

[14] Traphagen, K., & Traill, S. (2014). How cross-sector collaborations are advancing STEM learning. Los Altos, CA: Noyce Foundation.

resources for educators in an effort to build their capacity. The transition from expressing a need and goals around the critical factor to actually developing and implementing PD programs in their ecosystems is noticeable from round one to round two.

Mission

A clear, "shared vision for change" [15] that directs the work of the ecosystem.

Round One

17	8	8	0
Developing	Commentary	Implementing	Evaluating

Experts on collective impact initiatives find a common vision to be critical for success.[16] Fifty-three percent or 16 of the ecosystem partners cited a clear and shared mission as important for the development of the ecosystem. These partners represent 12 unique ecosystems. They described how a mission might evolve from commentary to implementation. No ecosystem had begun to evaluate progress toward the stated mission.

Commentary Stage

In the commentary stage when there is little more than an acknowledgement of the importance of a mission, partners saw the mission as providing direction for the work of the ecosystem, and they wanted to devise the mission in concert with other local partners. The quote below highlights the desire to convene mulitple partners as well as establish a direction for the ecosystem.

"That taskforce is comprised of educators K-12, post-secondary, business, public policy people, state agency people, museums, program providers, etc. and the idea was originally for this group to help set the direction and priorities of the afterschool world in [the state] in regard to STEM education."

Developing Stage

As ecosystems moved to the developing phase with their mission, ecosystem partners began to pinpoint the connections between the work of individual partners and the larger ecosystem. This tendency is described in more detail in the findings on interest, a separate critical factor. Partners also began to set collective goals. One ecosystem partner makes apparent how the mission and goals complement one another:

"Success for our ecosystem, and probably others, is having a clearer

[15] Kania, J., & Kramer, M. (2011). Collective impact. *Stanford Social Innovation Review, 36 - 41.*
[16] Ibid.

mission and vision…having identifiable common goals that everyone in the ecosystem understands and understands how their organization or them as an individual contributes to reaching those goals."

Implementing Stage

Those ecosystem partners who had already articulated a mission are considered to be in the implementing phase. They reported using multiple methods to ensure that all partners understood and could contribute to that mission. Some partners emphasized coordinating in-school and out-of-school STEM opportunities, while others had a more general plan to align partners' efforts with the ecosystem's mission. This partner felt that the time spent soliciting buy-in from partners was a smart investment:

"I think the work we've done with getting organizations kind of behind our vision has been super beneficial you know because around the state you have [many] different educational organizations out there, it's next to impossible to be able to connect with all of them."

In sum, the ecosystem partners saw the mission as guiding their work together and believed that developing the mission is a collaborative endeavor that entails making explicit the connections between partner's areas of expertise and the shared mission. To do this successfully, partners emphasized the need to intentionally cultivate buy-in.

Round Two

13	8	3	0
Implementing	Commentary	Developing	Evaluating

In round two interviews 12 ecosystem partners (57% of interviews) referenced a mission as essential to the development of the ecosystem. Each of these partners represented a different ecosystem and described their mission as being in the implementing phase more often than any other stages. This represents a shift in the way that partners described their mission in round one interviews. At that time, it was more common for ecosystem partners to acknowledge the importance of mission as indicated by the frequency of commentary quotes. The progression of a mission from commentary to implementing was present in round two interviews but it was much less pronounced than it was in round one interviews.

Commentary Stage

In round 2 interviews, ecosystem partners continued to perceived the mission as providing direction to their work and building consensus among diverse ecosystem stakeholders.

Developing Stage

Ecosystem partners rarely discussed their mission as being in the developing stage, however, when they did it was apparent that partners were still focused on the connections between the work of individual partners and the larger ecosystem. The critical factor, interest, describes in more detail partners' desire to align the work of individual partners with that of the local ecosystem. The quote below illustrates one partner's plan for connecting ecosystem partners in service of developing a mission.

"So we are really identifying anybody that wants to be engaged in STEM education and how they can be involved. So, that's goal one. Goal two is the development of the mission statement and then goal three is the creation of smaller work groups."

Implementing Stage

Ecosystem partners who discussed their mission as being in the implementing phase had begun to engage in coordinated work around their missions and/or used their mission to help them set clear goals. One ecosystem had structured their work to use both of these strategies. This ecosystem includes 11 regional hubs. Each hub has the flexibility to develop relevant local goals. The ecosystem partner states:

"We have a strategic plan that the hubs have contributed to. We also have outcomes for partnerships that we co-constructed with members of the field in different regions. When we determined statewide outcomes that we're going to track we tend to

Ecosystem Vignette: Communicating a Clear Mission

One ecosystem has clearly articulated the mission to members. One way leaders keep the mission at the forefront of the work is by printing it on all documents distributed to members. The mission of the ecosystem focuses on quality STEM education, college and career readiness, and STEM literacy. Furthermore, the mission is refined as needed to fit the needs of the ecosystem.

Partner's Perspective

"Well again, the mission of the [the ecosystem] is to develop educational outcomes for our students, for our children, in the STEM areas and through that enable and provide a wider range of opportunities for successful pathways to college and career."

pull from overlap that the regions are actually interested in, but they do have very different needs and different local contacts."

This partner makes it clear that the 11 hubs developed their outcomes together, despite unique regional needs, and goes on to share how the ecosystem uses statewide outcomes to track the hubs' progress toward these shared goals.

In conclusion, a similar percent of ecosystem partners in round one (53%) and round two interviews (57%) cited mission as a critical to the development of an ecosystem. Ecosystem partners continued to emphasize the need for collaboratively developing the mission and using it to guide their work together. More ecosystem partners discussed their mission as being in the implementing phase, during which partners established share goals and embarked on coordinated work.

Community

The larger community is actively engaged in raising the awareness and quality of STEM learning opportunities and increasing access to these learning experiences. This may include community events, parent education, and STEM advisory councils.

Round One

15	10	5	0
Commentary	Implementing	Developing	Evaluating

Half (15) of the ecosytem partners, representing 12 ecosystems, stated that authentically involving the larger community would contribute to the success of their ecosystems. Partners tended to talk about the community as parents and their children. Notably, in ecosystem applications completed at at the beginning of the Initiative, no ecosystem partners clearly identified family engagement as a strength and four ecosystems cited it as a need. As shown in Figure 7, ecosystem applications indicate that at the beginning of the year, community and family organizations were the least represented sector among established partners. Only nine ecosystems reported engaging with this sector.

Stages Overview

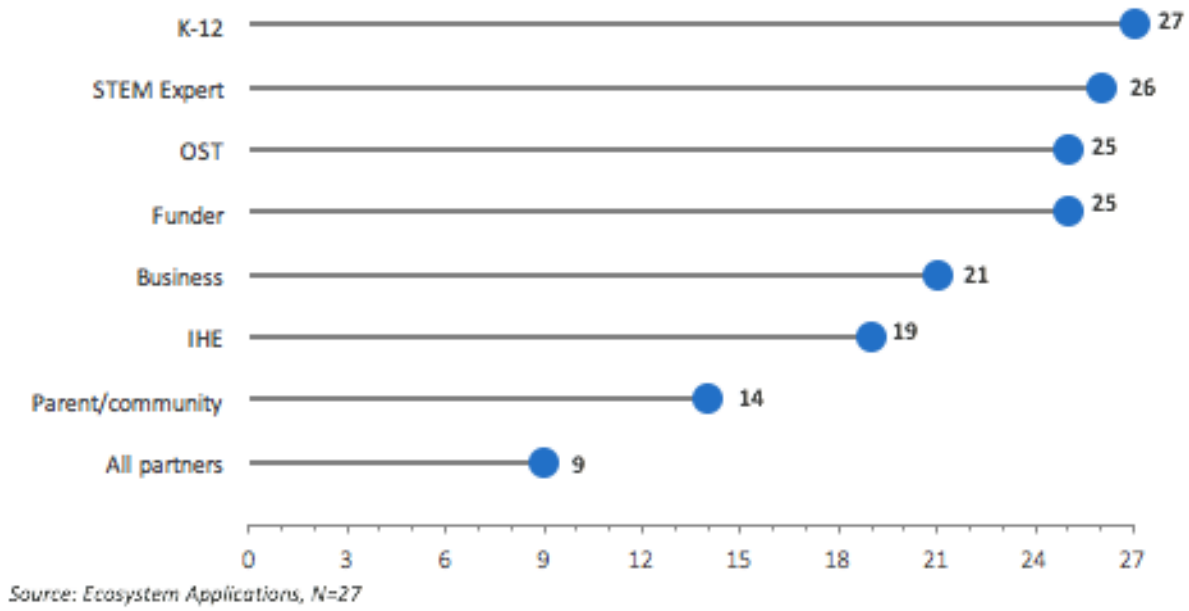
As indicated by the number of quotes classified as commentary, some ecosystem partners recognized the need for community engagement but had yet to move into action. One partner commented that community engaement was the last phase of a three-phase strategic plan. This stands in contrast to one ecosystem partner's view that a sustainable ecosytem must, "belong to the commmunity", stay attuned to community needs, and remain responsive to those needs.

At the same time, ecosystem partners in the implementing phase discussed strategies they used to boost community involvment. Interacting with community advisory councils, interviewing parents to hear their perspectives on STEM, and partnering with community development organizations that offer STEM learning opportunities are examples of ways that ecosystems involve the community. However, no partners indicated that they were evaluting the effectivness of their chosen strategies.

Engaging Parents and Students

Parents, as mentioned previously, were a focus of community engagement efforts. Ecosystem partners wanted to increase awareness of the importance of STEM among parents. They also wanted parents, as well as community members and students, to know which STEM learning opportunties were available in their surrounding area. One partner noted the demand from parents in her city for STEM learning opportunities stating,

Figure 7: Nearly all ecosystems are partnering with K-12, STEM experts, and OST providers



Source: Ecosystem Applications, N=27

"The larger context that we stumbled into through [the] families we were talking to and through work that we were doing in neighborhood schools was on the part of parents the real desire and need for much more in the opportunities for learning for their kids. I mean there is just a huge appetite among the residents of [this city]."

Three ecosystem partners shared ways that a greater awareness of STEM learning opportunities could be used by parents. Namely, parents may be exposed to ways they can support STEM learning at home, and parents can learn how to navigate the existing STEM opportunities that will help prepare their child for a STEM career of interest.

While there is a clear desire for parents and students to be involved in the ecosystem, only one ecosystem partner mentioned enlisting the community to help design the ecosystem. The ecosystem is housed at the school district, yet he felt that for the ecosystem to be sustained, it would have to be owned by the community. He said, "we really as an ecosystem have to turn that perception [of district ownership] to say, no this belongs to the community". Another ecosystem partner raised the absence of student voice in designing the ecosystem as an issue. She argues in the quote below that ecosystems are overlooking ideas by not involving students.

"I think there are some groups that aren't represented well. So far where are the students?... Where are the students that are between K-12 they

need to be represented in this conversation?... Let's get them involved in the conversation...from my conversations with kids in the last 4-5 years in the STEM initiatives they have some unbelievable ideas and if we don't take advantage of it we're probably missing something"

Overall, it appears that community involvement became increasingly more important to ecosystem partners over the course of the year. The initial ecosystem applications suggested limited involvement from community and parent organizations, while round one interviews indicate ecosystem partners recognize the value of including the community with an emphasis on parents, specifically. However, very few ecosystem partners view students or parents as contributing to the design of the ecosystem. Those that acknowledge parents and students as ecosystem designers also believe this group may be the key to sustainability and innovation.

Ecosystem Vignette: Strong Student Voice

Through the [STEM student leadership initiative], one ecosystem incorporates student voice into the ecosystem. This initiative is garnering attention from the federal government as an exemplar of how to increase student engagement in STEM. Currently there are 138 students representing 78 schools.

Partner's Perspective

"[STEM student leaders] are kind of like ambassadors for your school or school districts, but toward a STEM-related activity. Like they can help bring business partners and communities together with their student communities and create longer and stronger partnerships between the two."

Round Two

15	5	5	0
Implementing	Commentary	Developing	Evaluating

In round two interviews, 12 ecosystem partners (57% of interviews) from 12 ecosystems felt that engaging the community was integral to the development of their ecosystem.

Stages Overview

Compared to the round one interviews, there are more quotes indicating progress on involving communities as evidence by a decline in commentary quotes and an increase in developing and implementing quotes.

Engaging Parents and Students

In round 2 interviews partners continued to express a desire to engage the community in the ecosystem. Similar to round one interviews, only one partner mentioned inviting community members to help design the ecosystem. One aspect that was different from round one interviews was that four ecosystem partners identified unique strengths of the focal communities and/or shared that the ecosystem was attempting to meet the needs of the community. For example, one partner stated that they were going, "to be much more intentional in the linkage between the community-based work, the school work and what could be reinforced in the home setting" in neighborhoods where a large portion of academically struggling students lived according to school district data. The increased emphasis on community strengths and needs suggests that ecosystem partners had a deeper knowledge of the community as it relates to STEM education.

Promoting awareness of STEM among parents and students was also still a priority for ecosystem partners. Since more partners described their ecosystem as implementing, there were more robust examples of how ecosystems raised STEM awareness among parents and students. One partner connected with a local parent group to host a STEM awareness event for parents:

"We engaged with our parents' support group locally…And together with all of our core partners, we held an event...that was STEM-centric. So, it was kind of a single-day conference style structure for parents to come in and learn what programs are available with the school district around STEM"

Another partner described an event focused solely on the students:

"In the primary grades,…. there are a number of programs that our [public library] holds that provide STEM experiences for kids, engaging hands-on challenges that they can do, and it's free and available to everybody in the community. They even do some outreaching to kind of the, the areas of high-need, where there's low accessibility, by partnering with some of the community-based facilities there."

The quote below describes how multiple programs come together to host an event for both parents and their children:

'And several [programs], I mean some of them are based at the same school so, occasionally they will get…. all of their students together or…recognize each other's areas of expertise. One example is programming at [one middle school] has a family night every spring around the last week of their program and they invite other programs from the ecosystem to run hands-on activities during that family night for parents and siblings and who else shows up."

In general, round one and round two interviews indicate a focus on engaging parents and students with a strong push to communicate the importance of STEM and raise their awareness of available opportunities. The findings from round two interviews also suggest that more ecosystem partners are actively implementing strategies to involve the community.

STEM Literacy

Plans, programs, or services designed to foster STEM literacy in students. Some examples of STEM literacy include sufficient knowledge of STEM to engage in public discussions on related issues; the ability to be careful consumers of STEM information related to their everyday lives; and the skills needed to enter STEM careers of choice.

Round Two

18	9	1	2
Implementing	Commentary	Developing	Evaluating

STEM literacy did not emerge as a critical factor in round one interviews, indicating that ecosystem partners may have shifted their focus towards STEM literacy towards the end of the inaugural year of the Initiative. According to 13 (62% of) partners from 13 ecosystems in round two interviews, STEM literacy is an important aspect of advancing the work of the ecosystem. In 18 quotes, 13 partners described how they are implementing STEM literacy programs and initatives. The limited number of quotes in the developing and evaluating stages suggests programs are in place, but they are not established enough to be evaluated by partners.

Commentary Stage

Four partners (19%) described STEM literacy as a need or priority in their ecosystems. For example, one partner mentioned the goal of the ecosystem is for students to become STEM literate:

"We saw our goals in alignment with the fact that now we would be looking at the attainment of STEM literacy and becoming college and career-ready."

Three of the four partners described targeting their efforts towards historically underrepresented students. For example, one partner said:

"So our preliminary goals of our network, there are four of them. One is to increase STEM interest competency, resources and opportunities among PK through grade 20…students, with a particular focus on our first generation, low income, or underrepresented student populations."

One of the ways ecosystem partners are introducing STEM literacy is by engaging

students in the engineering design process. For example, one partner said:

"I would say that the broader understanding that we have [of] STEM literacy really has more to do with the engineering design process of problem solving and understanding that everything in our world is designed and therefore understanding the processes and having the understanding of the role that the areas of science, engineering, mathematics, technology, the arts may play in that design process for us is, I think, what develops a STEM literacy."

Overall, some partners are prioritizing STEM literacy and focusing their efforts on specific groups or approaches.

Implementing Stage

Community partners are utilizing the relationships with other organizations to cultivate STEM engagement both inside and outside of the formal K-12 school setting, which is a criterion for a productive STEM OST program.[17] Six partners described OST STEM efforts to help students make connections with STEM and the real world. For example, one partner commented:

"Our Boy Scout troops – very connected to a STEM agenda and they also work, they actually came to us probably about three or four years ago about them taking a high interest in STEM. Our YMCA – they run our afterschool programs. We're working now more closely to develop the connectedness of their agenda and our STEM development."

Seven partners (33%) mentioned in-school STEM efforts that support students to improve math and science achievement, develop student "STEM" leaders on campus, and build students' STEM identity. One partner described a program that entails STEM professionals coming on site to work with students on math:

"One that we're really excited about is…a program where we bring STEM professionals into elementary schools to work with elementary age students on basic fact fluency because we see that math is its own language so it's its own literacy - kind of numeracy is literacy kind of a thing."

Lastly, there is a sense of urgency to cultivate middle school students' STEM interests, as middle school is a critical developmental stage when students' competence, beliefs, and interests begin to solidify,[18] and promoting and maintaining

[17] National Research Council. (2015). *Identifying and Supporting Productive STEM Programs in Out-of-School Settings*. Committee on Successful Out-of-School STEM Learning. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

[18] Simpkins, S. D., Davis-Kean, P. E., & Eccles, J. S. (2006). Math and science motivation: A longitudinal examination of the links between choices and beliefs. *Developmental psychology*, *42*(1), 70; Neathery, M. F. (1997).

interest can increase the likelihood of students entering a STEM career.[19]Three partners described the importance of the middle school years for influencing students' interest in STEM. One partner said:

"One of the challenges in formal education is that you pretty much need to have some guidance by about eighth grade because you pretty much map out your high school program in eighth or ninth grade and so if, you know, if you decide – you know, you can't really decide when you're in eleventh grade that oh I want to be a mechanical engineer if you haven't taken kind of the courses that, that prepare you for that pathway."

In conclusion, some partners view STEM literacy as a priority in their ecosystems; most partners described how their ecosystems use in-school and OST settings to advance STEM literacy.

Interest

The goals, programs, and resources of the ecosystem uniquely contribute to the mission, goals or programs of the partnering organization(s).

Round Two

19	9	8	0
Commentary	Developing	Implementing	Evaluating

Interest did not emerge as a critical factor in round one interviews. According to 18 (86% of) partners from 18 eocsystems, the goals, programs, and resources from the ecosystem contributed to their organizations' growth. The round two interview findings suggest the programs and resources made available to organizations by their respective ecosystems initially provide partners with a sense of accountability, but later offer ways to better support their local needs to ultimately enhance their impact. This progression is evident in the quotes from the commentary to implementing stages.

Commentary Stage

In the commentary stage, partners referenced a need to prioritize the development of a common vision and clear goals across the ecosystem, an effective strategy for making a collective impact.[20] Fourteen of the 19 quotes residing in this stage describe the ecosystem as a mechanism for generating a sense of accountability to address the need for alignment. As said by one partner:

"Now [we] have to get our group together and say ok, based on this conversation we got to start to come up with parameters for our own ecosystem of what may be some actionable goals and may be some values that we're trying to uphold within our own group."

Quotes in this stage suggest the goals, programs, and resources from the ecosystem generate a sense of accountability to develop a common vision and clear goals across ecosystem partnerships.

Developing Stage

In the developing stage, partners report a need to document their progress toward set goals, and more closely tune into the needs of their local community. Of the nine quotes in this stage, six directly referenced the need for partners to document their progress toward meeting set goals.

[20] Kania, J., & Kramer, M. (2011). Collective impact. *Stanford Social Innovation Review, 36-41.*

Affirming the need for documenting their progress toward goals, one partner offered:

"To have them clarify for themselves … what's really important to them. Who do they want at the table with them when they decide about what's... in this collaborative to start to give back?"

Similarly, another partner stated:

"I think our original goal was to have an understanding of who is working in the STEM learning space…then developing kind of a shared vision and common language and I think we will get there by having meetings and agreements on what it is we're trying to get accomplished. And then also continuing to build bridges and develop collaborative opportunities that we can share."

Quotes in this stage suggest the goals, programs, and resources from the ecosystem encourage partners to document their progress toward previously established goals.

Implementing Stage

In the implementing stage, partners emphasize the available resources the ecosystem network provides. Of the eight quotes in this stage, four describe how the ecosystem network has supported their efforts, and two describe the ways in which cross-sector partnerships have helped attend to the local needs of their community. Describing how cross-sector partnerships have helped attend to the local needs of a community, one partner stated:

"[A parent-focused program] is one piece. Second piece is we worked very closely to build an effective working relationship with the local school district, which serves…it's the most overcrowded district... It shows the highest percentage of ELL kids and it's really struggling. So, we have identified and we will continue to identity what we are calling sort of high leverage possibilities for struggling learners or striving learners."

These findings suggest that partners use goals, programs, and resources of the ecosystem to support the local needs of a community.

Overall, almost all partners discussed the need to clarify and align their ecosystems' goals with the goals of their respective organizations. Some partners noted the benefits of aligning their organizations' efforts with the efforts of the ecosystem and are capitalizing on ecosystem resources to do so.

Conclusion

According to a sample of partners from the inaugural cohort of the STEM Learning Ecosystems Initiative, there are eight critical factors that are integral to the development of an ecosystem: cross-sector partnerships, strong leadership, career pathways, a clear mission, community engagement, educator capacity, STEM literacy, and the aligned interests of partners. Funding is seen as a foundational factor that can bolster or impede the critical factors.

The four stages – commentary, developing, implementing, and evaluating – demonstrated the maturity of the critical factor. From round one to round two, there was a general increase in the number of quotes in the implementing stage compared to the commentary and developing stages for almost all critical factors. This suggests growth in the critical factors over the course of the year. Leadership was the exception, as a predominance of the round one quotes for this critical factor were in the implementing stage. The number of excerpts for the evaluating stage was nonexistent or low across all of the critical factors in both round one and round two, suggesting that ecosystems have not yet begun to determine or assess outcomes related to the critical factors. This is understandable given that 16 or 59% of ecosystems have been functioning for three years or less. However, demonstrating effectiveness of ecosystems' efforts may become increasingly important for raising funds and cultivating buy-in from partners.

Of note is that cultivating collaboration across different sectors was embedded in the findings about every critical factor. A particularly striking example is the role of partnerships in developing career pathways. STEM workforce development is another cross-cutting theme found to be central to cross-sector partnerships, STEM literacy, and career pathways.

Recommendations

The findings support important recommendations for current and future ecosystems:

- Given that funding is a foundational factor, ensure ecosystem partners have a sustainability plan that is sensitive to the need for short- and long-term operating costs.

- Considering the centrality of partnerships to ecosystems, strategically cultivate partners who can meet the needs of the local ecosystem. For example, if an ecosystem is interested in expanding STEM programming, the leadership may focus on building partnerships with OST organizations. The findings indicate that K-12, business, and OST may be the most important sectors to engage first.

- A more targeted focus on involving students and parents as ecosystem designers is needed, as these stakeholders are the focus of many ecosystems efforts, and they will likely have valuable insights to offer from their experiences.

- A connection with the ecosystem benefited partnering organizations by connecting them to additional resources. Ecosystem leaders should highlight this benefit to promote buy-in from potential partners. As ecosystems move to evaluating their efforts, they should explore how they can adequately document how pooled resources benefit partnering organizations and the populations they serve. This will help to accurately capture the full impact of the ecosystem.

- According to partners, leaders have five core responsibilities including managing, connecting, organizing, funding, and evaluating. Provide leaders with resources and training to help them perform these responsibilities effectively.

- Very few ecosystems are evaluating the critical factors. As ecosystems progress they may need guidance on the appropriate ways to evaluate their use of the critical factors. Likewise, more research is needed to better understand the benefits of having these factors in place when developing a STEM ecosystem.

Methodology

Data Sources

The study of the STEM Ecosystems Initiative primarily uses a **qualitative approach**[1] to answer the research question: *how do partners building and running a STEM learning ecosystem define the parameters of an "effective" ecosystem?* The study uses three principal data sources: 1) interviews, 2) document analysis, and 3) observations. These sources are a subset of a larger dataset; chosen because they relate directly to the research question.

Interviews

We conducted one-hour interviews[2] with ecosystem partners. First round interviews occurred from November 2015 – March 2016. Second round interviews occurred from May 2016 – August 2016. Partners responded to questions about their background, the purpose and goals of the Initiative, developing partnerships, and implementation of the Initiative.

We analyzed **31 first round interviews** and **21 second round interviews** with ecosystem partners. As seen in Table 1, community partners interviewed in the first round represented 20 ecosystems, and community partners interviewed in the second round represented 21 ecosystems.

Table 1: Ecosystems Represented

Ecosystem	Round One	Round Two
1. Arizona SciTech	2	1
2. BoSTEM	1	1
3. Chicago STEM Pathways Cooperative	1	1
4. Colorado STEM	2	0
5. East Syracuse Minoa Central STEM Learning Ecosystem	1	1
6. EcosySTEM KC	2	1
7. EvanSTEM	2	1
8. Greater Austin STEM Ecosystem	0	1
9. Great Lakes Bay Regional STEM Initiative	1	1
10. Greater Cincinnati STEM Collaborative (GCSC)	1	1
11. Indiana STEM Ecosystem Initiative	2	1
12. Interdisciplinary Science and Engineering Partnership in Western New York	0	1

[1] A qualitative approach contributes new knowledge based on patterns and meaning developed from individual and group experiences. Researchers use "open-ended, emerging data with the primary intent of developing themes from data". (Creswell, p. 18., 2003) in Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches: Second edition*. Thousand Oaks, CA: Sage Publications.

[2] Interviews length depended on the partners' responses to questions. Interview length ranged from 30 – 90 minutes. Researchers asked every participant to reserve one-hour to participate in the interview.

Ecosystem	Round One	Round Two
13. NC STEM	1	1
14. NYC STEM Education Network	0	1
15. Orange County STEM Initiative	0	1
16. Oregon's Statewide Regional STEM Hub Network	0	1
17. Pittsburgh Regional STEM Ecosystem	2	1
18. Providence After School Alliance (PASA) AfterZone STEM – FUSE Initiative	1	1
19. Queens 2020	1	1
20. San Diego EcosySTEM	1	0
21. STEMcityPHL Regional Network	1	0
22. Tampa Bay STEM Network	2	1
23. Tulsa Regional STEM Alliance	4	1
24. Ventura County STEM	2	1
Total	**30**	**21**

As seen in Table 2, most ecosystem partners interviewed are from STEM-rich institutions and PK – 12. Across both rounds, 24 ecosystems were represented.

Table 2: Interviews by Sector

Sector	First Round Interviews Analyzed	Second Round Interviews Analyzed
Community	0	0
Higher Education	3	4
Out-of-School Time	4	3
Business	5	0
PK-12	8	4
STEM-Rich Institution	10	10
Total	**30**	**21**

Interview Analysis Strategy – First Round Interviews

For the analysis of interviews, we used a framework analysis[3] approach, which included analytic memos, two cycles of coding, and a critical factor analysis. After each interview, the researcher wrote an analytic memo summarizing themes discussed in the interview. Then each interview was coded twice and interpreted.

Coding Cycle One used an inductive approach in which we developed codes from analytic memos and then used these codes to analyze the interviews.

Coding Cycle Two took a deductive approach. We developed codes aligned with factors identified as critical to ecosystem development (e.g., strong leadership and cross-sector representation)

[3] Srivastava, A., & Thomson, S. B. (2009). Framework analysis: a qualitative methodology for applied policy research. *Journal of Administration and Governance.*

according to foundational literature[4] used by the national Initiative.

To identify critical factors, which were marked with codes, we reviewed how many partners mentioned the full range of potential factors. We deemed factors "critical" when at least half of ecosystem partners mentioned the factor at least once in their interviews. The interview was reviewed for presence of the factor, not the number of times the factor was mentioned. Take the factor of leadership as an example. We designated it as "critical" because more than half of the partners mentioned leadership at least once in their interviews. We started the analysis of each critical factor by identifying the number of quotes coded with that critical factor, the number of quotes that fit in each of the four stages, and the number of ecosystems represented by the partners who discussed the critical factor. Then, we examined the quotes for a critical factor to better understand how partners discussed the underlying concepts and nuances of that critical factor. The analysis of four critical factors – mission, pathways, STEM Literacy, and educator capacity – revealed distinct themes by stage. Therefore, findings for those factors are described by stages. For each critical factor, researchers made connections between themes and drew conclusions.

Interview Analysis Strategy – Second Round Interviews

The second round interviews demonstrate which factors community partners perceived as essential near the end of the first year of the STEM initiative. Of the 21 second round interviews analyzed, 16 of these interviews were community partners who represent 16 different ecosystems. Of the 16 interviews, there was only one interview per ecosystem.

In order to incorporate the perspectives of as many ecosystems as possible, we included one interview with the primary ecosystem leaders from the five ecosystems that received a site visit (See the site visit section below for more detail). We chose to analyze the interviews with the ecosystem partner with the most significant leadership role, because they tend to have the most in-depth knowledge of the ecosystem. While the site visits resulted in multiple interviews with ecosystem partners, only the ecosystem lead is included in the second round analysis so as not to unduly bias the findings toward the perspectives of one ecosystem.

Documents

From the review of the ecosystem *self-assessments* and ecosystem *applications* we developed a database of *14 ecosystem characteristics* listed below:

- Location
- Reach/size (e.g., city, district, etc.)
- Age
- Strengths
- Needs

[4] Olson, S., & Labov, J. (2014). STEM learning is everywhere: summary of a convocation on building learning systems. *National Academies Press*. 500 Fifth Street NW, Washington, DC 20001; Honey, M., Pearson, G., & Schweingruber, H. (Eds.). (2014). STEM integration in K-12 education: Status, prospects, and an agenda for research. *National Academies Press*; Fenichel, M., & Schweingruber, H. A. (2010). Surrounded by science: Learning science in informal environments. *National Academies Press*; Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (Eds.). (2009). Learning science in informal environments: People, places, and pursuits. *National Academies Press*.

- Leads
- Strategic priority (focus in year one)
- Goal
- Evaluation planned
- Presence of cross-sector partners
- Self-assessed level of practice
- Full-time coordinator present
- Budget size
- Website

Site Visits

We selected five ecosystems to visit based on the criteria presented in Table 3, which provides details about the site visit sample.

Table 3: Site Visit Samples

Characteristic	Site Visit Sample
Practice	• 2 Emerging • 2 Collaborative • 1 Effective
Reach	• 1 State • 2 Region • 1 City • 1 School District
Partners	• 2 with less than five partners • 2 with 5-8 partners • 1 with more than nine partners
Geography	• 1 Midwest • 1 Northeast • 1 South • 1 Southwest
Age	• 2 in operation less than 1 year • 1 in operation for about two years • 2 in operation for at least five years

Typically, the site visit lasted two to three days during which the research team:

- Conducted individual interviews with core leadership.
- Observed an authentic ecosystem event.

To accommodate partners' schedules, individual interviews with core leadership members could occur before, during, or after the site visit.

Data Limitations

Interviews – are not widely generalizable as they typically represent one individual's perspective. The interview protocols from the first to second round changed slightly. Although both protocols had a focus on the local ecosystem and covered the same topics such as ecosystem partners' perceptions of key elements of a successful ecosystem, the questions themselves differed, which may have resulted in partners' elaboration or omission of specific thoughts on aspects of an ecosystem.

Ecosystem documents – are self-report measures, which are subject to the biases of respondents. Some respondents may overstate particular attributes, others may understate attributes, and still others may report attributes inaccurately. Typically, respondents overstate desirable attributes and downplay undesirable attributes.