LOGIC MODEL TEMPLATE & RECOMMENDATIONS FOR NEXT STEPS

Assessing the Impacts of STEM Learning Ecosystems

NOVEMBER 2015

By: Saskia Traill and Kathleen Traphagen
with contributions from Elizabeth Devaney

STEM learning ecosystems harness contributions of educators, policymakers, families, businesses, informal science institutions, after-school and summer providers, higher education, and many others towards a comprehensive vision of STEM learning for all children. This paper offers evidence of the impact of cross-sector partnerships on young people, and a logic model template for communities so they may further develop the attributes, strategies, and measures of progress that enable them to advance opportunities for all young people to succeed. Further research will help us expand the promise and potential of these collaboration.

Table of Contents

STEM ecosystems

Executive Summary

STEM learning ecosystems harness the contributions of educators, policymakers, families, businesses, informal science institutions, afterschool and summer providers, higher education, and many others towards a comprehensive vision of science, technology, engineering, and math (STEM) learning for all children.

This paper offers emerging evidence of the impact of cross-sector partnerships on young people, and a logic model template for communities so they may further develop the attributes, strategies, and measures of progress that enable them to advance opportunities for all young people to succeed.

Further research grounded in these collaborative plans and using multiple methodologies will help us expand the promise and potential of STEM learning ecosystems.

INTRODUCTION

In February 2014, the Noyce Foundation published the working paper *How Cross-Sector Collaborations are Advancing STEM Learning*. The paper used the metaphor of ecosystems to describe how communities are attempting to create, enrich and connect varied learning opportunities to improve young people's knowledge and engagement in STEM (science, technology, engineering and mathematics) and better prepare them to be STEM-literate members of our civic communities.

As the 2014 working paper explained, *"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. A learning ecosystem harnesses the unique contributions of all these different settings in symbiosis to deliver STEM learning for all children. Designed pathways enable young people to become engaged, knowledgeable and skilled in the STEM disciplines as they progress through childhood into adolescence and early adulthood."*

The idea of cultivating community- or regional-level STEM learning ecosystems involves blurring the traditional boundaries separating formal and informal learning to create dynamic collaborations that increase equity and discover new synergies to better prepare all young people to succeed.

The cross-sector partners profiled in the 2014 working paper join many other practitioners across the country using the ecosystems approach to increase access to STEM learning opportunities, equip educators, build interest-driven STEM pathways, deepen family engagement, and more.

As interest in ecosystems grows, so does the need to understand how to measure the impact of ecosystem cultivation. This paper, which was commissioned by the Noyce Foundation as a follow-up to the 2014 cross-sector paper, has three main aims:

1. to share evidence of the impact of cross-sector partnerships;
2. to offer a logic model template for adaptation by ecosystem cultivators;
3. and to draw on research and lessons from multiple fields to provide recommendations to practitioners, researchers, funders, and policymakers about how STEM ecosystems can manage the complexities of measuring the impact of multi-level interventions in dynamic systems over time.

Examples from identified communities showcase emergent local, regional and statewide impacts of cultivating STEM learning ecosystems. Research is still needed, however, to fully understand how community, regional, or statewide ecosystem cultivation catalyzes improved and more equitable STEM learning and engagement outcomes over the long term. We offer initial recommendations for future action by the research community, funders, practitioners, and others, and reflect on some areas for further discussion.

To download a version of this logic model designed for adaptation, click here.

// RECOMMENDATIONS:

1. Shared vision, priority outcomes, common language and agreed-upon measurements are needed for ecosystem cultivation. Ecosystem cultivators can adapt this paper's logic model template to develop their own local model.
2. Research at multiple levels using a range of methodologies is needed to better understand the optimal conditions and effective practices that undergird robust ecosystems.
3. New ways to track key indicators over time and across settings are needed to fully assess the impacts of robust STEM learning ecosystems on youth.

1

Shared vision, priority outcomes, common language and agreed-upon measurements are needed for ecosystem cultivation. Local, regional and state-level ecosystem cultivators can adapt this paper's logic model template to develop their own local model.

We do not intend this template to be prescriptive nor to oversimplify the complex and dynamic set of STEM learning opportunities in an ecosystem. Rather, this template may serve as an important tool to help catalyze ongoing dialogue and relationship-building toward common vision, goals, language, outcomes and measurements among ecosystem stakeholders.

The logic model is based on a four-strategy framework for cultivating ecosystems and developing cross-sector partnerships that transform STEM education for young people.

STRATEGY 1. // ESTABLISH AND SUSTAIN CROSS-SECTOR PARTNERSHIPS TO CULTIVATE ECOSYSTEMS

Cross-sector collaborations designed to realize a collective vision of STEM success for young people are key to cultivating a rich STEM learning ecosystem. These collaborations are anchored by strong leaders and characterized by collaborative vision and practice. Ecosystem cultivators assess gaps and shift resources to ensure that young people who have been historically under-represented in STEM -- including girls, economically disadvantaged young people, linguistic minorities, young people of color, and those with disabilities -- access high-quality, diverse and inter-connected STEM learning experiences. The collaborators determine collective goals based on the community's needs, assets and interests and these goals drive decisions about how to engage in creative approaches to the remaining three strategies – creating/connecting STEM-rich learning environments; equipping educators, and building youth pathways to further learning, engagement, development and careers.

STRATEGY 2. // CREATE AND CONNECT STEM-RICH LEARNING ENVIRONMENTS IN DIVERSE SETTINGS

In a robust ecosystem, learning opportunities are high-quality, universally accessible, youth-centered, and connected so learners can deepen their skills and interests, and tackle increasingly complex challenges over time. Curricula and pedagogical approaches are grounded in seminal reports on STEM education by the National Research Council. As young people engage in STEM learning in and out of school, they experience the joy of learning and the rewards of persistence through unhurried opportunities to tinker, experiment, and explore subject matter that is relevant to them. They are actively engaged in science, engineering and mathematical practices. Young people's development of a "STEM identity" and increase of their self-perception of confidence in STEM is spurred on by engaging in challenging, relevant problem-solving on issues they care about; being publicly recognized for their efforts in and out of school; and gaining support from their parents and guardians for their pursuit of and interest in STEM. Development of a strong STEM identity leads to long-term success and engagement.

STRATEGY 3. // EQUIP EDUCATORS TO LEAD ACTIVE LEARNING IN DIVERSE SETTINGS

To lead active learning across settings that young people encounter throughout the day, educators--whether K-12 teachers, pre-service teacher candidates, after-school or summer program staff, experts in informal STEM institutions, or STEM professionals acting as mentors--need professional development and appropriate materials and curricula. Educators across sectors need competencies and tools to be able to work together to increase their efficacy, for example fostering young peoples' deep understanding of cross-cutting concepts and core ideas through multiple learning experiences throughout the day. Educators need opportunities to share effective practices, build common understanding, and gain respect for each other's roles. Finally, they must be equipped to support young people's ability to navigate and connect learning opportunities across settings.

STRATEGY 4. // SUPPORT YOUTH TO ACCESS PATHWAYS AND EXPLORATION TO FURTHER LEARNING AND CAREERS

Pathways and opportunities for exploration enable young people to become engaged, knowledgeable and skilled in the STEM disciplines as they progress through childhood into adolescence and early adulthood. Young people's interest in STEM learning is sparked in diverse environments, and then deepened by their cross-sector pursuit of more knowledge. Young people are aided by adults who are skilled at empowering them to navigate boundaries and access resources. Young people have opportunities to meet and build mentoring relationships with STEM professionals from similar backgrounds who serve as role models in their school and out-of-school experiences. In and out of school, young people learn from an early age about a range of STEM career possibilities. PreK-12 STEM learning is connected to post-secondary and STEM career opportunities to ensure that STEM learning pathways evolve to meet the changing needs of STEM employers. Parents and guardians receive consistent messaging, guidance and resources from multiple sources about how to support their children's long-term STEM success.

Assessing gaps, identifying partners, developing a collective vision and committing to shared outcomes creates a strong base to develop creative approaches to implementing strategies, based on each community's needs, assets, and interests. We hope use of this logic model or a similar tool to define the parameters of collaboration will help local ecosystem cultivators tackle several important and complex tasks: deepening relationships, defining common language and shared outcomes, and importantly, moving toward adopting common assessments. Shared logic will create a strong footing for approaching increasingly complex evaluation questions. For example, a community might first agree on its shared logic model, focus evaluation on process and implementation, then on effective practice related to set of strategies, and finally on impact on young people when sufficient time has passed for effects to surface.

Youth participating in Boston After School & Beyond's Summer Learning Project observe pond life at the Hale Reservation in Westwood, MA. Photo

// Photo Credit: Tiffany Knight

2 Research at multiple levels using a range of methodologies is needed to better understand the optimal conditions and effective practices that undergird robust ecosystems.

Youth in the California Academy of Sciences Science Action Club record citizen science observations to verify accuracy of NASA satellite images. // **Photo Courtesy of** California Academy of Sciences

Nearly everyone interviewed for this paper agreed on the need for more robust research about the value and impact of strategies to cultivate STEM learning ecosystems. Multiple methodologies should be employed to help us understand the full impacts of connecting STEM opportunities for young people and of building youth pathways that are designed to maintain interest and build STEM competencies. We need to understand the effects of cross-sector professional development and effective family involvement, among other strategies. Research is also needed to shed light on which ecosystem cultivation strategies lead to increased equity in opportunity and success for young people historically under-represented in STEM majors and careers.

We recommend that ecosystem leaders, researchers and funders work jointly to launch comparative studies looking at efforts in multiple communities, as well as in-depth community-level studies. In both cases, it will be important to disseminate findings broadly among ecosystem proponents. Using multiple methodologies -- such as ethnographic approaches, in-depth qualitative case studies, and individual learning narratives -- can help illustrate how the evolving dynamics and relationships that comprise a healthy ecosystem impact the quality, availability, and coordination of STEM learning opportunities.

Ecosystem researchers will need to have a flexible approach, comfort with the messiness and complexity that characterize ecosystems, interest in multi-disciplinary work, and a willingness to work with practitioners playing a central role in helping to design and implement research.

Involving researchers as partners in nurturing and developing strong ecosystems with common goals and visions will encourage even more responsive research methods and findings. Researchers may need support to be effective communicators of their plans and their findings to multiple types of audiences, using new and diverse mechanisms to disseminate findings. We also must understand and address the concerns of the practitioners we want to engage in this research. Many practitioners described a desire to build their personal and organizational relationships before engaging in research, despite interest in deepening understanding about cross-sector collaboration. The STEM Funder Network ecosystems initiative, with its focus on building a community of practice among cities, regions and states, will provide an initial stage for a multi-city study and a forum for practitioners and researchers to consider other specific research initiatives.

3 New ways to track key indicators over time and across settings are needed to fully assess the impacts of robust STEM learning ecosystems on youth.

Ecosystems need ways to assess a broader of set of STEM outcomes for all youth within their boundary area. Such outcomes could include evidence of active participation in STEM learning opportunities, self-perceptions of STEM identity, success in academic STEM courses, pursuit of higher education and STEM majors, and eventual employment in jobs that require STEM skills. Widespread adoption and administration of common measures would prove useful in building large data sets of affect and interest, though data-sharing capabilities would need to be in place so information could be interpreted by cross-sector practitioner teams for continuous improvement.

Photo Credit: Tiffany Knight

CONCLUSION

Ecosystem cultivators will need to find new ways to tackle complex questions about how we, as a society, can support long-term development of children and adults. Dealing with these challenges will require funders to provide flexible resources to the many innovative practitioners and researchers working in this space. Researchers and practitioners will need to work together within and across disciplines to expand the questions they seek to answer and the ways they work together to improve practice and ultimately the impact, sustainability, and reach of STEM education efforts. Those innovators need supporters, partners, cheerleaders, colleagues, networkers and storytellers. It is in that spirit we offer this paper.

A STEM Guide with the Maine Math and Science Alliance and her community's Youth Leadership Team organized a Teen Science Cafe to connect rural youth with a local scientist.

// **Courtesy Maine Mathematics and Science Alliance**

// **Photo Credit:** Sue Allen

Overview

In February 2014, the Noyce Foundation published the working paper *How Cross-Sector Collaborations are Advancing STEM Learning*. The paper used the metaphor of ecosystems to describe how communities are attempting to create, enrich and connect varied learning opportunities to improve young people's knowledge and engagement in STEM (science, technology, engineering and mathematics) and better prepare them to be STEM-literate members of our civic communities. The desire to connect learning experiences across settings emerges from research that shows context, culture and individual characteristics matter in how youth learn and that learning results from a confluence of experiences over time and across settings (Banks, et al., 2007; Barron, 2014; Bronfenbrenner, 1994; Friedman, 2013).

Within the naturally occurring 'ecosystems' that exist in all communities, youth access to STEM learning opportunities is influenced by geography, socio-economic status, family capacity, school quality, out-of-school time program availability and quality, and many other factors. Youth who are members of traditionally under-represented populations in the STEM fields often have less access than their more advantaged peers. In addition, STEM educators across settings – schools, out-of-school time programs, science centers, etc. — remain mostly unconnected to each other and unaware of the experiences that the youth they teach have – or could have — in other settings. It is not clear to many youth or their families how the 'random acts of STEM' youth may experience can possibly form a pathway to further education and careers.

The idea of cultivating community- or regional-level STEM learning ecosystems involves blurring the traditional boundaries separating formal and informal learning to create dynamic collaborations that increase equity and discover new synergies to better prepare all young people to succeed. The cross-sector partners profiled in the 2014 working paper join many other practitioners across the country using the ecosystems approach to increase access to STEM learning opportunities, equip educators, build interest-driven STEM pathways, deepen family engagement, and more.

Over the past year and a half, practitioners, researchers and grantmakers have further developed the ecosystem concept in their communities and at national and regional convenings. Twenty-seven communities have been selected to form the first cohort of the STEM Funders Network *Building the Field: Designing and Implementing Community-Based STEM Learning Ecosystems* Initiative. The STEM Funders Network has also developed an online toolkit for ecosystem cultivators.

// MEASURING THE IMPACT

As interest in ecosystems grows, so does the need to understand how to measure the impact of ecosystem cultivation. This paper, which was commissioned by the Noyce Foundation as a follow-up to the 2014 cross-sector paper, has three main aims:

1. to share evidence of the impact of cross-sector partnerships;

2. To offer a logic model template for adaptation by ecosystem cultivators, designed to assist in developing a shared vision, priority outcomes, use of common language and agreed-upon measurements among stakeholders from different sectors;

3. and to draw on research and lessons from multiple fields to provide recommendations to practitioners, researchers, funders, and policymakers about how STEM ecosystems can manage the complexities of measuring the impact of multi-level interventions in dynamic systems over time.

// THREE RECOMMENDATIONS

1. Shared vision, priority outcomes, common language and agreed-upon measurements are needed for ecosystem cultivation. Ecosystem cultivators can adapt this paper's logic model template to develop their own local model.

2. Research at multiple levels using a range of methodologies is needed to better understand the optimal conditions and effective practices that undergird robust ecosystems.

3. New ways to track key indicators over time and across settings are needed to fully assess the impacts of robust STEM learning ecosystems on youth.

We hope those who are interested in enhancing STEM learning in their communities will find this working paper useful as they consider the ecosystems approach and want to know more about how to measure the impact of their efforts.

// METHODOLOGY

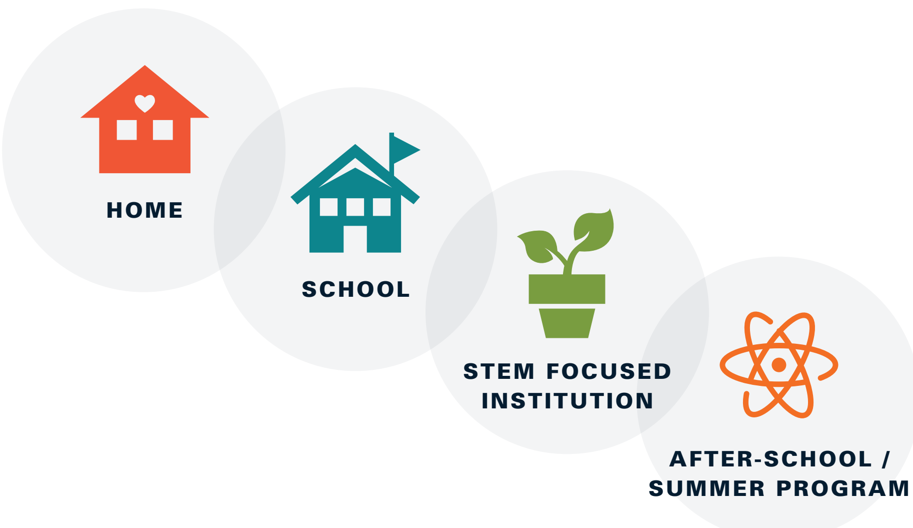
To understand how knowledge about assessment might be applied to measurement of STEM ecosystems, we scanned literature from education, applied social sciences, and evaluation sciences. We also interviewed practitioners from some of the cross-sector initiatives included in 2014 working paper as well as initiatives identified since the paper was published to understand how these partnerships are measuring their impacts and what they are learning. We did not engage in a comprehensive national scan to identify every effort to cultivate STEM learning ecosystems, and we are undoubtedly unaware of many such efforts. (See Appendix A for descriptions of the initiatives interviewed, and http://www.stemecosystems.org to see the list of the 27 communities participating in the STEM Funders Network *STEM Learning Ecosystems Initiative*.)

Finally, to understand how STEM ecosystem cultivators could better approach assessment and measurement, we conducted a series of fifteen key informant interviews. We identified individuals who study collaboration and systems building, contribute to and cultivate STEM ecosystems, or who have been involved in other related national efforts (e.g., the National Research Council's Committee on Successful Out-of-School STEM Learning). Interviewees included researchers, experts in out-of-school time STEM learning, experts in STEM-rich cultural institutions, and formal educators and systems leaders. We asked them to tell us how they would approach the assessment of STEM learning ecosystems, pitfalls, and potential benefits, and recommendation they have to advance this area. The list of interviewees is included in Appendix B.

Ecosystems Framework and Evidence of Impact

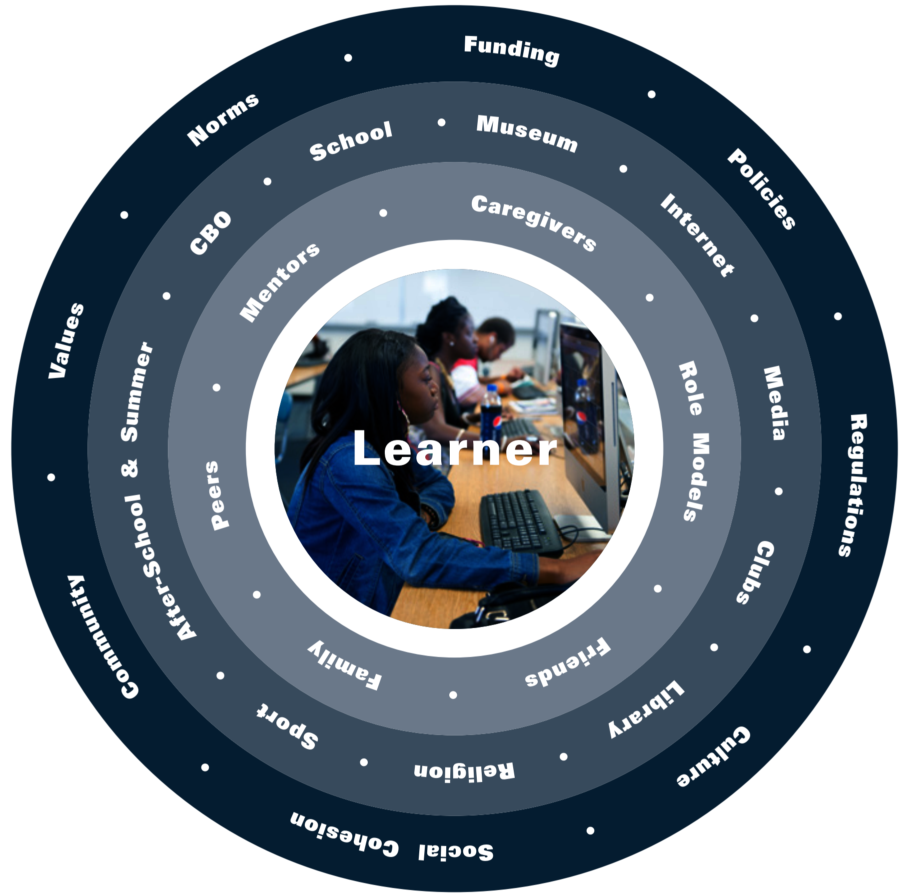
In this section we introduce the STEM Learning Ecosystems Framework and provide examples of the impact demonstrated by cross-sector partnerships to date. In our first paper we offered this definition of STEM Learning Ecosystems:

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. A learning ecosystem harnesses the unique contributions of all these different settings in symbiosis to deliver STEM learning for all children. Designed pathways enable young people to become engaged, knowledgeable and skilled in the STEM disciplines as they progress through childhood into adolescence and early adulthood.



// STEM LEARNING ECOSYSTEMS

Colleagues have created schematics that more broadly envision the ecosystem, including:



Adapted from chart by: Martin Storksdieck, Oregon State University

This and other conceptions of the learning ecosystem are more comprehensive than our original rendering and broaden the span of critical stakeholders in the STEM learning environment. Influenced by our colleagues, and informed by the experience of multiple community-based practitioners, in early summer 2015 we developed a 4-strategy framework that names and organizes the major areas of work for ecosystem cultivators at a community, regional or statewide level.

STEM Learning Ecosystems Framework

STRATEGY 1.
CULTIVATING CROSS-SECTOR PARTNERSHIPS

STRATEGY 2.
CREATING AND CONNECTING STEM-RICH LEARNING ENVIRONMENTS

STRATEGY 3.
EQUIPPING EDUCATORS

STRATEGY 4.
SUPPORTING YOUTH PATHWAYS

Below we explain the four strategies in detail and provide corresponding examples of impact achieved by specific initiatives, some of which we also cited in the 2014 working paper. Many of these initiatives – such as Urban Advantage (New York City); Museum of Science and Industry, Chicago's Re-Energize Program; or the California Academy of Science's Science Action Clubs — should not be considered representative of the whole ecosystem in their communities. Rather they are discrete programs that have incorporated cross-sector partnerships into their design. Others – such as OC STEM, Tulsa Regional STEM Alliance and the Oregon Statewide Regional Hub Network — do aspire to cultivate comprehensive community, regional or state level ecosystems. (See Appendix A for a description of each initiative).

// STRATEGY 1. ESTABLISH AND SUSTAIN CROSS-SECTOR PARTNERSHIPS TO CULTIVATE ECOSYSTEMS

What it looks like:

Cross-sector collaborations designed to realize a collective vision of STEM success for young people are key to cultivating a rich STEM learning ecosystem. These collaborations are anchored by strong leaders and characterized by collaborative vision and practice.

The leader plays the role of community influencer and champion, articulating, persuading and leading the charge. Cross-sector partners include schools and school districts; after-school and summer programs and systems; STEM-focused community institutions such as museums, science centers, institutions of higher education, STEM professional associations, private sector STEM businesses; philanthropic organizations; families; and young people. Ecosystem cultivators assess gaps and shift resources to ensure that young people who have been historically under-represented in STEM — including girls, economically disadvantaged young people, linguistic minorities, young people of color, and those with disabilities — access high-quality, diverse and inter-connected STEM learning experiences.

The collaborators determine collective goals based on the community's needs, assets and interests and these goals drive decisions about how to engage in creative approaches to the remaining three strategies – creating/connecting STEM-rich learning environments; equipping educators, and building youth pathways to further learning, engagement, development and careers.

Ecosystem cultivators build understanding and respect for the role of STEM educators and institutions in sectors beyond their own. They understand and leverage their own and each other's 'enlightened self-interest' in the work. They build a common language that describes their goals and approaches to teaching and learning in the STEM disciplines and measuring their impact. They identify and deliver on policy and financing opportunities that encourage and sustain cross-sector approaches. They also engage in broad communications to build support for their work.

Impact can be measured in population served; evidence of formal collaboration between sectors, and evidence of shared vision for advancing STEM education.

Evidence of Impact: Examples

Forming a shared vision and generating new initiatives through a lead entity

- Formed in 2014, the **Tulsa Regional STEM Alliance (TRSA)** includes stakeholders from higher education, K-12, philanthropy, STEM institutions, government, business and community organizations who have committed to "engage partnerships to accelerate capacity and broaden opportunity for STEM learning in Tulsa," according to the TRSA design principles. In 2015, TRSA partners will produce 20,000 hours of STEM programming, 4000 hours of STEM professional development and 15,000 hours of STEM mentorship through 150 STEM events.

- **The Orange County STEM Initiative,** formed under the leadership of local funders in 2012, has created a comprehensive strategic plan that includes in-school, out-of-school and other programming to ensure young people have access to high-quality STEM experiences across many settings. In the 2015-2016 school year, the project is reaching students, educators and other stakeholders in 28 school districts. Among OC STEM's strategies to embed the ecosystems approach

Photo Credit: Tiffany Knight

is the creation of a position with the OC County Department of Education to catalyze STEM partnerships, and an 18-month *Orange County STEM Learning Ecosystems: Leadership for Articulated STEM Programs Institute,* facilitated by WestEd, that provides professional learning opportunities and other support to teams comprised of district level administrators, K12 teachers, parents, business and community partners, informal science partners; after-school providers, and early education teachers from nine districts. In a recent survey, 82% of Institute attendees reported finding value or high value in understanding the concept of a STEM learning ecosystem and their role as an informal, formal, preschool, community or business member within their district's STEM Learning Ecosystem (Orange County STEM Learning Ecosystems: Leadership for Articulated STEM Programs Institute, Participant Survey, July 2015).

> "Ecosystem cultivators build understanding and respect for the role of STEM educators and institutions in sectors beyond their own."

Creating state-level infrastructure to support local cross-sector partnerships

- Created in 2013, **Oregon's Statewide Regional Hub Network** includes six regional "STEM Hubs" that bring together representatives of K-12, post-secondary, out-of-school programs, business and industry, workforce, economic development, civic leaders, community-based organizations, STEM-rich institutions, and families. In 2015, the Oregon Legislature and the Governor passed legislation to maintain current funding and add up to five more STEM Hubs to reach every community in the state. The Portland-Metro STEM Partnership (PMSP), one of Oregon's STEM Hubs, has established a cross-sector group called the Collaboratory to create stronger connections and alignment between the experiences that students have in and out of the classroom. Focus areas include the use of common assessment frameworks for student (and educator) STEM identity, motivational resilience, and grit/perseverance. PMSP is also developing a STEM Common Measurement System that includes defined outcomes for students, teachers and professional development experiences mapped to the affective, conceptual and practice domains (Saxton, et al, 2014).

Embedding cross-sector approaches in state and local STEM education policy

- The **Indiana Afterschool Network (IAN),** along with stakeholders from the Indiana Department of Education (IDOE), community-based organizations, and the business community, developed a set of aligned quality standards for after-school and expanded learning STEM programming. The IDOE included after-school STEM learning as a required component for STEM School Certification, embedding cross-sector learning opportunities in the definition of a quality STEM school. IAN also received support from the Governor's Office Education Roundtable to use after-school as a vehicle for STEM teacher preparation.

- **New York City** released a STEM framework that states: "In practice, STEM education involves both formal (classroom) and informal (after-school) instruction across all grade levels (Pre-K–12)." One of the four domains of the Framework is strategic partnerships. The New York City Department of Education is encouraging use of the Framework by school teams to redesign their STEM education. Indicators of effective practices include meaningful collaborations with higher education, museums, and STEM-centric organizations; effective parent engagement; and use of shared data with partner organizations.

Photo Courtesy of ExpandED Schools

As they engage in STEM learning in and out of school, young people experience the joy of learning and the rewards of persistence through unhurried opportunities to tinker, experiment, and explore subject matter that is relevant to them. They are actively engaged in science, engineering and mathematical practices (as detailed in the Framework and Next Generation Science Standards and other similar state standards for science education and the Common Core Standards for Mathematical Practice).

Educators understand and nurture the reinforcing connections among students' competencies to engage in STEM practices and development of key social/emotional skills. Adults align their instructional practice, learning goals, and focus to create connected opportunities to learn throughout the day, in multiple settings. Classroom, home, and community experiences are relevant and connected to one another.

// STRATEGY 2. CREATE AND CONNECT STEM-RICH LEARNING ENVIRONMENTS IN DIVERSE SETTINGS

What it looks like:

In a robust ecosystem, learning opportunities are high-quality, universally accessible, youth-centered, and connected so learners can deepen their skills and interests, and tackle increasingly complex challenges over time. Curricula and pedagogical approaches are grounded in seminal reports by the National Research Council including: A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (2012); Surrounded by Science: Learning Science in Informal Environments (2010); Community Programs to Promote Youth Development (2002).

Young people's development of a "STEM identity" and increase of their self-perception of confidence in STEM is spurred on by engaging in challenging, relevant problem-solving on issues they care about; being publicly recognized for their efforts in and out of school; and gaining support from their parents and guardians for their pursuit of and interest in STEM. Development of a strong STEM identity leads to long-term success and engagement (Nagaoka, et al., 2014).

Impact can be measured in teacher- and student-reported interest and engagement, young people's skills development in areas necessary for success in STEM, academic performance, and long-term pursuit of STEM opportunities (e.g., STEM major or career).

Evidence of impact: Examples

- An evaluation of the **Boston Summer Learning Project** showed that participants improved in their communication, initiative, engagement in learning and relationship skills, and made gains in academic skills during the summer (Summer Learning Project Evaluation, National Institute on Out-of-School Time, 2012). Teachers also reported, in a November 2012 survey, that Summer Learning Project students had an easier transition back to the classroom in the fall than their peers (National Institute on Out-of-School Time, 2012).

- Students of teachers who participated in the **Museum of Science and Industry, Chicago's *Get Re-Energized*** (GRE) professional development program performed better on both pencil-and-paper assessments of "formal" knowledge of energy and on tasks that required them to identify and understand important energy concepts in applied, real-world situations (Schmidt & Cogan, 2014).

- An evaluation of the **Chicago Pre-College Science and Engineering Program** that included program observations, focus groups with students, teachers and parents, and student and parent surveys, found that after two years, students' development of process skills helped them to think through and solve problems and develop an understanding about scientific inquiry. Students also developed their understanding of what engineers do (Samuels & Beer, 2012).

- Using ten years of data on student achievement, researchers have found that schools' participation in the **Urban Advantage (UA)** program in New York City has a positive impact on student outcomes. UA schools outperform non-UA schools on the eighth grade science exams, and the impact of participating in UA is much higher for schools with the lowest prior science performance, and more pronounced among Black and Hispanic students. In addition, students who attend a UA school are more likely to pass the state's Living Environments Regents exam than those at non-UA schools (Weinstein, Whitesell & Schwartz, 2014).

(left) **A California Academy of Sciences Science Action Club participant observing and documenting local biodiversity.**

// **Photo Courtesy of** California Academy of Sciences

(right) **Learning about elasticity, surface tension and chemistry using bubbles at the SHINE Afterschool Program in rural Pennsylvania.**

// **Photo Courtesy of** SHINE Program, Lehigh Carbon Community College

// **Photo Credit:** Ashley Heater

- An analysis of 2012 and 2013 data found that 71% of girls attending Austin, TX public schools who participated in the central Texas-based **Girlstart** after-school program passed the fifth grade Texas state science test, compared to 48% of a group of non-participant girls matched by grade level, ethnicity, socio-economic status and Limited English Proficiency status, and compared to 62% of students in Girlstart partner schools. For math, the results were 85% of Girlstart girls passing, vs. 70% of the comparison group and 73% of students in Girlstart schools (Bussiere & Hudgins, 2014).

- Classroom teachers reporting on their students who were enrolled in the **SHINE** after-school program in rural Pennsylvania found that, of those identified as needing improvement, 79% improved their academic performance; 81% improved their homework completion; 62% improved their classroom behavior; and 41% improved their school attendance. SHINE parents who responded to a survey in 2014-2015 reported improvements in their child's performance in math (95%), science (74%), reading (88%), ability to use technology (68%), self-confidence (90%) and attitude toward school (87%) (Lehigh Carbon Community College, 2015).

- 87% of participants in the **Museum of Science and Industry, Chicago's** community and school-based after-school programs, the **Science Minors Clubs,** indicated that they enjoy science and 92% expressed interest in doing more science activities (Krishnamurthi, Ballard, & Noam, 2014).

- A 2010 survey of **Detroit Area Pre-College Engineering Program (DAPCEP)** Summer Series alumni found that 90% of students graduated from high school, 89.3% are currently pursuing a Bachelor's degree, and 80.6% of those currently pursuing a Bachelor's degree are pursuing a STEMM (Science, Technology, Engineering, Math or Medical) degree. Of the 713 who participated in summer programming over the past five years, 13% responded to the survey (Communication with DAPCEP, July 2015).

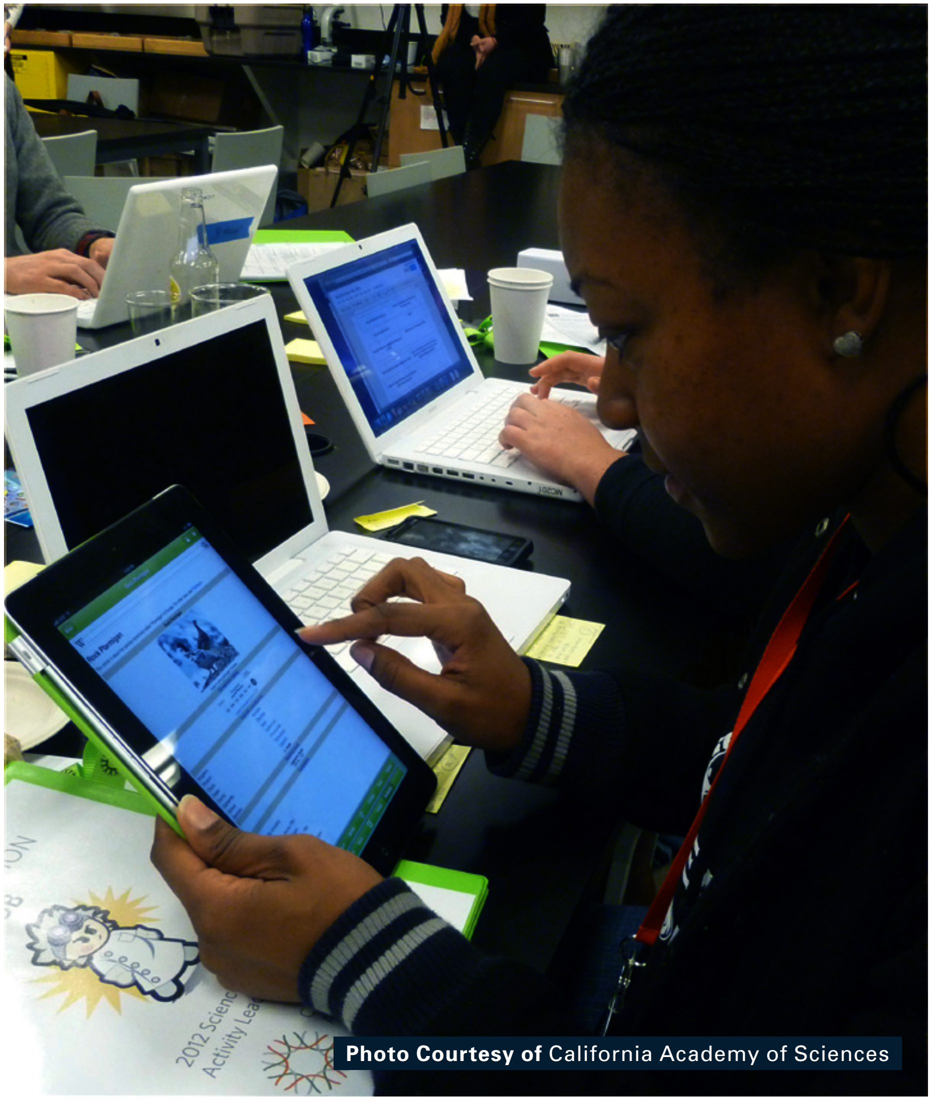


Photo Courtesy of California Academy of Sciences

// STRATEGY 3. EQUIP EDUCATORS TO LEAD ACTIVE LEARNING IN DIVERSE SETTINGS

What it looks like:

Effective STEM learning includes the acquisition of knowledge, skills, attitudes, and dispositions, as well as the generation of excitement, interest, motivation, and identity as a scientist (National Research Council, 2014b). Educators use a variety of instructional methods to build this array of competencies and characteristics and to ensure that young people fully engage in scientific practice and engineering design. Young scientists and engineers create arguments from evidence, plan and build models, manipulate, test, and reflect. They work in teams, they solve problems on their own, they accept and build on negative or unexpected findings, and they push past perceived failures.

To lead active learning across settings that young people encounter throughout the day, educators—whether K-12 teachers, pre-service teacher candidates, after-school staff, experts in informal STEM institutions, or STEM professionals acting as mentors—need professional development and appropriate materials and curricula.

Educators across sectors need competencies and tools to be able to work together to increase their efficacy, for example, fostering young peoples' deep understanding of cross-cutting concepts and core ideas through multiple learning experiences throughout the day. Educators need opportunities to share effective practices, build common understanding and gain respect for each other's roles. Finally, they must be equipped to support young people's ability to navigate and connect learning opportunities across settings.

Impact can be measured by changes in educator instructional strategies, reports of satisfaction, and success of students.

High school students participating in the "work and learn" Summer Learning Project with the Boston Private Industry Council and Boston After School & Beyond.

// Photo Credit: Tiffany Knight

Evidence of impact: Examples

- The **Museum of Science and Industry, Chicago's Get Re-Energized** program provides inquiry-based, hands-on professional development focused on energy topics to science teachers in urban, high-poverty schools who have expressed that they have limited ability to teach science effectively. An evaluation of the program found that participating teachers outperformed those not in the program on assessments of general science knowledge and energy-specific topics (Schmidt & Cogan, 2014).

- To have maximum impact in a school, **Urban Advantage** has found it is important to have a concentration of science teachers in each school in the program and to have those teachers involved over multiple years. Evaluations have also pointed to the importance of school culture, teacher capacity for collaboration, administrative support, and the school's ability to use UA's resources to involve families as factors contributing to the impact of the program on students' success in middle school science (Weinstein, Whitesell & Leardo, 2013).

- Observations of staff trained by the **Museum of Science and Industry, Chicago's** after-school **Science Minors Club's** program revealed that 80% encouraged youth to formulate testable questions and 93% fostered the collection of data and recording of observations. At 93% of sites, staff was observed providing opportunities for youth to use tools like a hand lens, calorimeter and rulers to make observations, take measurements or collect data and 100% utilized cooperative groups and individual roles to promote collaboration between youth participants. Eighty percent of observed sites provided opportunities for youth to report out their findings and communicate their ideas to the broader group and 86% supported youth in making connections between their work and their everyday lives (Krishnamurthi, Ballard, & Noam, 2014).

- Teachers participating in the **Boston Summer Learning Project** reported feeling more connected to their students, coworkers, schools, and communities as a result of participating in the program, while 81% reported learning strategies and instructional approaches that they will take back to their school-year classrooms (National Institute on Out-of-School Time, 2012).

- All of the classroom teachers who also taught in the **SHINE** after-school program reported that being a SHINE teacher resulted in improved student learning in their regular classrooms. Teachers responding to surveys from 2008-2014 had an average of ten years in the classroom and 3.38 years in the SHINE after-school program. A majority of teachers also reported that because of their experience in the SHINE program, they have improved classroom management skills; they utilize assessments more effectively to improve student learning; and they better understand the important role families play in child(ren)'s educational success (Lehigh Carbon Community College, 2014).

- 100% of Activity Leaders who taught in community-based after-school **California Academy of Sciences Science Action Clubs** for at least one year expressed increased confidence explaining science concepts to youth and engaging youth in open-ended science discussions. Additionally, 80% reported increased confidence facilitating youth participation in citizen science (Public Profit, 2015).

// STRATEGY 4. SUPPORT YOUTH TO ACCESS PATHWAYS AND EXPLORATION TO FURTHER LEARNING AND CAREERS

What it looks like:

Pathways and opportunities for exploration enable young people to become engaged, knowledgeable and skilled in the STEM disciplines as they progress through childhood into adolescence and early adulthood. Young people's interest in STEM learning is sparked in diverse environments; and then deepened by their cross-sector pursuit of more knowledge (Barron, 2006). Young people are aided by adults who are skilled at empowering them to navigate boundaries and access resources. They may often draw on the power of digital media to connect them with peer, adult and community support (Ito, et al., 2013).

What young people know and are able to do is assessed, shared and respected in diverse environments. Assessment methods may include badges, portfolios or other competency-based proof points demonstrating mastery of skills and knowledge (Alliance for Excellent Education 2013).

Young people have opportunities to meet and build mentoring relationships with STEM professionals from similar backgrounds who serve as role models in their school and out-of-school experiences. In and out of school, young people learn from an early age about a range of STEM career possibilities. PreK-12 STEM learning is connected to post-secondary and STEM career opportunities to ensure that STEM learning pathways match the needs of STEM higher education and workforce. Parents and guardians receive consistent messaging, guidance and resources from multiple sources about how to support their children's STEM success.

Impact can be measured in documented support for students and families and students' progress in STEM over time.

Evidence of impact: Examples

- The community-based "STEM Guides" hired by the **Maine Math and Science Alliance** to find effective and inexpensive ways to connect youth to STEM learning outside of school have made more than 1,000 individual connections between local youth and STEM assets in their ecosystems (Communication with Maine Math and Science Alliance, July 2015).

Photo Courtesy of ExpandED Schools

"To lead active learning across settings that young people encounter throughout the day, educators — whether K-12 teachers, pre-service teacher candidates, after-school staff, experts in informal STEM institutions, or STEM professionals acting as mentors – need professional development and appropriate materials and curricula."

- A 2014 analysis found that girls who participated in the **Girlstart** after-school program as elementary school students registered for advanced and pre-AP math and science courses at the secondary level at a significantly higher rate than non-Girlstart girls from a matched comparison group (1.58 advanced courses per girl, compared to 1.00 per non participant girl (Bussiere & Hudgins, 2014). A Girlstart 2015 participant survey found that 78% expressed a strong interest in entering a STEM career; 87% reported that a job in a STEM field means their ideas can help people; and 98% demonstrated awareness of the importance of higher education as a way to broaden their career options. Forty two percent are aspiring first generation college students (Girlstart, 2015).

- In observations of **Museum of Science and Industry, Chicago Science Minors Club** sites, 86% of facilitators supported youth in making connections to their everyday lives and 78% of participating youth indicated that they use science in their everyday lives (Krishnamurthi, Ballard, & Noam, 2014).

- 54% of **SHINE** middle school students indicated they would like to study math and science in college while 66% were excited about learning engineering. 91% said they learned about STEM careers and 97% were excited about STEM activities (SHINE Project Evaluation Report 2012-13).

- A recent analysis found that 56% of Oregon **SMILE** after-school club alumni enrolled in college - about the same percentage as graduating seniors in Oregon overall, but much higher than the first generation, students of color and low-income students targeted by SMILE. For students who spent four or more years in SMILE, the college-going rate was 73% (SMILE, 2015).

These examples showcase emergent impacts from cultivating STEM learning ecosystems and provide evidence of the ability of specific cross-sector collaborations to positively affect students and educators. What we don't yet know is how the community, regional, or statewide ecosystem cultivation catalyzes improved and more equitable STEM learning and engagement outcomes over the long term. Research on the impact of systems change, both within and outside the field of STEM education, is scarce (Chi, Dorph, & Reisman, 2014; Saxton, et al., 2014). The June 2015 report of the National Research Council's Committee on Successful Out-of-School STEM Learning calls for "creative and responsive approaches to evaluating the success of programs at the individual, program, and community levels" and investing in research "to improve our understanding of STEM learning in out-of-school programs and explore how STEM learning ecosystems work." (National Research Council,2015).

* * *

The next section of this paper discusses more fully how ecosystem stakeholders might undertake assessment activities that capture the impact of complex system changes over time and the ways in which collaborations across sectors can drive improvements for young people's success.

Recommendations for Ecosystem Research and Assessment

Below we offer initial recommendations for action by researchers, funders, practitioners, and others, and reflect on areas for further discussion. We offer short- and long-term next steps that clarify how evaluation and assessment of ecosystems can elucidate the necessary conditions to foster the effectiveness and continuous improvement of local ecosystem cultivators.

// RECOMMENDATIONS:

1. Shared vision, priority outcomes, common language and agreed-upon measurements are needed for ecosystem cultivation. Ecosystem cultivators can adapt this paper's logic model template to develop their own local model.

2. Research at multiple levels using a range of methodologies is needed to better understand the optimal conditions and effective practices that undergird robust ecosystems.

3. New ways to track key indicators over time and across settings are needed to fully assess the impacts of robust STEM learning ecosystems on youth.

We recognize that these areas link and overlap with each other, but we have grouped them to enable focused discussion of each.

High school teachers participating in the Tulsa Regional STEM Alliance-sponsored Flight Night Quadcopter Teacher Institute.

// Photo Courtesy of Tulsa Regional STEM Alliance

1

Shared vision, priority outcomes, common language and agreed-upon measurements are needed for ecosystem cultivation. Local, regional and state-level ecosystem cultivators can adapt this paper's logic model template to develop their own local model.

Eric Jolly, Director of the Minnesota Museum of Science and Chair of the National Research Council's Committee on Successful Out-of-School STEM Learning, noted, "Coherence is essential to understanding partnership. We need to ask ourselves if partners have shared and consistent goals and if the necessary components are being put forward...It is like rowing a canoe with a partner – if you aren't aiming for the same point, you will never get there." With that maxim in mind, we designed a logic model template to help catalyze ecosystem cultivators' progress toward a shared vision, priority outcomes, use of common language and agreed-upon measurements among stakeholders from different sectors.

A logic model can be a useful basic building block for designing evaluations, but we debated the value of developing this template for a few reasons. First, as Bronwyn Bevan, Director of the Institute for Research and Learning at the Exploratorium, notes, ecosystems "...are populated by people and by institutions and are not simple. They have evolved over time as a product of complex interacting systems." (National Research Council, 2014b, p. 31). Research on systems evaluation suggests that the complex interactions inherent in ecosystems are impossible to fully capture and evaluate using the logic model approach (Hargreaves, 2010). Second, we were concerned that a template may appear to be prescriptive, which was not our intent. Ultimately we decided to offer this template as an important tool to help catalyze ongoing dialogue and relationship-building toward common vision, goals, language, outcomes and measurements among ecosystem stakeholders.

Young people and staff at the Boston After School & Beyond Summer Learning Project at the Sportsmen's Tennis Enrichment Center. // Photo Credit: Casey Atkins

To download a version of this logic model designed for adaptation, click here.

LOGIC MODEL // **STRATEGY 1:**
ESTABLISH CROSS-SECTOR PARTNERSHIPS TO CULTIVATE ECOSYSTEMS

Early Stages: Networking and Cooperation

Inputs

- Credible, highly engaged lead organization committed to collaborative practice
- Receptive partners:
  - Schools/school districts
  - Out-of-school time (OST) system/programs
  - STEM-expert museums, science centers
  - Institutions of higher education
  - STEM companies
  - Businesses that recognize the need for STEM competencies
  - STEM professional associations
  - Libraries
  - Community-based organizations
  - Philanthropies
  - Families and parent organizations
  - Youth organizing and advisory groups
- Financial, human capital, and other resources

Activities

- Create structures for networking and cooperation:
  - Assess readiness to begin ecosystem cultivation process
  - Develop a deeper understanding of ecosystem's assets and gaps by mapping:
    1) learning opportunities for youth in and out of school
    2) existing and potential ecosystem partners
    3) existing cross-sector initiatives
  - Define shared vision, design principles, priority goals and desired outcomes
  - Define enlightened self-interest and role(s) for each stakeholder
- Identify and engage additional partners
- Build partners' familiarity with system evaluation strategies

Outputs

- Self-assessment for readiness
- Ecosystem maps
- Gap analysis
- Shared vision, priority goals and desired outcomes
- Design principles
- Evidence that partners understand their own and other's enlightened self-interest and their role(s) in emerging ecosystem
- Evidence of partners' familiarity with different approaches to system evaluation

Outcomes

- Collaboration agreement(s)
- Evidence of initial financial and human capital support
- Evidence that stakeholders have increased interest in and knowledge of STEM learning in settings that are not their own and what connections exist among settings
- Stakeholders are beginning to use common language to describe STEM learning in different settings

Measurement

- Documents showing in-kind and financial support • Readiness self-assessments • Ecosystem map • Gap analysis • Goal and outcome statements • Evaluation alternatives
- Interviews/surveys with stakeholders across sectors
- Analysis of partnership to determine level of diversity and representation of all sectors

LOGIC MODEL // STRATEGY 1:
ESTABLISH CROSS-SECTOR PARTNERSHIPS TO CULTIVATE ECOSYSTEMS

Later Stages: Collaboration and Synergy

Inputs

- Credible, highly engaged lead organization committed to collaborative practice
- Receptive partners:
  - Schools/school districts
  - Out-of-school time (OST) system/programs
  - STEM-expert museums, science centers
  - Institutions of higher education
  - STEM companies
  - Businesses that recognize the need for STEM competencies
  - STEM professional associations
  - Libraries
  - Community-based organizations
  - Philanthropies
  - Families and parent organizations
  - Youth organizing and advisory groups
- Financial, human capital, and other resources

Activities

- Engage in activities from Strategies 2-4 that best meet priority goals
- Sponsor cross-setting site visits, job shadows, literature reviews, retreats, etc., for all partners
- Expand and/or reallocate financial and human capital resources to support cross-sector initiatives
- Adjust policies and practices to support cross-sector initiatives
- Engage in outreach and communication to key stakeholders and broader community
- Implement evaluation that provides useful and timely data, encourages reflective practice, and enables continuous improvement
- Build capacity of partners to engage in evaluation process

Outputs

- Partners participating in cross-sector learning
- Newly expanded/connected STEM learning opportunities for young people and educators
- New pathways youth can navigate toward STEM success
- Committed, long-term funding
- Policy and practice changes to support cross-sector STEM are embedded in partners' strategic planning documents, defining and requiring cross-sector learning
- New or reallocated resources to support cross-sector work, (e.g. a school district appointing a STEM partnerships director)
- Number/reach of communications
- Partners are developing capacity to reflect on their actions and decisions, use data to inform course adjustments

Outcomes

- Cross-sector partnerships expand/connect youth and educators to STEM learning across settings
- Partners are well versed in and committed to cross-sector approaches
- Articulated pathways guide youth from K-12 to higher education to STEM careers
- Resources and policies supporting cross-sector work are institutionalized
- Partnership has secured stable financial/human capital support for infrastructure and evaluation
- Increased understanding among community members of importance of STEM learning in and out of school
- Measurable population level improvement in STEM learning and engagement outcomes for youth

Measurement

- Map of additional STEM learning opportunities, showing cross-sector connections • Map of new articulated pathways and evidence that youth are accessing • Examples of grant awards • Evidence of partners institutionalizing resource and policy support for ecosystem approaches • Open rates/re-posting rates for digital resources show engagement/impact of communications
- **Note:** Better measures of population level improvement in STEM learning and engagement for youth are needed. Current measurements include K12 grades, standardized test scores, graduation rates and rate of entrance into post-secondary STEM majors or technical education, rates of employment in STEM fields or in jobs requiring STEM skills.

LOGIC MODEL // **STRATEGY 2:**

CREATE AND CONNECT STEM-RICH LEARNING ENVIRONMENTS IN DIVERSE SETTINGS

Inputs

- STEM partners named in Strategy 1
- Leaders and practitioners from STEM learning environments in multiple settings: K12 classrooms, OST, science centers, libraries, homes, etc.
- Research-aligned STEM curricula with adequate materials
- Access to digital media
- Educators from different settings equipped with knowledge and skill to lead learning
- Financial, human capital and other supports to expand, connect and improve quality of STEM learning environments

Activities

- Provide subsidies, transportation and family outreach to increase access of underserved youth to multiple STEM learning opportunities
- Expand access to STEM-rich learning for youth through field trips, mobile science labs, visiting STEM professionals
- Link STEM learning in and out of school through intentional use of common language and matching curricula scope/sequence
- Use OST programs and other out-of-school settings to more deeply explore cross-cutting STEM concepts with emphasis on scientific inquiry, engineering design, collaboration, and problem-solving
- Link programs and other learning opportunities to enable youth to progress from one to the next by age, interest and/or skill
- Build career exploration and internship opportunities with explicit classroom preparation components
- Show parents/guardians how to support youth to learn across STEM settings

Outputs

- Increased recruitment of underserved youth to access multiple STEM learning opportunities
- Increased horizontal and vertical points of connection between and among schools and informal STEM learning organizations
- More partnerships between schools and youth programs with time for joint planning and delivery of STEM-rich learning experiences
- Curricula that encourage cross-sector learning opportunities, including interdisciplinary project-based learning and school/afterschool aligned curricula
- Resources for parent and guardians to support youth STEM pursuits delivered by educators in various learning settings
- STEM learning institutes enroll educators across settings

Outcomes

- Increased participation of underserved youth in multiple and connected STEM learning opportunities
- Increased quality of STEM learning opportunities through use of STEM-rich environments in and out of school
- Better resources and spaces to facilitate scientific inquiry, engineering design, collaboration, and problem-solving
- Increased parent/guardian involvement and support of their child(ren)'s pursuit of STEM learning
- Increased youth capacity to apply STEM skills and knowledge to novel and applied problems
- Increased youth understanding of math concepts, cross-cutting concepts in science and core ideas of science
- Greater self-perceptions of youth engagement and interest in STEM
- Increased understanding by youth and parents/guardians of the requirements and pathways to pursue STEM careers

Measurement

- Participation tracking using a comprehensive data system (e.g. school attendance system, YouthServices.net, KidTrax, ETO) • Observation using a research-validated quality assessment tool (e.g. DoS, STEM PQA) • Localized measure of the efficacy of STEM teaching and learning K12 • Self-report youth surveys that measure engagement, motivation and interest in STEM (e.g. Common Instrument) • Badges and portfolio assessments of student competencies • Localized measures of STEM knowledge/competency and persistence • Parent/guardian surveys that measure perceptions of their role in supporting their child(ren)

LOGIC MODEL // STRATEGY 3:
EQUIP EDUCATORS TO LEAD ACTIVE LEARNING IN DIVERSE SETTINGS

Inputs

- Financial/in-kind support for professional development (PD), pre- and in-service teacher education, and co-teaching across sectors
- PD leaders with flexibility and capacity to train educators across sectors and with deep knowledge of STEM learning informed by the NRC's Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (2012); Surrounded by Science: Learning Science in Informal Environments (2010); and Community Programs to Promote Youth Development (2002)
- Adequate materials and resources for educators
- Co-planning by partners
- Business and higher education STEM professionals to mentor and sponsor educator externships

Activities

- Design/implement relevant, high-quality joint PD and co-teaching for educators across settings
- Offer educators across settings externships with STEM professionals
- Implement cross-sector placements, e.g.: K-12 teachers and district STEM specialists in OST programs • Educators from STEM-expert institutions in K-12 and OST programs • OST educators and STEM-expert institutions in the school day
- Tap school STEM specialists and science center staff to advise on OST STEM
- Within STEM expert institutions, connect K-12 and OST PD programs
- Use OST, science centers, informal learning spaces as pre-service practical sites
- Use technologies for learning, e.g. videoing, peer-to-peer review, and social media
- Develop Lead STEM Practitioners to provide PD and consultation across settings

Outputs

- Increased high quality PD and coaching support that is accessible to educators from all sectors
- Increased hours teachers and educators from diverse settings are engaged in joint PD, coaching and/or co-teaching
- Increase in number of Lead STEM Practitioners working across sectors
- STEM learning institutes enroll educators across settings
- Evidence of cross-sector connections among district STEM specialists, teachers, educators from STEM-expert institutions, and OST site directors and educators
- Evidence of educators across settings participating in externships w/STEM professionals
- Evidence of pre-service STEM educators completing practica in diverse settings
- STEM educator certification/badges

Outcomes

- Teachers and educators in a variety of settings who can design and facilitate STEM learning opportunities grounded in scientific inquiry and practice and engineering design
- New skills, outlook, knowledge and change in practice that educators can apply in multiple settings
- Educator and administrator attitudes across sectors support an integrated approach to STEM teaching and learning
- Engaged students with ability to think critically, collaborate on projects, and analyze information

Measurement

- Documentation of PD participation • Educator surveys on use and impact of PD in their own practice and respect for other educators' roles • Program/classroom observations using school district observation protocol like Classroom Assessment Scoring System or a valid quality assessment tool designed for OST (e.g. DoS, STEM PQA) • Localized measure of the efficacy of STEM teaching and learning K12 • Localized measures of STEM knowledge/competency and persistence • Student engagement and interest surveys, e.g. the Common Instrument • Number of educator certifications/badges

LOGIC MODEL // STRATEGY 4:

SUPPORT YOUTH TO ACCESS PATHWAYS AND EXPLORATION TO FURTHER LEARNING AND CAREERS

Inputs → Activities → Outputs → Outcomes

Inputs

- Scan of existing partnerships that connect young people to learning experiences over time
- Searchable databases – such as the Connectory – used to catalogue and identify STEM opportunities
- Mechanisms for collaboration across K-12 and higher education
- STEM mentors from business, higher education, and STEM professional associations
- Resources for trainings and convenings for educators, families and youth

Activities

- Identify gaps in access and barriers to scale
- Promote use of searchable database of STEM opportunities
- Ensure that STEM learning opportunities across sectors include timely information about career opportunities and requirements
- Increase opportunities for youth to take and pass Advanced Placement (AP) courses and exams as pathway to STEM majors
- Increase opportunities for youth to experience STEM careers through internships, jobs and shadow days
- Increase number/quality of mentorship experiences for youth
- Increase youth access to STEM professionals with career knowledge
- Institute badges/ portfolios so youth can demonstrate competency/knowledge across settings
- Assess and align curriculum and competency expectations in K-12 and higher education and create articulated pathways from education to business and industry
- Teach STEM educators, parents/guardians, and advisors to provide support to youth in navigating pathways

Outputs

- Increase in use of searchable database of STEM opportunities
- Increased confidence of parents/guardians and educators in providing guidance to youth on pursuing STEM interests and preparing for STEM career/education
- Increased STEM career awareness among youth, educators and parent/guardians
- Increased number of STEM professionals mentoring youth on interest, career and education pathways
- Increased opportunities for young people to experience STEM careers through internships, jobs and shadow days
- Articulated pathways from K-12 to higher education or other post-secondary learning to jobs in business and industry
- Evidence of new credentialing opportunities such as digital badges and opportunities for students to earn academic credit for STEM internships, and acceptance of the credentials in multiple settings

Outcomes

- Increased number of youth pursuing STEM interests across settings and over time
- Increased number of Advanced Placement courses in STEM subjects taken and exams passed
- Increased understanding by youth and parents/guardians of the requirements and pathways to pursue STEM careers
- Increased self-identification of youth as scientists
- Increased parent/guardian and educator support for youth in pursuing STEM interests in different settings
- Increased number of students persisting along articulated pathways and succeeding in postsecondary education and careers
- Increased understanding among youth and families of the importance of STEM skills and literacy even for those not choosing a STEM career

Measurement

- Case studies and learning narratives of youth pursuing STEM interests • Evidence of digital badges/portfolios earned and accepted across settings • AP course enrollment, scores and passage rates • Number of students taking and completing college-accredited high school courses (e.g. CA's A-G classes) • Number of students enrolled and progressing in articulated pathways • Student portfolios demonstrating growth of STEM competencies over time • Surveys of youth interest in STEM, measured over time • Educator, STEM professional, and parent/guardian surveys on their knowledge of STEM pathways and confidence in capacity to mentor youth toward goals • Youth surveys on their knowledge of STEM pathways and requirements for career and post-secondary entrance

// USING THE STEM LEARNING ECOSYSTEMS LOGIC MODEL

This logic model was informed by tools and ideas developed by fellow system builders such as the *Every Hour Counts Measurement Framework and A Framework for Performance Measurement and Evaluation of Collective Impact Efforts* (Every Hour Counts, 2014; Parkhurst, M., Preskill, H., and Splansky Juster, J., 2014).

While ecosystem cultivators may aspire to implement all four strategies to their fullest extent, constraints in capacity, funding and policy will likely drive focus on one particular strategy within a given timeframe. That said, the first strategy - establishing cross-sector partnerships to cultivate ecosystems – is intended to be foundational. Assessing gaps, identifying partners, developing a collective vision and committing to shared outcomes creates a strong base to develop creative approaches to the remaining three strategies, based on each community's needs, assets, and interests. We suggest a two-stage approach to Strategy 1, recognizing its complexity, but it is up to communities to decide how to time their progression from the initial to the second stage.

We hope use of this logic model or a similar tool to define the parameters of collaboration will help local ecosystem cultivators tackle several important and complex tasks: deepening relationships, defining common language and shared outcomes, and importantly, moving toward adopting common assessments. Shared logic will create a strong footing for approaching increasingly complex evaluation questions. For example, a community might first agree on its shared logic model, focus evaluation on process and implementation, then on effective practice related to set of strategies, and finally on impact on young people when sufficient time has passed for effects to surface.


Photo Courtesy of ExpandED Schools

Deepening Relationships Across Sectors

Cross-sector collaborations often face hurdles of unequal power and strong accountability requirements that threaten risk-taking and trust. Previous studies by Bevan (2010) and Russell, Knutson and Crowley (2012) have pointed out that cross-sector collaborations require more time and resources than are typically recognized by either the collaborators or their funders. Collaborations among schools and external organizations are particularly challenging for several reasons. Schools and school districts typically hold the advantage in power because of their resources and organizational stability. School leaders are heavily influenced by external drivers such as district, state and federal education policy and accountability requirements. External partners often have different cultures, educational values, and goals for young people. More research is needed to define the success factors for collaborations between external organizations and schools. Russell, Knutson and Crowley's 2012 study comparing two relationships – between a school district and a cultural organization; and the same school district and a community-based non-profit youth provider – found that "while the social capital dimensions of collaboration such as norms of trust and mutuality enabled some degree of collaboration, constraints related to partnership governance and the institutional context prevented either partnership from achieving robust joint work." Using the template to construct a shared logic model will provide a structured way for collaboration that helps to recognize and articulate shared goals and outcomes.

Defining Common Language for Stakeholders Across Sectors

We hope that building a logic model will help advance a common language among ecosystem cultivators so that they have a platform for further collaboration. In *Learning to Improve*, Bryk and his colleagues describe the importance of establishing common language to focus a shared desire for improvement. By defining a specific problem, 'network improvement communities' can implement changes and inform each other of improvements efficiently because they share an understanding of what they are trying to solve and a common language to discuss it. The multiple meanings in the field of "out-of-school learning," "informal learning" and the various definitions of expanded and extended learning provide one example where achieving clarity within a community is important. We know of one community that convened a series of meetings to discuss cross-sector STEM education without any representation of after-school providers, only because the conveners thought "out-of-school-time providers" meant only the local science centers.

Communities that develop a common language to express their shared goals for young people, such as Boston's ACT (Achieve, Connect, Thrive) Skills Framework, or communities with a clear and comprehensive vision statement for STEM education, can advance continuous improvement efforts through effective communication. A research-practice partnership called the California Tinkering Afterschool Network (CTAN), funded by the National Science Foundation and the S.D. Bechtel, Jr. Foundation, created a process called value mapping (Ryoo & Shea, forthcoming). Value mapping supports partners from various organizations in learning about each other's perspectives, educational philosophies, and values while developing shared language and research goals that maintain different perspectives. The process began at the start of a cross-organization collaboration in order to disrupt traditional partnerships involving researchers and educators, in which researchers define problems and set research plans. The mapping activity allowed partners to reflect on the important aspects of what brought them together while exchanging thoughts with colleagues about their values, allowing all partners to have input and ownership of the project. The subsequent maps of partner values have been used to inform research questions, joint data analysis, and construct vision statements.

Defining Common Outcomes for an Ecosystem

In order to come to agreement on a set of outcomes to measure, each partner in the ecosystem should describe the outcomes they value and how they are measuring them as well as listen to the valued outcomes and measurements of other partners. A shared vision does not mean partners have to give up their own priorities about what should be measured. Partners may select a subset of outcomes to track collectively that are important to everyone but that may not include all important outcomes to an individual organization or sector (Forum for Youth Investment, 2014; Hanleybrown, Kania & Kramer, 2012;Parkhurst & Preskill, 2014). Certainly, outcomes valued by an individual partner that are not selected by a collaborative group may still be measured at the program level.

Ecosystems may consider outcomes other than educational success. Anita Krishnamurthi of the Afterschool Alliance commented, "There is a lot of movement within the larger STEM education community to define STEM competencies necessary for life success and

Photo Courtesy of ExpandED Schools

then to design curricula and programs to help students achieve those competencies. This aligns with a view that prioritizes equity and fairness as STEM outcomes." She notes that private sector stakeholders may view employment as a key end-goal, which might drive design of programming, outcomes and measurements. Each community's logic model must reflect the motivations for collaboration of their community's active stakeholders.

Getting to Common Assessments

Although more widespread use of common measurements of STEM learning and engagement across settings and communities would advance understanding of effective practices in the field, implementing common measures is complex and difficult. The ecosystem approach may offer an opportunity to catalyze progress in this area. Using the logic model template will help local sites establish common vision, outputs and outcomes, and advance the foundational commitment to shared enterprise that will be necessary for the successful adoption of common measurements. Our hope is that strengthening the national movement around ecosystems will increase demand from local communities for common tools.

However, in the short term we expect that local ecosystem cultivators who agree about outcomes may still disagree about which measurement tools are most appropriate. For example, practitioners are often concerned primarily with the burden of assessment on young people and educators as they evaluate potential assessment tools. Researchers aiming to aggregate and compare data among programs or communities might prioritize standardization or strong reliability, preferring metrics that have been normed and validated and that can be used as evidence in high-standard peer review journals. These factors are all valid and important, but can, at times, be at odds with one another.

Fortunately, there are several tools that measure important impacts, such as youth engagement in STEM, that are normed and validated, are relatively easy to administer, and are being adopted by practitioners in an increasing number of communities (see logic model for specifics). Thus communities now have some excellent options. The ecosystems approach provides a structure to talk these issues through, with mutual respect and shared understanding, and arrive at a common path moving forward.

Even when communities are not quite ready to use the same instruments, progress can still be made. For example, in the multi-city FUSE initiative developed by ExpandED Schools (formerly TASC) and taken to multiple cities by Every Hour Counts, cross-sector partnerships in Boston, Providence and New York City came together to agree on expected outcomes for young people and their educators. Each city had existing social and emotional survey tools already in place and had buy-in from local funders, practitioners, researchers and intermediaries. Requiring a new survey tool would have been unnecessarily disruptive and complex. Instead, researchers analyzed findings from similar measures to draw conclusions across the three cities.

A word on the role of grantmakers and researchers. They can urge the field to use common measures, but will be most effective if they can identify ways for the information to drive continuous improvement and short-term benefit to local communities in addition to building knowledge for the broader field over the long-term. Funder requirements to use certain measures may alienate practitioners from relying on those measures to assess themselves critically and should be treated with caution. And, in cases where different ecosystems are using different tools to measure similar constructs, we recommend fostering a sense of community that creates desire among local ecosystem cultivators to analyze promising practices and the potential for replication or adaptation of each other’s strategies. This desire may in turn, spur communities to want to use common measures with one another. Researchers who know which measures are the best and what kinds of questions they answer well will then be effective change agents. Even with consensus around common approaches to evaluation and measurement, efforts to put those new metrics into place take time, resources, and committed evaluators. Survey administrators need training, Departments of Education may need to give approval, and data collection issues must be analyzed and corrected.

2 Research at multiple levels using a range of methodologies is needed to better understand the optimal conditions and effective practices that undergird robust ecosystems.

Nearly everyone interviewed for this paper agreed on the need for more robust research about the value and impact of strategies to cultivate STEM learning ecosystems. Gil Noam, Director of the Program in Education and Afterschool Resiliency at Harvard University, commented, "I think the need to understand the impact of work at the ecosystem level is critical. There are many outcomes – social and emotional development and well-being – that traditionally aren't being captured. Many of them can also be linked to STEM. Importantly, we need to study how quality across the ecosystem can be increased." (G. Noam, personal communication, August 2015).

The following set of questions form the basis for a research agenda focused on understanding the conditions that lead to successful STEM learning in dynamic ecosystems:

- ☐ What are the cognitive and affective impacts of connecting STEM content for young people across settings and are there differences rooted in age, learning context, approach or environment?

- ☐ What are the most effective cross-sector professional development approaches and how can a diverse set of STEM educators (formal and informal professionals and volunteer mentors) work collaboratively throughout the school year and summer to improve their capacity to build STEM competencies in young people?

- ☐ What are the best ways to design and implement formal and informal youth pathways to STEM literacy and engagement that offer flexibility to adapt to changing educational contexts as young people develop?

Photo Credit: Tiffany Knight

- ☐ How does effective family involvement shift over time, and what are the most effective ways to build capacity of families and youth to navigate and connect opportunities tailored to individual interest and goals?

- ☐ In what ways, if at all, do ecosystem cultivation strategies lead to increased equity in opportunity and success for young people historically under-represented in STEM majors and careers?

- ☐ What additional opportunities for increasing quality, scale and/or greater sustainability are created and what may be weakened or eliminated as a result of aligning and connecting learning contexts?

- ☐ How are ecosystem partners better able to achieve their goals as a result of involvement in cultivation work? How does the interdependence characteristic of an ecosystem affect the health of the partners?

- ☐ How does ecosystem cultivation help to create the policy and funding conditions that enable depth, spread and sustainability of high-quality STEM learning opportunities?

- ☐ Which ecosystem activities among partners result in the greatest changes for young people?

- ☐ Which ecosystem models are most conducive for organizing different types of local ecosystems?

Ecosystems that have developed a strong shared logic model will be well positioned to delve into these complex questions. We recommend that ecosystem leaders, researchers and funders work jointly to launch comparative studies looking at efforts in multiple communities, as well as in-depth community-level studies. In both cases, it will be important to disseminate findings broadly among ecosystem proponents.

Photo Courtesy of ExpandED Schools

Photo Credit: Tiffany Knight

(left) **California Academy of Sciences *Science Action Club* participants and staff dissect owl pellets together.**

// **Photo Courtesy of** California Academy of Sciences

(right) **Girlstart's summer camps in Austin, Texas integrate technology and hands-on STEM learning.**

// **Photo Courtesy of** Girlstart

Use multiple research methodologies to answer complex questions

In her 2010 planning guide for evaluating systems change, Hargreaves explains that experimental or quasi-experimental approaches are a mismatch for researching "systems with complex dynamics" or those having parts that are "massively entangled and interdependent, that coevolve with each other and with the environment, and with equilibrium that is in flux and sensitive to conditions."

The field of community health – which also contends with measuring the impact of a variety of interventions carried out in diverse settings – offers lessons for STEM learning ecosystems. In 2001, Fawcett and colleagues pointed out that evaluating community initiatives for health outcomes required a different type of relationship between community-based practitioners and researchers – one that did not rely on "methods borrowed from clinical trials and other researcher-controlled methods of inquiry." Instead, Fawcett and colleagues argued for precedence to local initiative leaders in the design of the inquiry and the interpretation of the results. They emphasized the importance of evaluations providing a continuous flow of useful information to initiative implementers. Such information included documenting and supporting the collaborative process of design, planning and goal setting, and also documenting changes in programs, policies and practices catalyzed by the initiative. They recommended that evaluations focus on gathering data on these 'intermediate outcomes' before turning to the 'distal outcomes' of impact on people's health and behavior (Fawcett, et al, 2001). One example in Kansas City, studied by Collie-Akers and colleagues, involved researchers and community health coalition partners jointly developing a systematic method for documenting and characterizing the intensity, duration, reach and strategy of coalition activities, or what the researchers called "intermediate outcome of collaborative action—the number and extent of changes brought about in the community over time." Noted the researchers: "This measurement approach has high utility in a participatory research context: it shows progress along the way, thereby prompting systematic reflection and adjustments by members of the community-led coalition." (Collie-Akers, Fawcett & Schultz, 2013).

Photo Courtesy of Girlstart

Additional evaluation approaches for ecosystem cultivators and researchers to consider include:

- **Ethnographic approaches** that focus on how the different impacts of multiple changes depend upon cultural and societal contexts, particularly relating to whether or not ecosystem cultivation can make progress on righting the imbalance of access to opportunity – and indeed if and how different ecosystem cultivators intentionally prioritize this goal.

- **In-depth qualitative case studies** that follow decision points and assess the effects on quality, scale, sustainability and other large-scale elements of systems change. These studies might use Coburn's scaling framework to evaluate efforts of ecosystem cultivators to scale their work, attending to the multiple dimensions of depth, sustainability, spread and how ownership of core ideas "shifts" from reformers to those with authority to institutionalize the reform (Coburn, 2013).

- **Mapping analysis and other methodologies within network science** that can assess key signs of ecosystem health — strong shared vision and goals, mutual respect, and strength of relationships across sectors. This type of research could help us understand the workings and relative strengths of different models of ecosystem cultivation.

- **Cross-sectional studies** that collect information at one specific point in time about the prevalence of a particular variable within a population, for example, access to STEM in after-school, interest in STEM, or use of STEM-rich cultural institutions.

- **Retrospective studies,** in which previous information about a cohort is collected and analyzed, such as hours of STEM instruction in middle school; completion of Algebra I in eighth grade.

- Creation and analysis of **individual learning narratives** that unpack and clarify the multiple influences on a young person's choices to pursue or not pursue STEM engagement over time, to understand individuals' "learning lives" as they grow, change, and bring together different experiences, including life-wide and life-long learning (Penuel, Lee and Bevan, 2014). This analysis observes change over time, movements across boundaries and places, social spaces and domains (Barron, 2014; Kumpulainen and Sefton-Green, 2012). Rapidly evolving digital technologies will be critical to these types of studies. In conceptual or pilot stages currently are tools which enable researchers to 'digitally trace' young peoples' pursuit of STEM knowledge and connections online and allow youth to self-document their interest or activities on mobile platforms. The development of large databases of learning narratives would improve researchers' capacity to undertake individual and cross-case, cross-setting and cross-time analysis (Barron, 2014).

The questions articulated above will also require researchers willing to take on projects with multiple methods and with multiple disciplinary foundations—researchers will need to be flexible and become more comfortable with research practices new to them. This will require spending time working with diverse practitioners who each have a stake in the design and outcomes of the study. Just as practitioners need to reach across sectors, we encourage researchers to reach across disciplines.

We should also learn from existing multi-disciplinary research centers, such as the NSF-funded research at the Learning in Informal and Formal Environments (LIFE) Center, a multi-institutional collaboration that values learning in multiple settings and brings together psychology, neuroscience, education, anthropology, sociology, and others. We can learn from affiliated researchers the benefits and challenges of working in a multi-disciplinary center and how to promote practices that enable strong, practical research findings.

Large-scale public and private education funders focused on STEM research typically bound their programs by the nature of the learning setting (formal or informal). Funders will need to provide sustained support in new ways. For example, OC STEM initiative funders are supporting evaluators to lead the development of a theory of change through interviews with practitioners, focus groups, and observations of program activities. This process will help the researchers engage with diverse stakeholders who may hold different views about how the program works in concept and in practice; what constitutes a healthy STEM ecosystem; and how an ecosystem approach differs from alternative approaches. Strong theories of change lay the groundwork for developmental and summative evaluations.

Youth participating in Boston After School & Beyond's Summer Learning Project at Sociedad Latina. // Photo Credit: Tiffany Knight

The SYNERGIES project in Parkrose, Oregon, now in its fifth year, aims to understand how, when, where, why and with whom children access and use STEM resources in their daily lives. The project's insights may have tremendous potential for efforts to cultivate STEM learning ecosystems across the nation.

Led by researchers at Oregon State University, project staff have followed a cohort of approximately 400 fifth graders from 2010 in the under-resourced Parkrose neighborhood of Portland, along with their peers, siblings and significant adults in their lives. The first three years were devoted to collecting baseline data and building relationships with stakeholders.

Preliminary results indicated that certain activities correlated strongly with STEM interest in children, including:

- Using the library
- Talking with someone at home about what they are learning
- Hiking/spending time outdoors
- Doing science kits/experiments
- Visiting websites of interest
- Gardening
- Reading books/magazines
- Building/taking things apart

However, interest in STEM topics among children decreased significantly between 5th and 8th grade, and 8th graders were significantly less likely to engage in the above activities than 5th graders. The project also found that some families are able to actively cultivate STEM interest development in their children (College of Education, Oregon State University 2014).

SYNERGIES project staff have engaged the Parkrose community in redesigning their STEM learning ecosystem. The project is researching how (physically and virtually) and why youth utilize (formal and informal) community learning resources to engage with and learn about STEM.

SYNERGIES developed a complex computer simulation of STEM interest pathways utilizing agent-based modeling to understand how decline in STEM interest is related to the interactions of young people with peers and adults in STEM-related activities. The model has revealed several major insights, including the recognition that absence of encouragement is an important constraint on interest development, and that friends are an important factor in sustaining interest.

Next, SYNERGIES will develop and refine learning interventions with partners that better support STEM interest and participation pathways for Parkrose youth. The long-term goal is to develop strategies and data-based tools to improve STEM learning in Parkrose that can be broadly applied to improvements in STEM education locally, nationally and internationally. //

3 New ways to track key indicators over time and across settings are needed to fully assess the impacts of robust STEM learning ecosystems on youth.

At the moment, most communities have no population-level data for tracking youth success in STEM, with the exception of standardized test results in math and, for a few grades, science. The inadequacy of using test scores as a sole measure of gains in student knowledge (or, for that matter, many other valued student outcomes) rule out their use as sole or dominant metrics to measure ecosystem success as a whole. Standardized tests may be more sensitive to teaching that is oriented toward the test format and specific content than affective changes towards STEM or skill development related to scientific practice and inquiry (Penuel, Lee and Bevan, 2014). Development of performance-based assessments aligned to the Next Generation Science Standards (NGSS) might offer an opportunity to better understand if and how young people can apply their science knowledge (National Research Council, 2014a). Yet even if assessments for NGSS are developed and implemented as performance tasks, they would be unlikely to assess affective aspects of students' relationship with STEM disciplines.

Ecosystems need ways to assess a broader of set of STEM outcomes for all youth within their boundary area. Such outcomes could include evidence of active participation in STEM learning opportunities, self-perceptions of STEM identity, success in academic STEM courses, pursuit of higher education and STEM majors, and eventual employment in jobs that require STEM skills. These data can be analyzed by specific populations of interest, including economically disadvantaged young people; Black or Hispanic young people, girls/women and young people with disabilities or who are English Language Learners.

To measure STEM interest and engagement, the PEAR Institute's Common Instrument is widely used among informal STEM practitioners. However, it is still only typically used by those young people who participate in after-school programs, not those who do not participate. 4H's YEAK (Youth Engagement, Attitudes and Knowledge) survey has similar constraints. Widespread adoption and administration of these or other tools could prove useful in building large data sets of affect and interest, though data-sharing capabilities would need to be in place so information could be interpreted by cross-sector practitioner teams for continuous improvement.

Over the past few years, the National Assessment of Educational Progress has expanded information about students' learning opportunities and experiences in and outside of school. Researchers should make use of this large and standardized assessment tool to explore the correlations between these student characteristics and their NAEP scores. These analyses will help to further link students' learning experiences with their STEM literacy and capabilities.

We also recommend exploring employment sector data, which can shed light on whether local residents are qualified for STEM jobs and how the knowledge and skill requirements for these jobs are evolving over time. Ecosystem cultivators might also explore how to satisfy requirements for tapping the National Student Clearinghouse for data on higher education enrollment, choice of majors in STEM disciplines, retention, and graduation. Understanding the links between K-12 interest, engagement, and achievement in STEM and connections to STEM success in college would be tremendously helpful in building programs throughout young people's lives that lead to enthusiastic, long-term participation in STEM disciplines.

Conclusion

The STEM Funders Network ecosystems initiative offers a significant opportunity for ecosystem cultivators to address the issues we have raised in this paper. Involving researchers as partners in nurturing and developing strong systems with common goals and visions will encourage even more responsive research methods and findings.

Researchers may need support to be effective communicators of their plans and their findings to multiple types of audiences, using new and diverse mechanisms to disseminate findings. Support to communication outlets that engage more than one sector, which few current outlets do (e.g., trade group and member-based conferences, peer-reviewed and issue-area journals, and interest-based listservs) will further cross-sector communication.

Photo Courtesy of ExpandED Schools

We also must understand and address the concerns of the practitioners we want to engage in this research. For school leaders who feel pressure from data being used for accountability, shared research designs may feel particularly risky or burdensome. Many practitioners described a desire to build their personal and organizational relationships before engaging in a robust collaborative research design, despite interest in deepening understanding about cross-sector collaboration. Building a network of like-minded practitioners that can come together to discuss these concerns and share strategies for overcoming concerns will encourage risk-taking.

Ecosystem cultivators will need to find new ways to tackle complex questions about how we, as a society, can support long-term development of children and adults. Dealing with these challenges will require funders to provide flexible resources to the many innovative practitioners and researchers working in this space. Researchers and practitioners will need to work together within and across disciplines to expand the questions they seek to answer and the ways they work together to improve practice and ultimately the impact, sustainability, and reach of STEM education efforts. Those innovators need supporters, partners, cheerleaders, colleagues, networkers and storytellers. It is in that spirit we offer this paper.

Appendix A:

Background on Emerging Ecosystems and Cross-Sector Partnerships

BOSTON SUMMER LEARNING PROJECT / Boston, MA

Boston After School & Beyond and the Boston Public Schools co-manage the Summer Learning Project. BPS teachers and community-based educators together provide a full-day, integrated learning experience for five weeks during the summer. In 2014, 18 community partners served 681 students directly through this initiative. An additional 19 programs serving 2,823 students across 40 sites also opted into the Summer Learning Project's quality improvement system. Together, this group of 58 sites — known as the Summer Learning Community — work year-round alongside more than 100 Boston Public Schools to promote skill development and close the opportunity gap between low-income students and their higher-income peers. All programs take place outside the school building, each using a different mix of time, location, enrichment, and staffing based on the specific needs and interests of the children and youth. All are focused on the common goals of academic progress in science, math and language arts; improvement in specific social emotional skills (engagement, initiative, communication, and relationships with adults); and deepening school-community partnerships. The Boston Summer Learning Project is funded with support from the Boston Opportunity Agenda, the Wallace Foundation, the Charles Hayden Foundation, the Eos Foundation, Klarman Family Foundation, the Yawkey Foundation, and the Boston Public Schools.

CALIFORNIA ACADEMY OF SCIENCES, SCIENCE ACTION CLUBS / San Francisco, CA

The Academy's Science Action Club (SAC) program sparks an interest in science among middle school youth and their afterschool activity leaders. The Academy provides afterschool programs with professional development training, themed lesson plans, supplies for hands-on nature investigations and digital technology resources.

Youth in SAC explore the environment, contribute to citizen science projects, and develop scientific skills to study and sustain the natural world. In 2014-2015, 600 5th-8th graders participated in 20 Science Action Clubs across the San Francisco Bay Area. A new partnership between the California Academy of Sciences and the California School-Age Consortium will enable SAC expansion to 100 clubs and more than 1500 youth throughout California in fall 2015.

Additional SAC partnerships include the San Francisco Unified School District, afterschool providers (Beacon Centers, YMCA, Boys and Girls Clubs), citizen science partners (Cornell Lab of Ornithology, NASA, Your Wild Life), Public Profit, and the Center for Hands-on Learning. Science Action Club is part of the Academy's Global Environmental Literacy Initiative, with major funding provided by Pisces Foundation.

THE CARBON / SCHUYLKILL COUNTY PENNSYLVANIA ECOSYSTEM

The Carbon/Schuylkill County Pennsylvania Ecosystem is the result of a grass-roots initiative that began in 2004. The heart of the ecosystem is SHINE (Schools and Homes in Education) after-school program which has cultivated partnerships reaching every facet of this rural community. SHINE, administered by Lehigh Carbon Community College, provides academic support for 497 students from 7 high poverty school districts and one technical school over 700+ miles. SHINE's comprehensive 42 week after- school/summer program includes kindergarten home visits, 1st-4th grade STEM centers, 5th- 8th grade STEM Career Academy, high school career awareness/mentoring opportunities. Community partners are invested in exposing students to real life STEM experiences. Business/industry are providing staff and labs for STEM activities. Superintendents and the SHINE director are bridging afterschool and STEM curriculum in the K-12 setting. SHINE provides 15 community college education majors a 36-week pre-service experience as teacher assistant/interns in the after-school centers. STEM-rich institutions provide professional development to current/ future teachers/staff in both informal/ formal settings. Parents are engaged in monthly STEM activities. The effectiveness of the collaborative has been documented in a longitudinal study over a 10 year period, using 20 qualitative/quantitative assessment tools. Cross/sector partnerships have evolved organically creating a seamless pathway from pre-school to college promoting school readiness, STEM education and college readiness. Policymakers and community leaders in Luzerne County, PA will replicate the SHINE Model the fall of 2015 by opening 7 new SHINE STEM Centers in economically disadvantaged school districts and technical schools.

CENTER FOR THE ADVANCEMENT OF SCIENCE EDUCATION, MUSEUM OF SCIENCE AND INDUSTRY / Chicago, IL

MSI's Center for the Advancement of Science Education (CASE) was created with a strategic vision to shape and lead best practices in science education. CASE was developed following the convening of a national advisory committee comprised of civic leaders, senior staff from regional non-profits serving at-risk youth and national leaders in science education. The committee informed the core priorities for CASE, with educational services for schools and community groups placed firmly at its center. CASE focuses on improving science education by:

1. facilitating high-quality science teaching and learning in and out of schools
2. increasing awareness, interest, and engagement with science
3. encouraging students to consider STEM-related post-secondary study and careers.

Curriculum is aligned with evidence-based best practices and with the Next Generation Science Standards to support learning in and outside the classroom. MSI's teacher professional development program has trained 913 teachers from 347 schools, including teachers in nearly 40% of Chicago Public K-8 Schools. MSI will train another 1,000 high-need teachers over the next 5 years. MSI also offers training and curriculum for afterschool site facilitators at more than 100 community-based sites annually through the Science Minors Clubs, reaching 10,000+ students each school year. Other initiatives include Science Achievers for high school-age youth, including hands-on skill building, work experience and college readiness; a Fab Lab reaching 3,000 youth annually and Summer Brain Games, an eight-week partnership with the Chicago Public Library designed to get parents and kids engaged in science learning during the summer months. More than 70,000 children and their families actively participated during summer 2015.


Photo Courtesy of ExpandED Schools

CHICAGO PRE-COLLEGE SCIENCE AND ENGINEERING PROGRAM / Chicago, IL

Created in 2008, the Chicago Pre-College Science and Engineering Program (ChiS&E) provides engaging, hands-on science, engineering, and mathematics activities on Saturdays for 320 students in grades K-6 and their parents annually, in university and science museum settings. ChiS&E's founder and current CEO, Kenneth Hill, also founded and served as CEO (1976-2004) of the Detroit Area Pre-College Engineering Program (DAPCEP). Modeled in large part after the Detroit program, ChiS&E aims to:

1. expose, motivate and prepare children and youth from underrepresented population groups to enter the STEM fields
2. increase parents' knowledge and skills in science and engineering along with their capacity to support their children in pursuing education and careers in these fields
3. increase the effectiveness of teachers in engaging students and parents in science-related learning activities.

ChiS&E has added an early algebra focus to the original DAPCEP model, thanks to support from the W. K. Kellogg Foundation for the infusion of pre-algebra concepts for students and parents in its K-3 "Little Engineers" program. Programs are led by certified teachers, university professors, or graduate students. Younger students and their parents learn alongside one another—parent participation is required in grades K-3 and 5-6. The ChiS&E/DAPCEP model is unique among out-of-school STEM education programs in starting in grade K, requiring parent participation, and providing for sustained engagement of students through the K-12 grade levels. In recognition of the effectiveness of ChiS&E strategies to prepare students for post-secondary study in STEM fields, the College of Engineering at the University of Illinois at Urbana-Champaign has identified ChiS&E as its principal out-of-school K-12 STEM education partner in developing a pipeline of Chicago Public School graduates for entry into the college's undergraduate science and engineering programs.

DETROIT AREA PRE-COLLEGE SCIENCE AND ENGINEERING PROGRAM / Detroit, MI

The Detroit Area Pre-College Science and Engineering Program (DAPCEP) was founded in 1976 and now serves 3,500 youth between the ages of 5-18 in the Detroit area. DAPCEP and Chi S&E share similar goals and program strategies. DAPCEP programs feature engaging, age-appropriate hands-on science and engineering activities led by certified teachers from the students' schools, university professors, or graduate students in out-of-school time. Programs are offered at science centers or university campuses. Younger students and their parents learn alongside one another. DAPCEP has also developed an in-school course focused on hands-on investigative science and engineering projects leading up to the science fair and provides training and materials for Detroit teachers to teach the course during the school day or after school. DAPCEP's major supporters include the Detroit Public Schools, the Michigan state Department of Education, the National Science Foundation, and local corporate and philanthropic foundations.

Through the Maine Math & Science Alliance, youth in rural Maine work with local scientists to explore spy satellite technology and drones. // **Photo Credit**: Veronica Young, MMSA

GIRLSTART / Texas

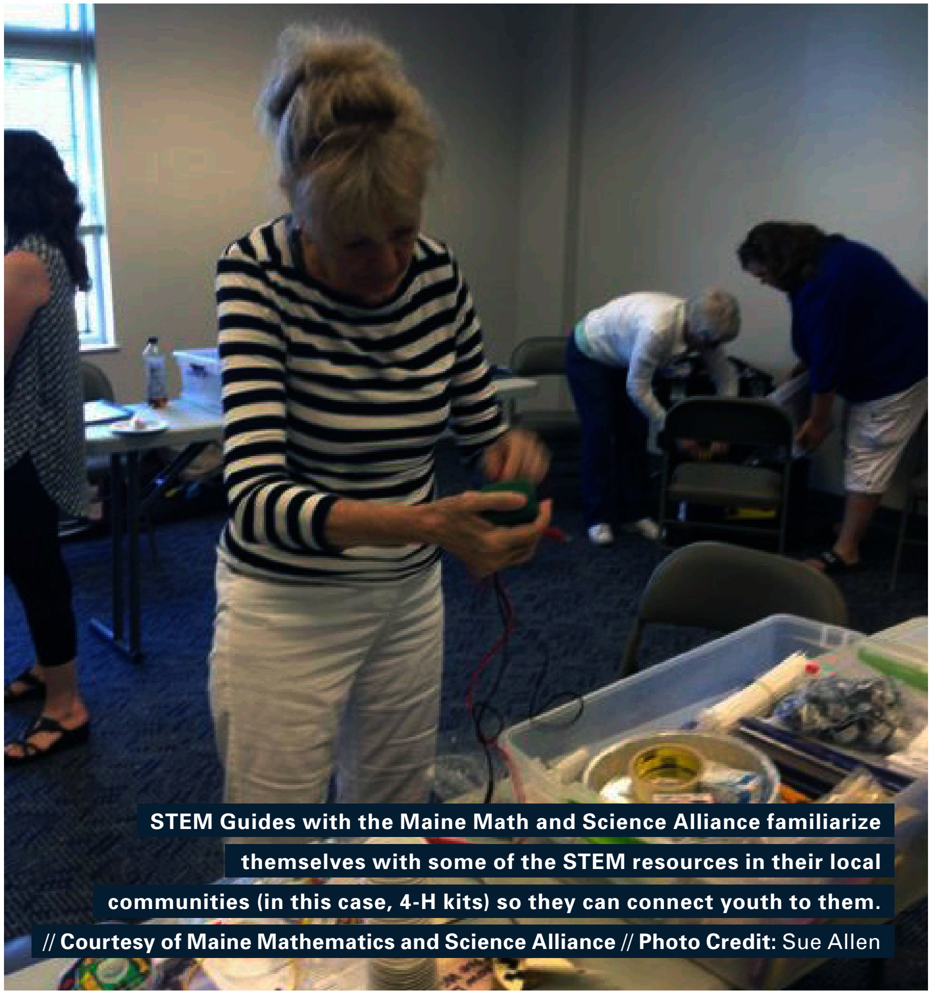
Girlstart's mission is to increase girls' interest and engagement in STEM through innovative, nationally-recognized informal STEM education programs. Girlstart's year-round programs foster STEM skills development, an understanding of the importance of STEM as a way to solve the world's major challenges, as well as an interest in STEM electives, majors, and careers. Girlstart goals are to:

1. increase girls' competency in scientific investigations (the scientific method and engineering design process)
2. increase girls' facility and mastery in STEM skills
3. increase girls' confidence and interest in conducting STEM activities
4. increase girls' awareness of STEM careers and interest in pursuing STEM electives, subjects, majors, and careers

Girls in an Austin, Texas Girlstart summer camp make new discoveries engaging in hands-on science experiments. // Photo Courtesy of Girlstart

While 100% of Girlstart target participants—girls—are already underserved in STEM, the organization is particularly interested in reaching girls who are also at-risk, live in a low-income or non-urban environment, or are of a diverse ethnicity. Founded in Austin in 1997, Girlstart has served 60,000+ girls and 10,000 teachers and families. Girlstart began an expansion in 2010. In 2014, Girlstart served more than 15,000 girls, teachers, and family members, 97% participating at no cost. The organization's 2006-2009 National Science Foundation-funded Project IT Girl demonstrated strong program outcomes: 100% of participants graduated from high school. 87% subsequently entered a 4-year university, and 80% then pursued STEM majors and careers.

Girlstart serves girls in Central Texas, San Antonio, the Rio Grande Valley, Houston, Dallas Fort Worth, Waco, and Bryan/College Station. Girlstart's 2015-2017 strategic plan calls for broad scale-up in Dallas Fort Worth, Houston, and the Rio Grande Valley, as well as preparation for national replication. Girlstart is funded through private and corporate philanthropies, including Dell, Google, KDK-Harman Foundation, Michael and Susan Dell Foundation, Motorola Solutions Foundation and Freescale.



STEM Guides with the Maine Math and Science Alliance familiarize themselves with some of the STEM resources in their local communities (in this case, 4-H kits) so they can connect youth to them.
// Courtesy of Maine Mathematics and Science Alliance // Photo Credit: Sue Allen

INDIANA AFTERSCHOOL STEM INITIATIVE

In 2010, with start-up funds from the Noyce Foundation, Indiana Afterschool Network (IAN) began creating a statewide system to advance STEM learning beyond the school day. Diverse partners came together to develop the core system elements of partnerships, policy, funding, quality, and professional development. IAN has grown its Indiana Afterschool STEM Taskforce to more than 100 influential leaders from business, government, education, cultural institutions, and youth programs. Taskforce meetings attract 50-70 participants statewide, hosted by Indiana's largest STEM companies. Locally, IAN has created out-of-school time/OST coalitions focused on creating coordinated region-wide STEM ecosystems in four counties, with 50+ new local partners, resources and outcomes. IAN has raised more than $2 million for STEM programming and training. IAN's focus areas include development of afterschool STEM standards; an online searchable database of OST STEM opportunities, professional development largely geared to the OST workforce but also including joint training among formal educators and youth workers, and successfully advocating policy changes at the state level to integrate a multi-sector approach to STEM learning.

Youth in rural Maine explore the "Foldscope," an origami field microscope designed at Stanford and introduced to them by local Maine Math and Science Alliance STEM Guides.

// **Photo Credit:** Becky Carino

MAINE MATHEMATICS AND SCIENCE ALLIANCE

In collaboration with 4-H and several other partners, the Maine Mathematics and Science Alliance (MMSA) is developing STEM learning ecosystems in several areas of rural Maine. MMSA has established three "STEM Hubs"—regions with populations of between 8,000-10,000 that lack large-scale institutions such as science centers, but do have STEM resources such as rich natural environments, deep local knowledge, and many small-scale events and programs on potentially STEM-relevant topics.

MMSA is iteratively developing a new genre of professional STEM Guides who serve as the human connective tissue in their community ecosystems. The Guides are embedded and respected members of their communities, familiar with both their assets and needs. Their role is not to create new programs, but to find effective and inexpensive ways to connect youth to what already exists. MMSA describes STEM Guides as informal guidance counselors who connect youth with science opportunities outside school. Guides connect youth to STEM through the following strategies:

1. Customized interactions with individual youth and their families (analogous to a hotel concierge), leveraging a common STEM Resource Bank (www.steminme.org) as well as extensive personal connections.

2. Giving youth the chance to experience a broad range of existing robust, proven STEM resources such as 4-H STEM Ambassadors, library programs such as Star Parties, or the nationally disseminated Teen Science Café program or Engineering Adventures program.

3. Building capacity through connections with community stakeholders (e.g. through meetings, booths at community festivals and Farmers' Markets, school-community STEM fairs, sponsoring the Hour of Code in a library).

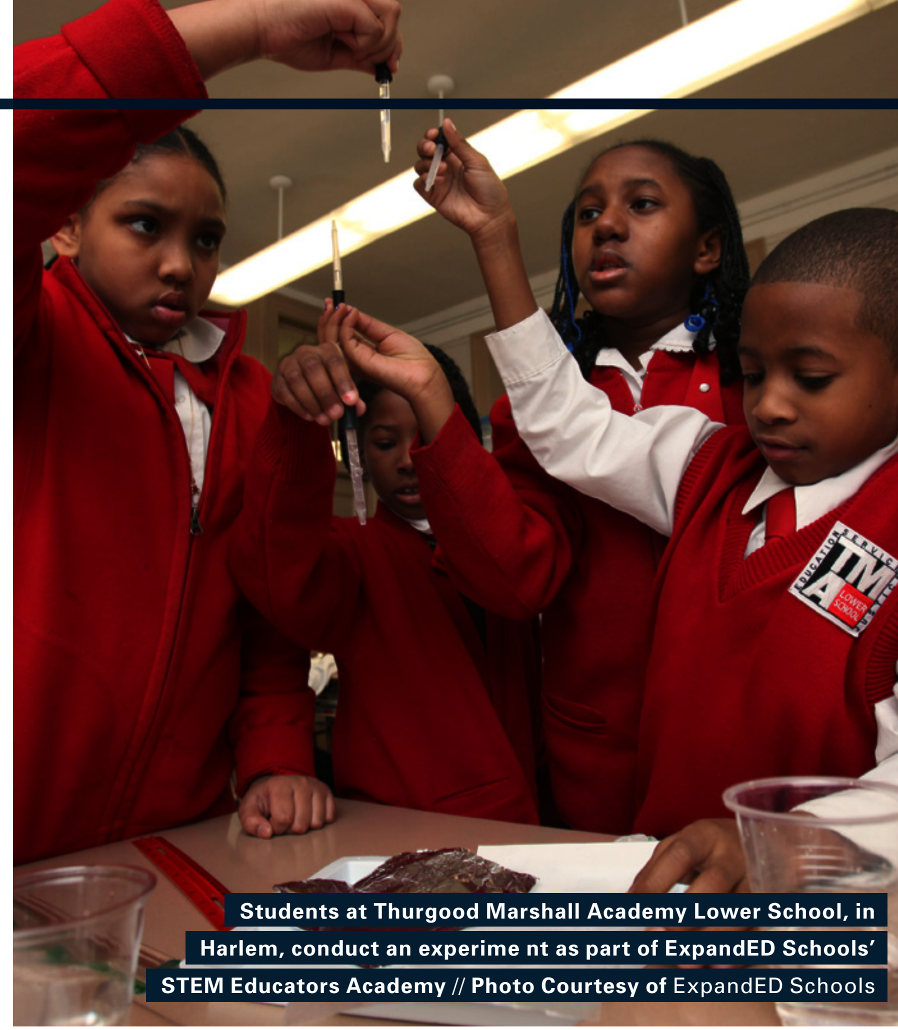
4. Positioning STEM Guides as micro-funders of STEM opportunities for those who can't afford them (e.g. gas cards and entry fees).

5. Finding mentors and role models for youth within the local community.

Only in its second year, the program has already reached over 200 youth with over 1,000 individual connections to STEM resources.

NEW YORK CITY STEM EDUCATION NETWORK / New York, NY

The NYC STEM Education Network builds on a strong collaboration of city agencies, youth development and education-focused organizations, museums and cultural institutions, higher education institutions, and supportive, long-term funders. Working together, the network has developed cross-sector collaborations to address critical needs in boosting young people's engagement and interest in science, their science identity and their acquisition of scientific practices and engineering design. Growing out of the Network and launched in 2013, is the STEM Educators Academy. ExpandED Schools (formerly TASC), the New York Hall of Science (NYSCI), Institute of Play (IOP) and The Intrepid Sea, Air & Space Museum have coordinated their expertise and resources to implement an innovative professional development approach that prepares educators to deliver an exceptional STEM learning experience to students living in some of New York City's most disadvantaged communities. The Academy is funded by the Pinkerton Foundation and expanded to twenty-five schools and 75 educators in fall 2015. Participating schools and community partners commit to:



Students at Thurgood Marshall Academy Lower School, in Harlem, conduct an experime nt as part of ExpandED Schools' STEM Educators Academy // Photo Courtesy of ExpandED Schools

- Identify teaching teams who will participate in 42 hours of joint professional development (including the summer institute and two mid-year seminars), 15 hours of targeted workshops and 16 hours of on-site observation, coaching and technical assistance. Teams consist of one science or math teacher and two community educators with interest in STEM.
- Provide an additional 100 hours of rigorous, inquiry-based and engaging STEM designed to spark the interest and passions of students and boost achievement in after school and during expanded learning time to a minimum of 40 students each year.
- Co-facilitate lessons once per week by teachers and community educators during the out-of-school hours to ensure alignment of instructional strategies and learning goals.
- Meet weekly to discuss lesson plans, strategize future topics/ activities, and share individual student successes and challenges.

New York City is also participating in Frontiers in Urban STEM Education (FUSE 3.0), in partnership with Boston After-School and Beyond, Providence After School Alliance, and Every Hour Counts, to redefine STEM education through formal-informal collaboration.


Photo Credit: Tiffany Knight

ORANGE COUNTY STEM INITIATIVE

/ Orange County, CA

The Orange County STEM Initiative is a collaboration of funders (from corporate foundations such as Broadcom, Boeing Company, and Allergan to family philanthropies such as Kay and Samueli Foundations), the Orange County Department of Education, other community stakeholders including students, parents, teachers, businesses, science institutions and youth development providers. The goal is to develop a continuum of active, hands-on and "minds-on" STEM learning from early childhood through higher education to employment in STEM-related fields, encompassing all aspects of student development, including family and school support.

The initiative has created a comprehensive strategic plan that includes in-school, out-of-school and other programming to ensure young people have access to high-quality STEM experiences across many settings. In 2015, the project is reaching students in all 28 school districts in Orange County. Program highlights include:

- A partnership with Discovery Science Center, Tiger Woods Learning Center, and the Orange County Department of Education to provide professional development and program support for out-of-school time programs on STEM learning.
- An 18-month STEM Ecosystem Institute, facilitated by WestEd, to provide professional learning opportunities and other support to cross-sector teams of educators and school district leaders.
- OC Pathways – a state funded grant for promoting Career Pathway programs that articulate between middle, high school and community colleges, including internship opportunities for students and externship opportunities for STEM teachers.

- With support from JP Morgan Chase, OC STEM will provide STEM Learning for parents in affordable housing tracts who are unemployed, and/or underemployed, with the goal of parental success in STEM and strong influence for children in the home seeing STEM learning modeled by the parent.

Photo Courtesy of ExpandED Schools

OC STEM has invested in a formal, ongoing qualitative and quantitative evaluation process for the Ecosystem Institute and the activities that support out-of-school time providers.

OREGON'S REGIONAL STEM HUB NETWORK

In 2013, Oregon's Regional STEM Hubs were created as a strategic initiative recommended and overseen by Oregon's STEM Investment Council and the Chief Education Office to improve math and science achievement, as well as increase post-secondary STEM degrees and certificates in the State of Oregon. These regionally-focused, multi-sector partnerships unite schools, institutions of higher education, non-profits, businesses, civic leaders and communities to drive local STEM innovation and improvements at the systems-level, while also aiming to reduce inequities in opportunities for students of color and those in poverty. The six regional Hubs leverage local resources and opportunities to bring STEM to students early and often, engaging them in and beyond the classroom. Their borders are fluid, overlapping into surrounding communities and connected through multiple professional networks through which ideas and resources flow. Hubs work toward aligning partner efforts towards a common agenda with key commitment to using relevant data for continuous improvement.

One of the examples of a program that has a presence in all six Hubs and throughout Oregon is the SMILE Program based at Oregon State University. The SMILE (Science and Math Integrated Learning Experiences) Program has been led by Oregon State University (OSU) for the past quarter century to increase post-secondary enrollment of underserved populations in the STEM fields. SMILE supports after-school clubs serving 650 students grades 4-12 in 40 schools in 17 rural communities throughout the state. SMILE engages children who are low-income, minority and often the first generation of their families to consider college. The clubs meet weekly and are led by 50+ public school science teachers. Since inception, the SMILE Program has served more than 7,500 students and partnered with 385 teachers. Other components of SMILE include exposure to higher education through college connection events such as day-long trips to a regional college for elementary and middle school club members, an overnight High School Challenge held at OSU, and annual Math and Science Family Nights at partner schools for students and their families. Each year approximately 185 former SMILE club members enter college. SMILE is funded by Oregon State University, federal grants such as University/School Partnership resources through the Department of Education, broader impact partnerships in National Science Foundation grants, and the USDA, among others. SMILE also receives support from local school districts, charter schools, and private philanthropy. SMILE was replicated in Rhode Island starting in 1994, with the University of Rhode Island as the lead and there are now 16 schools in the Rhode Island program.

TULSA REGIONAL STEM ALLIANCE (TRSA)

The Tulsa Regional STEM Alliance includes stakeholders from higher education, K-12, philanthropy, STEM institution, government, business and community organizations. On the national level, TRSA is a member of the US2020 City Network and works in concert with Million Women Mentors, SeaPerch, Creatrex, AAUW Tech Trek, Harvard PEAR, and the United States Naval Academy as well as the STEM Funders Network. In 2015, TRSA will produce 20,000 hours of STEM programming, 4000 hours of STEM professional development and 15,000 hours of STEM mentorship through 150 STEM events. This work is built around key design principles:

- Stimulate regional economic prosperity and growth with an entrepreneurial STEM vision
- Engage partnerships to accelerate capacity and broaden opportunity
- Strive to make STEM literacy attainable and desirable for all
- Involve committed STEM stakeholders
- Deliver an Alliance that connects and leverages existing assets and develops new capacity to innovate, scale and sustain effective STEM teaching and learning and career pathways resulting in an innovative workforce
- Foster the development of socially responsible, values-based leaders and STEM workforce with a consciousness and eye toward a more contemporary Tulsa — enabling the future — while addressing the largest grand challenges
- Value and promote a STEM culture and a single community of practice from families to educators to corporate leaders
- Ensure an evidence-based approach with measurable and sustainable results

Photo Credit: Skillings Video

TRSA has designed a “mesh network” to leverage its stakeholders strengths, expertise and passion to fuel progress in the STEM education arena, encompassing the formal, after school and informal education spaces.

URBAN ADVANTAGE / New York, NY

Urban Advantage is a multi-institution partnership program led by the American Museum of Natural History in New York City focused on middle school science education. Urban Advantage has the dual goals of improving teachers’ practice and students’ learning in science. Teachers and school administrators receive immersive professional development at informal science education institutions such as zoos, botanical gardens, museums, and science centers. Students improve their abilities to do authentic investigations that support science and engineering practices through experiential learning in and out of school as well as outreach to their families. The program was launched in 2004 with 30 schools and 60 teachers and is currently serving over 280 middle schools and over 800 science teachers, reaching over 80,000 students a year. Urban Advantage is funded by the New York City Council and the New York City Department of Education. The UA framework has been used to develop and implement a UA program in Denver and Aurora Colorado called Metro Denver Urban Advantage with support from the National Science Foundation.

Appendix B: List of Interviews

- Bronwyn Bevan, Director, Institute for Research and Learning, Exploratorium
- Jessica Donner, Director, Every Hours Counts
- Jeremy Eltz, Science Specialist, Indiana Department of Education
- Eric Jolly, President, Science Museum of Minnesota, Chair, National Research Council Committee on Successful Out-of-School STEM Learning
- Anita Krishnamurthi, Vice President, STEM Policy, Afterschool Alliance
- Jay Labov, Senior Advisor for Education and Communication, National Academy of Sciences
- Priscilla Little, Consultant
- Chris Mazzeo, Education Northwest I Director, REL Northwest
- Ellen McCallie, Program Director, National Science Foundation
- Peter McLaren, Science and Technology Specialist, Rhode Island Department of Education and Member, National Research Council Committee for Developing Assessment of Science Proficiency in K-12
- Gil Noam, Director, PEAR Program, Harvard University
- Charles Smith, Director, Weikart Center for Youth Program Quality
- Lee Shumow and Jennifer Schmidt, Northern Illinois University
- Cary Sneider, Associate Research Professor, Portland State University
- Jessica Werner, Executive Director, Youth Development Executives of King County

References

Alliance for Excellent Education. (2013). *Expanding Education and Workforce Opportunities Through Digital Badges.* Retrieved from: http://all4ed.org/reports-factsheets/expanding-education-and-workforce-opportunities-through-digital-badges/

Banks, J. A., Au, K. H., Ball, A. F., Bell, P. Gordon, E. W., Gutiérrez, K. D., et al. (2007). *Learning in and out of school in diverse environments.* Seattle, WA: The Life Center and the Center for Multicultural Education, University of Washington. Retrieved from: https://education.uw.edu/cme/LIFE

Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecology perspective. *Human Development*, 99:193–224. Retrieved from: http://life-slc.org/docs/barron-self-sustainedlearning.pdf

Barron, B. (2014). Formative assessment for STEM learning ecosystems: Biographical approaches as a resource for research and practice. Commissioned by the Committee on Successful Out-of-School STEM Learning, Board on Science Education, Division on Behavioral and Social Sciences and Education, National Research Council. Retrieved from: http://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_089994.pdf

Bevan, B., Dillon, J., Hein, G.E., Macdonald, M., Michalchik, V., Miller, D., Root, D., et al. (2010). *Making Science Matter: Collaborations Between Informal Science Education Organizations and Schools.* A CAISE Inquiry Group Report. Washington, DC: Center for Advancement of Informal Science Education (CAISE). Retrieved from: http://informalscience.org/images/research/MakingScienceMatter.pdf

Boston After School & Beyond. (2015). *Achieve-Connect-Thrive Skills Framework*. Retrieved from: http://bostonbeyond.org/initiatives/act_framework/

Bronfenbrenner, U. (1994). Ecological Models of Human Development. In *International Encyclopedia of Education, Vol. 3, 2nd Ed.* Oxford: Elsevier. Reprinted in: Guavain, M. & Cole, M. (Eds.), Readings on the development of children, 2nd Ed. (1993, pp. 37-43). NY: Freeman.

Bryk, A., Gomez, L., Grunow, A. & LeMahieu, P. (2015). *Learning to Improve: How America's Schools Can Get Better at Getting Better.* Cambridge, Mass: Harvard Education Publishing Group.

Bussiere, L., & Hudgins, T. (2014). *Girlstart After School: Analysis of program impact on participants' academic achievement.* Retrieved from http://issuu.com/girlstart/docs/after_school_impact_analysis

California Academy of Sciences (2015). *Science Action Clubs 2014-2015 program evaluation data.* Unpublished.

Chi, B., Dorph, R., & Reisman, L. (2014). *Evidence & impact: Museum-managed STEM programs in out-of-school settings.* Berkeley, CA: The Lawrence Hall of Science.

Coburn, C. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. *Educational Researcher, 32(6): 3-12.*

College of Education, Oregon State University. (2014). *SYNERGIES in the Parkrose Community, Preliminary Results.* Retrieved from: http://education.oregonstate.edu/book/preliminary-results

Collie-Akers, V.L., Fawcett, S.B., & Schultz, J.A. (2013). Measuring progress of collaborative action in a community health effort. *Rev Panam Salud Publica.* 34(6):422-8.

Common Core State Standards Initiative. *Standards for Mathematical Practice.* Retrieved from: http://www.corestandards.org/Math/Practice/

Every Hour Counts. (2014). *Measurement Framework: How to Measure Success in Expanded Learning Systems.* Retrieved from: http://www.afterschoolsystems.org/content/document/detail/4060/

Fawcett, S.B., Paine-Andrews, A., Fancisco, V.T., Schultz, J.A., Richter, K.P, Berkley-Patton, J., Fisher, J., Lewis, R.K., Lopez, C.M., Russos, S., Williams, E.L., Harris, K.J., & Evensen, P. (2001). Evaluating community initiatives for health and development. In Rootman, I., McQueen, D., et al. (Eds.), Evaluating health promotion approaches. (pp. 241-277). Copenhagen, Denmark: World Health Organization - Europe. Retrieved from: https://communityhealth.drupal.ku.edu/sites/communityhealth.drupal.ku.edu/files/files/R11.pdf

Fenichel, M., and Schweingruber, H.A. (2010). *Surrounded by Science: Learning Science in Informal Environments.* Board on Science Education, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Forum for Youth Investment. (2014). A Big Picture Approach To Community Planning And Action. Retrieved from: http://forumfyi.org/files/Big%20Picture%20Approach%20to%20Community%20Planning%20and%20Action%20-%20May%202013.pdf

Friedman, A. (2013, Sept. 9) Learning: A holistic view. *Education Week*. Retrieved from: http://www.edweek. org/ew/articles/2013/09/11/03friedman_ep.h33.html

Girlstart. (2015). *August 2015 Program Update.* Retrieved from: http://issuu.com/girlstart/docs/august_2015_program_update_767b2a7dc9d8f2

Hanleybrown, F., Kania, J., & Kramer, M. (2012). Channeling Change: Making Collective Impact Work. Stanford Social Innovation Review. Retrieved from: http://www.ssireview.org/blog/entry/channeling_change_making_collective_impact_work

Hargreaves, M. (2010). Evaluating Systems Change: A Planning Guide. Mathematica Policy Research. Retrieved from: http://www.mathematica-mpr.com/~/media/publications/PDFs/health/eval_system_change_methodbr.pdf

Ito, M., Gutierrez, K., Livingstone, S., Penuel B., Rhodes, J., Salen, K., et al. (2013). Connected Learning: An agenda for research and design. Irvine, CA: Digital Media and Learning Research Hub. Retrieved from: http://dmlhub.net/publications/connected-learning-agenda-for-research-and-design/

Krishnamurthi, A., Ballard, M. & Noam, G. (2014). Examining the Impact of Afterschool STEM Programs. Los Altos, CA: The Noyce Foundation. Retrieved from: http://www.afterschoolalliance.org/ExaminingtheImpactofAfterschoolSTEMPrograms.pdf

Kumpulainen, K. & Sefton-Green, J. (2012). What is Connected Learning and How to Research It? *International Journal of Learning and Media, 4(2)* 7-18.

Lehigh Carbon Community College. (2015). *2008-2014 Return on Investment – SHINE Carbon and SHINE Schuykill.* Unpublished.

Lehigh Carbon Community College (2015). *SHINE Program 2014- 2015 Elementary Parent Survey.* Unpublished.

Nagaoka, J., Farrington, C.A. and Ehrlich, S.B. (2014). A Framework for Developing Young Adult Success in the 21st Century: White Paper: Defining Young Adult Success. Chicago Consortium on Chicago School Research. Retrieved from: https://ccsr.uchicago.edu/sites/default/files/publications/Wallace%20Framework%20White%20Paper.pdf

National Institute on Out-of-School Time. (2012). Boston Summer Learning Project Teacher Survey, unpublished. The publicly available booklet found here, http://bostonbeyond.org/summer-learning-project-2013-info-booklet/, references results from the evaluation by NIOST in addition to a lot of other information from that year's SLP project.

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

National Research Council. (2014a). *Developing Assessments for the Next Generation Science Standards.* Committee on Developing Assessments of Science Proficiency in K-12. Board on Testing and Assessment and Board on Science Education, James W. Pellegrino, Mark R. Wilson, Judith A. Koenig, and Alexandra S. Beatty, Editors. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Research Council. (2014b). *STEM Learning Is Everywhere: Summary of a Convocation on Building Learning Systems.* S. Olson and J. Labov, Rapporteurs. Planning Committee on STEM Learning Is Everywhere: Engaging Schools and Empowering Teachers to Integrate Formal, Informal, and Afterschool Education to Enhance Teaching and Learning in Grades K-8, Teacher Advisory Council, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Research Council and Institute of Medicine (2002) *Community Programs to Promote Youth Development.* Committee on Community-Level Programs for Youth. Jacquelynne Eccles and Jennifer A.Gootman, eds. Board on Children, Youth, and Families, Division of Behavioral and Social Sciences and Education. Washington, DC: National Academy Press.

Next Generation Science Standards. Retrieved from: http://www.nextgenscience.org/

Orange County STEM Initiative. (2015). *STEM Learning Ecosystems: Leadership for Articulated STEM Programs Institute, Participant Survey.* Unpublished.

Oregon State University SMILE Program, (2015). *Evaluation data,* Unpublished.

Penuel, W., Lee, T., and Bevan, B. (2014). *Designing and Building Infrastructures to Support Equitable STEM Learning Across Settings.* San Francisco: Research+Practice Collaboratory.

Preskill, H., Parkhurst, M. & Splansky Juster, J. (2014). Guide to Evaluating Collective Impact: Learning and Evaluation in the Collective Impact Context. Collective Impact Forum and FSG. Retrieved from http://collectiveimpactforum.org/resources/guide-evaluating-collective-impact

Russell, J., Knutson, K., & Crowley, K. (2013). Informal learning organizations as part of an educational ecology: Lessons from collaboration across the formal/informal divide. *Journal of Educational Change 14(3):* 259-281.

Ryoo, J.J. & Shea, M.V. (forthcoming). *Value Mapping: An activity for surfacing diverse perspectives in collaborative work.* http://www.exploratorium.edu/education/california-tinkering-afterschool-network-research-practice-partnerships-resources

Samuels, M. & Beer, D. (2012). Chicago Pre-College Science and Engineering Program, *Year two evaluation report.* Chicago, IL: The University of Chicago.

Saxton, E., Burns, R., Holveck, S., Kellye, S., Prince, D., Rigelman, N., & Skinner, E. (2014). A common measurement system for K-12 STEM education: Adopting an educational evaluation methodology that elevates theoretical foundations and systems thinking. *Studies in Education Evaluation, 40:* 18-35.

Schmidt, W. & Cogan, L. (2014). *An investigation of the Museum of Science and Industry, Chicago's 2012-13 Get Re-Energized module.* East Lansing, MI: Education Policy Center at Michigan State University.

Traphagen, K. & Traill, S. (2014). *How Cross-Sector Collaborations Are Advancing STEM Learning: A Working Paper.* Los Altos, CA: The Noyce Foundation.

Weinstein, M., Whitesell, E.R., & Leardo, M. (2013). *Beating the odds: How school-level factors influence success with Urban Advantage.* New York, NY: New York University.

Weinstein, Whitesell & Schwartz (2014). Museums, Zoos and Gardens: how formal-informal partnerships can impact students' performance in science. *Evaluation Review, 38(6):* 514-545.

Author Bios

Saskia Traill is the vice president of policy and research at ExpandED Schools (formerly TASC), a nonprofit dedicated to closing the learning gap by increasing access to enriched education experiences. She has co-authored articles, policy briefs and reports on a range of issues, including best practices in expanding learning, engaging young people in STEM and how to fund innovative education strategies. Saskia holds a Ph.D. from Stanford University and a BA from Columbia University.

Kathleen Traphagen is an independent writer and strategist with expertise in education and youth development. Her client portfolio includes national networks of philanthropies focused on out-of-school time and STEM learning, and local networks focused on reading proficiency (Springfield, MA), and K-12 education (Boston). Kathleen has 20+ years of experience in the non-profit and governmental sectors. She served as Executive Director of the Boston 2:00-to-6:00 After School Initiative and as Senior Policy Analyst for the Mayor's Office of Intergovernmental Relations. Kathleen holds an MBA from Northeastern and a BA with University Honors from Carnegie Mellon.

STEM ecosystems

This report was commissioned by the Noyce Foundation and written by Saskia Traill and Kathleen Traphagen, with contributions from Elizabeth Devaney.

Suggested citation: Traill, S. & Traphagen, K., with Devaney, E. (2015). *Assessing the Impacts of STEM Learning Ecosystems: Logic Model Template and Recommendations for Next Steps.* Noyce Foundation.

To download this and other publications written or commissioned by the Noyce Foundation and the STEM Funders Network related to STEM learning ecosystems, visit stemecosystems.org

We thank the individuals we interviewed and the leaders of the initiatives whose work we cite for giving freely of their time and sharing their data and expertise with us. A special thanks to Ron Ottinger of the Noyce Foundation for his support, inspiration and guidance.

This report also benefitted from the comments and suggestions of Bronwyn Bevan, John Falk, Kirby Girolami Callam, Anita Krishnamurthi, Jan Morrison, Gil Noam, Ron Ottinger, Cary Sneider, Gerald Solomon, and Martin Storksdieck. Thanks to each of you for your guidance.

The Strategy Framework icons courtesy Stephanie Doctrow (Collaborative Communications) and the STEM Ecosystems logo courtesy Casey DenBleyker (Social Driver).

Cover Photo: Courtesy of Boston After School & Beyond

Design by: madebywe.org