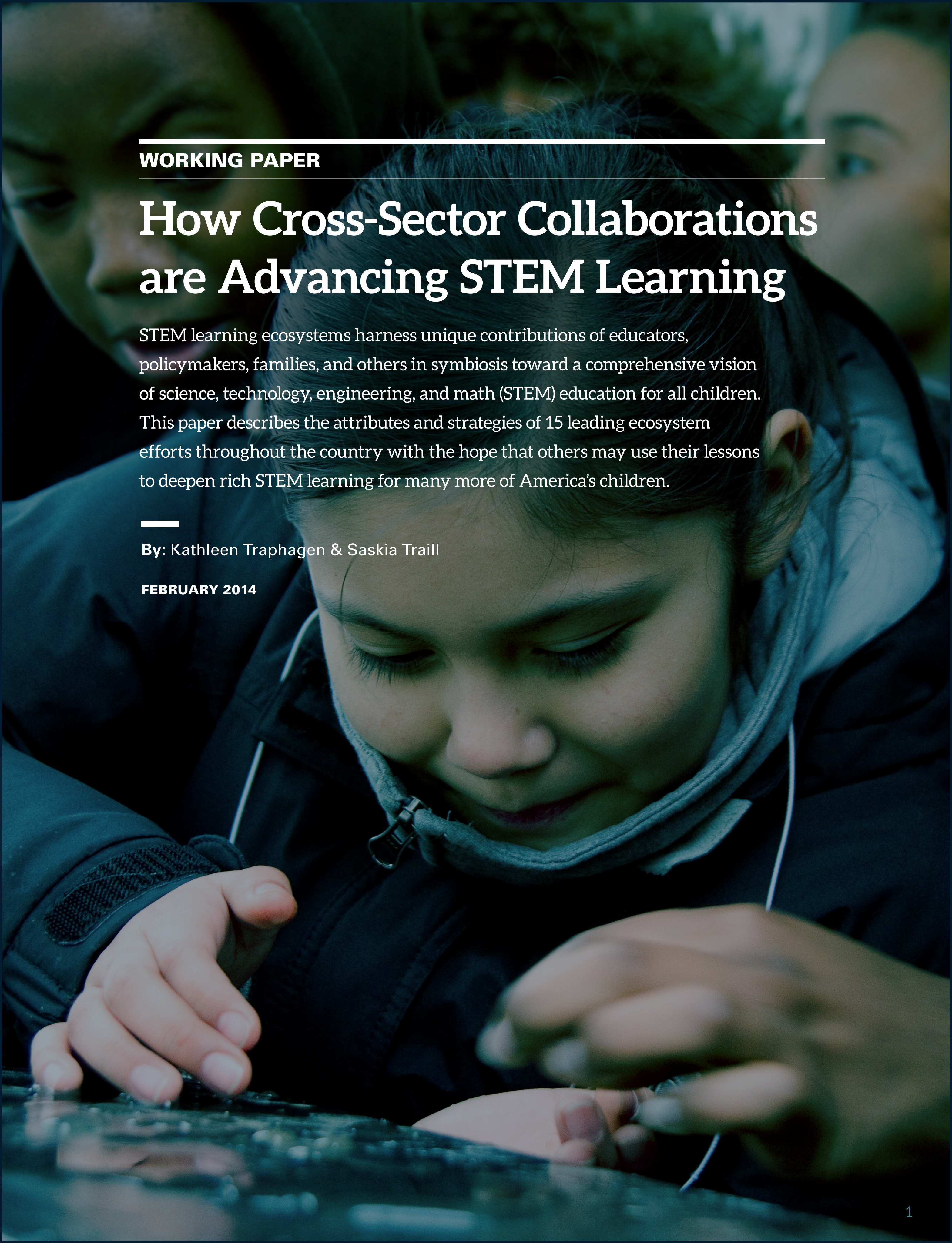

WORKING PAPER

How Cross-Sector Collaborations are Advancing STEM Learning

STEM learning ecosystems harness unique contributions of educators, policymakers, families, and others in symbiosis toward a comprehensive vision of science, technology, engineering, and math (STEM) education for all children. This paper describes the attributes and strategies of 15 leading ecosystem efforts throughout the country with the hope that others may use their lessons to deepen rich STEM learning for many more of America's children.

By: Kathleen Traphagen & Saskia Traill

FEBRUARY 2014

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Executive Summary

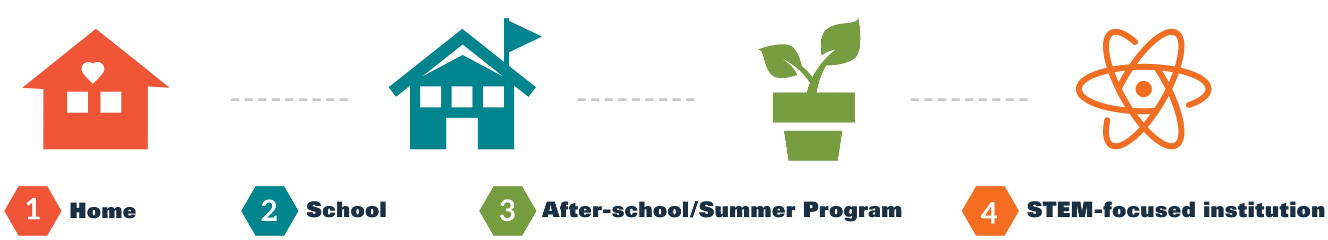
Introduction

Substantial energy is now focused on improving science, technology, engineering and math (STEM) education in the United States. Common Core and the Next Generation Science Standards are catalyzing reform of curricula, assessments and teacher professional development. Students also develop STEM skills and knowledge in many ways and multiple places outside of school – in afterschool and summer programs, at science centers and museums, at home with their families, and online.

Yet in most communities, cultural, logistical, financial and philosophical barriers divide educators and leaders from different STEM learning settings. In this paper, we examine an approach to STEM learning that may eventually overcome those barriers: the STEM learning ecosystem. The ecosystem metaphor, while not perfect, captures key concepts of this broader vision: diverse, individual actors interconnected in symbiotic relationships that are adaptive and evolve over time.

STEM Learning Ecosystems – A Definition

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 have the potential to:

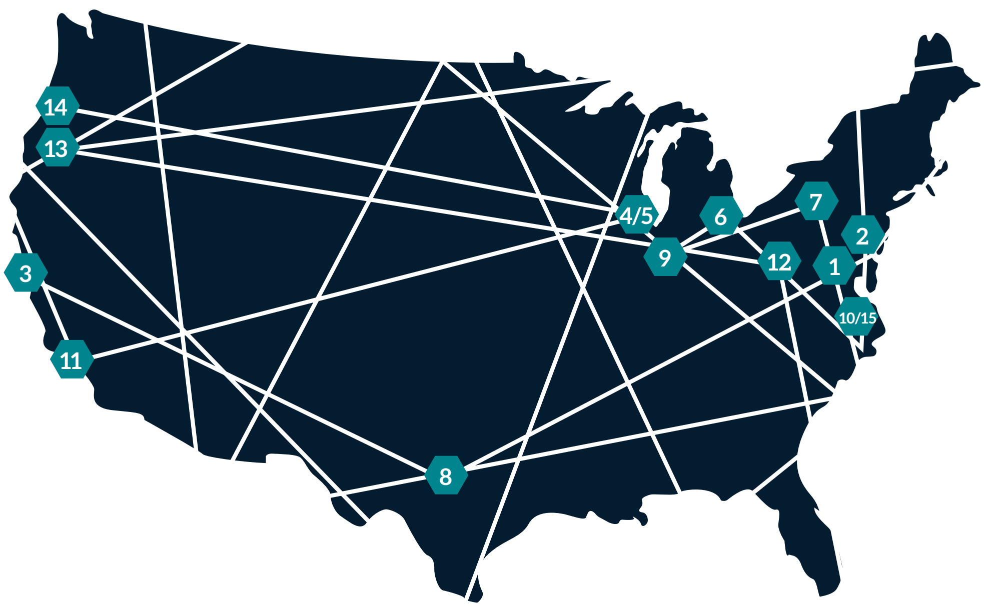
1	**Enable children's understanding of cross-cutting concepts to unfold and deepen in intentionally connected ways over time and across settings**
2	**Build children's scientific practice skills and knowledge through multiple exposures and experiences, including those in which children have the freedom to make and learn from mistakes as part of scientific tinkering and experimentation**
3	**Spark and nurture children's interest in and enthusiasm for STEM over time, by not only bringing science lessons to life in STEM-rich learning environments like museum exhibits, biology labs, recording studios, and marine research vessels, but also exposing children to STEM professionals and a variety of STEM career options**
4	**Ensure that children build complex skills, including how to exercise their own agency, solve real-world problems, build relationships with adults and peers, and test out their own leadership and teamwork capabilities as they experience STEM learning connected across different environments**
5	**Intentionally support those youth historically under-represented in STEM including girls, linguistic and racial minorities, and economically disadvantaged young people, to foster diverse and inter-connected STEM learning experiences**
6	**Increase understanding and build capacity among parents and caregivers to support their children's learning by ensuring they receive consistent messaging, guidance and resources from multiple, diverse learning settings**
7	**Implement creative and diverse methods of assessment, equipping young people with certifications, badges, portfolios or other proof points demonstrating mastery of skills and knowledge that are understood and respected in diverse environments**

Approach of this Study

Commissioned by the Noyce Foundation, this paper identified 15 burgeoning efforts that includes a cross-sector collaboration among formal K-12 education, after-school or summer programs, and/or some type of science-expert organization.

Our goal is to spark conversation, networking, and further research about learning ecosystems by a broad range of stakeholders in the STEM education sector.

Emerging STEM Learning Ecosystems Profiled in this Report



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    Oregon
14. **SYNERGIES**
    Portland, Oregon
15. **URBAN ADVANTAGE**
    New York, NY

Attributes of STEM Learning Ecosystems

STEM learning ecosystems are anchored by strong leaders and a collaborative vision and practice.

Ecosystem building requires at least one organization to be the community influencer and champion who can articulate, persuade and lead the charge. In some cases, ecosystem leaders are experienced system builders with a record of success guiding multi-sector education initiatives, but rely on others for STEM content and knowledge. Since the role of ecosystem driver is as much about creating the capacity for new ways of working as it is about understanding STEM learning, these more general system builders are bringing needed expertise to the challenge.

In many cases, we found the actual on-the-ground programming supporting such a vision is in the very early stages or at a small scale, but the long-term goals are much larger and integrative. Programming differs from more typical cross-sector transactions, with the organizations acting not so much as vendors but collaborators, setting mutual goals and developing aligned strategies to deliver on those goals.

The organizational leaders are confronting the challenges of cobbling together a coalition where the members have uneven power dynamics – schools have more resources, more stability and more credibility, while after-school providers have more flexibility but are often battling outdated perceptions that staff education or experience levels preclude “real” teaching. On the other hand, educators from the informal settings can bring their own preconceptions of the classroom environment as rigidly structured and unimaginative. Each sector also has its own terminology, creating barriers to shared understanding. In our interviews, we found organizational leaders strategically working through these challenges.

STEM learning ecosystems are attentive to the enlightened self-interest of all partners.

Coalition leaders pay attention to meeting the “enlightened self-interest” of their members, ensuring that their participation in ecosystem-building activities enables them to deepen their work toward their own organization’s mission. A belief that all parties are committed to meeting their mutual goals and bringing money, talent and time to a shared table grows the effort and creates shared power. Many initiatives began their ecosystem transformation by working in alignment with a partner and are moving along a continuum of integration, through both natural evolution and deliberate efforts.

Collaborating organizations in STEM learning ecosystems are opportunistic and nimble.

Many of the initiatives have the capacity to be flexible and adjust their own plans to seek common ground. They are opportunistic, taking advantage of funding, political will, others’ flexibility, and available resources to make progress. They have evolved somewhat organically rather than by following a predetermined work plan.

Strategies of STEM Learning Ecosystems

We asked initiative leaders to describe how they were approaching their work. We have identified six major strategies they are using to creating and connecting STEM-rich learning environments:

1. **Building the capacity of educators in all sectors, by tapping resources and expertise from STEM-expert institutions, schools, after-school/summer programs, and others.**
2. **Equipping educators from different settings with tools and structures to enable sustained planning and collaboration.**
3. **Linking in- and out-of-school STEM learning day by day.**
4. **Creating learning progressions for young people that connect and deepen STEM experiences over time.**
5. **Focusing curricula and instruction on inquiry, project-based learning and real-world connections to increase relevance for young people.**
6. **Implementing programs and public outreach to engage families and communities in understanding and supporting children’s STEM success.**

Conclusion and Recommendations

This limited investigation into emerging STEM learning ecosystems in the U.S. uncovered tremendous activity, from urban centers to rural districts. Practitioners of all stripes are working to connect previously disparate settings in explicit ways that support STEM teaching and learning among educators, young people and their families. They have gone beyond binary, transactional arrangements, however they still face formidable challenges to moving toward the aspirational definition of STEM Learning Ecosystems offered in our introduction:

Challenges

1. **Accessing adequate, sustained funding.** Said Kenneth Hill of the Chicago Pre-College Science and Engineering Program, "The only reason we don't have 2000 children and parents yet [in our Saturday classes] is we need more money."
2. **Collecting data and assessing outcomes** in a comprehensive manner, across learning settings and over time.
3. Finding time and trust to successfully **navigate differences among formal and informal cultures**, including language and terminology, education and experience, accountability and vision.
4. **Successfully engaging families**, as efforts often fall short in attracting participation and assessing their impact is difficult.
5. Figuring out which organization or group of organizations is best positioned to **drive the ecosystem building effort**, and giving them the power to do so.
6. **Transitioning through leadership changes**, particularly in the formal education system, which can set back efforts.

In conclusion, we provide recommendations in the areas of practice, research and evaluation, and policy. These issues should be on the field's collective agenda, rather than faced by each initiative in isolation from others.

Recommendations

1 PRACTICE

1. **Get ready to scale by learning more about what works and what does not.** Public and private funders should help emerging STEM ecosystems better understand how to scale their efforts, including how to integrate strategies for scaling into their design.

2. **Create a community of practice for STEM learning ecosystems:** National stakeholders, including Achieve, Inc., the National Academy of Sciences, Afterschool Alliance, Association of Science-Technology Centers (ASTC), the National Science Teachers Association, the Council of State Science Supervisors, and Every Hour Counts should support an ongoing community of practice for emerging STEM ecosystems to share innovative and effective practices, address the challenges specified above, and help to develop and grow their efforts.

3. **Examine how STEM learning ecosystems can help realize the goals of Common Core mathematics, NGSS and the Framework for K-12 Science Education.** As the lead organization coordinating the development of the Next Generation Science Standards and the Common Core state standards, Achieve Inc. should integrate into its ongoing work an examination of the potential for STEM learning ecosystems to help realize the goals of Common Core mathematics, NGSS and the Framework for K-12 Science Education. This effort could focus on how interconnected STEM learning experiences provide a rich tapestry for teaching and learning cross -cutting concepts and scientific practices over the full developmental trajectory of preK-12.

2 RESEARCH & EVALUATION

1. **Learn how to assess learning outcomes across settings:** Although many of these initiatives are quite sophisticated in tracking outcomes of individual program components, none of them have developed a way to track the impact of all the interconnections they are building among STEM learning experiences.

   An important, related challenge is the imperative states now face to develop assessments for the new Next Generation Science Standards, which may spur formal educators and education policymakers to think in new ways about designing and implementing assessments. Those who see the value of what children and youth can learn in many different learning settings have an opportunity to help push the conversation and the vision beyond conventional parameters of what happens in the classroom.

2. **Disseminate relevant research more broadly and across sectors.** We recommend that researchers, practitioners, and public and private funders work to make relevant research more accessible across the broad array of stakeholders involved in STEM learning. We identified web resources that could encourage cross-sector dissemination of a common research base. None of our interviewees cited using these types of resources in developing their model. Broad dissemination of relevant research and existing resources could be part of the work of the learning community described above.

RESOURCES FOR CONNECTING RESEARCH AND PRACTICE

- Learning in Informal and Formal Environments (LIFE) Center, www.life-slc.org
- Relating Research to Practice, http://relatingresearchtopractice.org/
- The Center for Informal Learning and Schools, cils.exploratorium.edu
- Learning Activation Lab, www.activationlab.org

3. **Increase opportunities to connect research and practice across sectors.** We recommend that public and private funders encourage researchers and practitioners to develop collaborative agendas that span across informal and formal environments. Research agendas should build on the implementation and impact questions of both formal and informal learning. This collaborative approach to research and practice is a challenge within one STEM learning setting, so it will take extra effort to build research-and-practice models that address the entire STEM learning ecosystem.

3 POLICY

1. **Craft a policy agenda that identifies strategic levers at different levels to advance ecosystem building efforts.** The U.S. Department of Education, state education agencies, local school districts and private funders can encourage or require formal educators to partner with community organizations and STEM-rich cultural institutions. Public and private youth development funders can encourage or require community partners applying for youth development funds to address STEM and connections to formal education.

   Schools and school districts, youth development providers and science institutions can also proactively select people for leadership positions who understand the value of collaboration and possess collaborative skills and experience.

2. **Take better advantage of the flexibility embedded in existing policies.** Many funding streams offer more flexibility than is currently used in practice.

By separating recommendations into discrete areas, we do not mean to suggest that only some stakeholders should tackle any one of these recommendations. It will require a diverse range of stakeholders in each of these areas to make progress. Our hope is that the ideas of this report help spark the curiosity and imagination of all the stakeholders working to ensure that young people are engaged, inspired and prepared in the STEM disciplines as they develop into future scholars and leaders in our communities.

Introduction

Substantial energy is now focused on improving science, technology, engineering and math (STEM) education in the United States. New data continue to justify the attention and highlight the complexities of the challenge: another round of middling PISA results for American students released in 2013; persistent under-representation of women and people of color in the STEM fields; continuing difficulties in sustaining young people's interest in STEM; and the startlingly poor showing of American adults on a recent international assessment of literacy and numeracy skills.[1]

Bolstering the STEM workforce is not the only reason to concern ourselves with these issues. Exposure to high-quality STEM experiences can inspire wonder and curiosity in students about the natural and human-constructed worlds and motivate them to want to learn more. Study of the STEM disciplines can foster students' ability to think critically about issues in a world that is now dominated by science and technology. Successful STEM learning develops in young people the ability to make rational decisions for themselves, their families and their communities.

Promising reforms are knocking on the door of the K-12 STEM classroom, including the Common Core and Next Generation Science Standards, both focused on deep conceptual understanding and expert application of knowledge and skills. High-profile efforts to better recruit, prepare and support STEM teachers as well as create specialized STEM schools are also driving reform in how STEM is taught in school.[2] Other efforts aimed at improving K-12 education overall are closely aligned to teaching and learning in the STEM disciplines, including competency-based education and the call for educators to explicitly focus on "deeper learning" skills young people need to live and work in today's global society – critical thinking, perseverance, problem-solving, teamwork and the capacity to pursue learning throughout life.[3]

Outside the school walls, STEM learning is everywhere. More than 90 million people visit science museums and centers every year to experience hands-on STEM learning.[4] Efforts by after-school and summer providers to integrate high-quality STEM learning experiences into their programming align well with the field's sharpening focus on active, relevant learning girded by positive relationships among children and adults. Portable digital devices have catalyzed thousands of creative opportunities for learning to happen anytime, anywhere, in ways that are both individualized and instantly connected to a worldwide community.[5] Media and online outreach aims to educate parents about the importance of STEM learning and the availability of local activities for young people.[6]

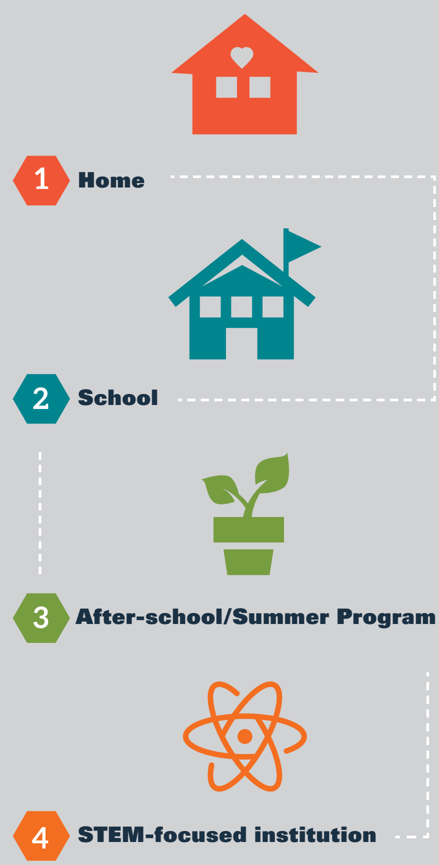
Bolstered by the National Research Council's Surrounded by Science report and Center for Advancement of Informal Science Education (CAISE) research, as well as other studies pointing to the value of intentionally connecting learning environments, many cross-sector efforts have emerged.[7] Schools are contracting with youth organizations to lead STEM-focused activities after school. Science centers and museums are increasingly offering training to schoolteachers, hosting student field trips and providing vouchers for family visits. These cross-sector partnerships are encouraging, but mostly limited in scope. Their arrangements tend to be binary and transactional, rather than holistic. For example, a science center trains teachers, but not after-school educators. A community-based organization leads the after-school program, but neither the content nor approach is connected to the school's STEM curricula. Efforts focus on one age group – for example, middle school students – and do not build on experiences the children might have had before or inform those that will come after. Even rarer are effective family involvement strategies that offer tailored support over time as children grow and their interests and skills mature. In most communities, the cultural, logistical, financial and philosophical barriers that divide educators and leaders from different STEM learning settings remain largely in place.

In this paper, we examine an approach to STEM learning that may eventually overcome those barriers: the STEM learning ecosystem. Over the past few years, many different thought leaders – practitioners, researchers, policymakers, funders and others – have been engaged in conversations about defining a broad and inclusive vision of STEM learning that puts the child at the center of the enterprise.[8] The ecosystem metaphor, while not perfect, captures key concepts of this broader vision: diverse, individual actors interconnected in symbiotic relationships that are adaptive and evolve over time.

STEM Learning Ecosystems – A Definition

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.

Stakeholders in a STEM ecosystem develop a shared vision and assess the strengths and gaps of their efforts to reach that vision. Educators, whether K-12 teachers, after-school staff, or experts in informal STEM institutions, work across settings to increase their individual efficacy, while at the same time deepening understanding and respect of the role of educators in other settings. Effective practices are shared across settings, while innovative program models are flexibly adapted to solve entrenched STEM learning challenges. Cross-sector professional development opportunities and communities of practice improve pedagogy and build knowledge among educators across settings.



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This ecosystem approach is bolstered by two recent studies of mathematically talented students that found those "who had greater exposure to accelerated, enriched, and individualized STEM learning opportunities achieved more significant STEM accomplishments later in life than their matched counterparts." An analysis of this research noted that an important implication of the findings is the "need to ensure that students have access to a wide spectrum of enriching and accelerated learning opportunities, and, in particular, that opportunities include those that are individualized."[10]

STEM learning ecosystems could also help strategically target financial and other resources where they are most needed, a critically important task in this era of record-setting economic inequality. A new study has found that by age 12, disadvantaged children have received about 6,000 fewer hours of learning time than their more affluent peers, and their families have been outspent by about $90,000 on learning and enrichment activities by more prosperous families.[11] Without access to enriching informal learning environments, children have fewer chances of finding that spark that will ignite their interest and ability to persevere in STEM.

Approaching STEM learning with an ecosystem mindset could also play a key role in helping communities meet the vision of the Common Core state standards in mathematics, the Next Generation Science Standards, and the broader Framework for K-12 Science Education. As a 2010 report by CAISE asserted, the Framework's vision of scientific literacy "involves a rich array of conceptual understanding, ways of thinking, capacities to use scientific knowledge for personal and social purposes, and an understanding of the meaning and relevance of science to everyday life" that no single sector can provide by itself.[12] In a STEM learning ecosystem, young people's experiences could connect horizontally across formal and informal settings at each age, and scaffold vertically as they build on each other to become deeper and more complex over time.

Approach of this Study

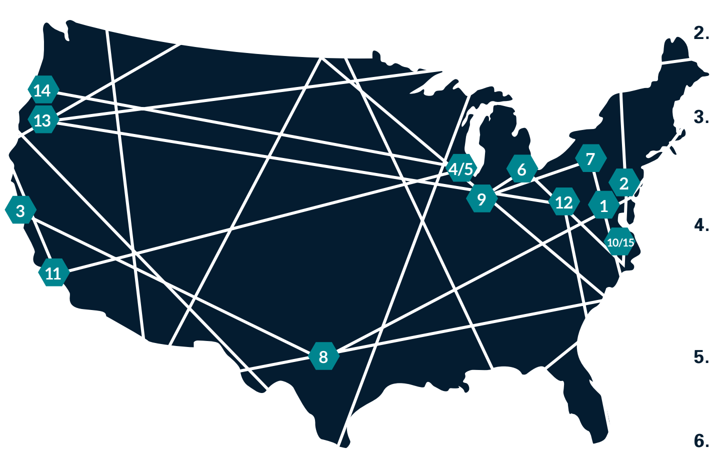
Commissioned by the Noyce Foundation, this paper sets out to provide shape and definition to the emerging concept of STEM learning ecosystems by identifying burgeoning efforts in a range of places across the U.S. – urban, rural, suburban; resource-rich, resource-poor, and in-between. Not intended to be an exhaustive analysis of current efforts, the goal of this paper is to spark conversation, networking, and further research about learning ecosystems by a broad range of stakeholders in the STEM education sector.

Our data-gathering strategy was to access an ever-expanding web of thought leaders, policymakers, funders and practitioners from formal and informal STEM learning settings and ask them to recommend examples of cross-sector STEM learning collaborations. We talked to about three dozen people and narrowed our focus for this paper to 15 initiatives. None of these initiatives constitutes the fully formed ideal described above nor encompasses the full ecosystem of STEM learning in their communities. However, each minimally includes a cross-sector collaboration among formal K-12 education, after-school or summer programs, and/or some type of science-expert organization. Within this group, we found significant differences in scale, vision, approach, and impact. Some are moving toward extensive multi-sector collaborations, while others are just beginning to envision what a more connected ecosystem might look like.

We did find many attributes and strategies in common, which we detail in forthcoming sections. We conclude by offering recommendations to spur further progress, exploration and study. An appendix provides contact information on each of the models studied.

A note on terminology: as we talked to leaders from many sectors to prepare this study, we encountered significant differences in terminology. For this paper, we use "formal" to mean schools and school systems and "teachers" to mean certified K-12 schoolteachers. "Informal" refers to programs offered after-school or during the summer, by community-based youth providers, schools, or by science museums and centers, also referred to as "science-expert institutions." "Educators" is the broad term we use to reference both classroom teachers and staff leading these programs.

Emerging STEM Learning Ecosystems Profiled in this Report



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Background on Each Initiative

AfterZone Summer Scholars

PROVIDENCE, RI

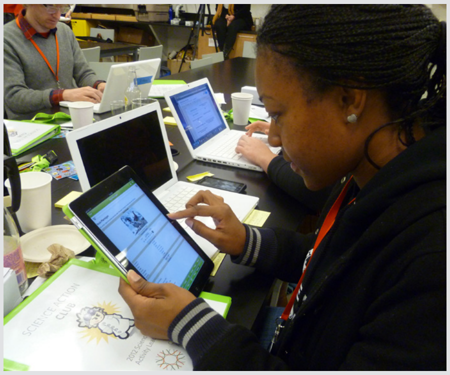
Led by the Providence After School Alliance and the Providence Public School District along with approximately 20 local community organizations (a mix of environmental, botanic garden, arts, engineering, sailing and museum groups) the AfterZone Summer Scholars program provides four weeks of STEM programming to 500 middle school students over the summer. The AfterZone Summer Scholars program gets students out into the community for the summer while providing them with fun, hands-on, learning experiences in the field that focus on building STEM skills. Teaching teams consisting of a community-based STEM educator, a district teacher, and a PASA youth development specialist who co-develop and co-teach a collaborative curriculum that connects STEM and math skills with hands-on field research. The program builds relevant, real-life skills of young people, exposes them to parts of their community they wouldn't otherwise see, and builds capacity of teachers and community educators to facilitate inquiry learning. The program was launched with a blend of private funds and public funds for after-school and summer learning, and continues to be supported by private funders and through public school funds from the Providence Public School District (Title I, Career and Technical Education and School Improvement Grants).

Boston Summer Learning Project

BOSTON, MA

Boston After School & Beyond and the Boston Public Schools co-manage this collaborative approach to STEM-rich summer learning that addresses the knowledge, skills, and experiences young people need to acquire in order to succeed in school, college, work, and life. Schools draw on the strengths of teachers and program providers to provide a full-day, integrated learning experience for five weeks during the summer. In 2013, 51 Boston Public Schools and 18 community partners served more than 1,700 students in the program. 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 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 and the Boston Public Schools.

Boston Photo Credit: Tiffany Knight



California Academy of Sciences, Science Action Clubs

SAN FRANCISCO, CA

The Academy's Science Action Club (SAC) Program ignites the spark for science in San Francisco middle school youth and their after school activity leaders. Currently there are 10 SAC clubs serving 400 students; plans for expansion by 2015 will add an additional five sites for a total of 600 youth. Through dynamic and authentic science investigations, youth explore their local environment, make observations about the natural world, and contribute data to real scientific research. The Academy provides after-school programs with blended professional development, science-themed activity modules, and essential supply kits. Each site has an SAC Alliance Team that includes an OST activity leader, site coordinator, school science teacher, school leader, and parent. Partners include the San Francisco Unified School District, after-school program providers (Beacon Centers, YMCA, Excel) and Citizen Science Partnerships (Cornell Lab of Ornithology, NASA). The SAC program is funded by the S.D. Bechtel, Jr. Foundation and the Hearst Foundations.

CALIFORNIA ACADEMY OF SCIENCES
SCIENCE ACTION CLUB

Center for the Advancement of Science Education, Museum of Science and Industry

CHICAGO, IL

In 2003, the Museum of Science and Industry, Chicago (MSI) convened a think tank of civic leaders, educators, scientists, and non-profit leaders serving at-risk youth and created a strategic plan that placed educational services for schools and community groups at the apex of its vision for the future. The Center for the Advancement of Science Education (CASE) was founded in 2006 to increase participation in science by youth during their middle and high school years. Its goals are to: 1) increase awareness, interest, and engagement with scientific progress and inventions; 2) influence students to choose STEM careers; and 3) facilitate high-quality science teaching and learning in and out of schools. The Center offers field trips, youth programs, and professional development in science teaching prioritizing fourth to eighth grade educators in high-need schools with limited experience teaching science. Since its inception, CASE has supported 800+ science teachers in sustained professional development. This year CASE will also provide training and capacity building for 130 after-school programs for 8-13 year olds in and around Chicago through the Science Minor Clubs initiative. CASE aims to build an ecosystem for children around science learning that connects their out-of-school time and in-school experiences. A growing number of schools with both MSI-trained teachers and Science Minor after-school clubs are working to improve and emphasize science during the school day and after school. The Museum of Science and Industry's Institute for Quality Science Teaching is funded by The Dover Foundation, the Noyce Fondation, the Carnegie Foundation and the National Oceanic and Atmospheric Association and other sources.

Chicago Pre-College Science and Engineering Program Detroit Area Pre-College Science and Engineering Program

CHICAGO, IL & DETROIT, MI

The Detroit Area Pre-College Science and Engineering Program (DAPCEP) was founded in 1976 and now serves 3,000 youth between the ages of 4-18 in the Detroit metropolitan area. The more recent Chicago program was started in 2008 by the founder of DAPCEP and serves 221 children between Kindergarten and fourth grade and their parents/guardians in side-by-side classes. Following the same basic program design, they both aim to:

1. Expose, motivate and prepare children and youth from underrepresented population groups to enter the STEM fields (note: DAPCEP has recently added another "M" to STEM in an effort to expand students' exposure to the medical fields);

2. Increase parents' knowledge and exposure to opportunities in STEM fields, thus improving their capacity to support their children through their primary and secondary education and future entrance into STEM occupations;

3. Increase the effectiveness of teachers in engaging students and parents in science-related learning activities.

The programs provide highly engaging, age-appropriate hands-on science and engineering activities led by teachers/instructors from the students' schools, university professors, or graduate students in out-of-school time. Programs are offered at corporate campuses, 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 to participation in the Metropolitan Detroit Science & Engineering Fair. DAPCEP provides teacher professional development, curriculum and materials to Detroit teachers to support facilitation of the course during the school day or after school. DAPCEP's major supporters include the Detroit Public Schools, the National Science Foundation, and local corporate and philanthropic foundations. Chi S & E is supported by the National Science Foundation, the Chicago Public Schools, local philanthropies, universities and corporate donors.

Participants in the Museum of Science and Industry, Chicago's Science Minor After-School Club show off their science project.

Expanded Learning Network of the Southern Tier (ELNoST)

CORNING, NY

ELNoST is a regional network of the New York State Afterschool Network, a public-private partnership dedicated to building a youth-serving system that increases the quality and availability of after-school and expanded learning programs. While NYSAN promotes STEM throughout the state, ELNoST has fully integrated STEM learning into its youth work and, as a result, is leading a collaborative STEM ecosystem with a broad coalition of local support. Partners include industry leader Corning, Inc., a regional organization that provides professional development for school staff, local science museums, and funders. The partners meet together regularly to discuss the system of learning opportunities for young people in and out of school with a focus on STEM, shifting individual members' practice towards a more coordinated STEM learning ecosystem. ELNoST is supported by the Community Foundation of Elmira-Corning and the Finger Lakes and The Triangle Fund.

Girlstart

CENTRAL TEXAS

Girlstart is a nonprofit organization based in central Texas focused on STEM education for girls. Girlstart partners with 43 elementary schools in Central Texas, San Antonio, Dallas, and McAllen to provide school-based after-school programs. Girlstart also provides school-wide family science nights and science fairs; professional development for pre-service teachers, out-of-school time educators, and elementary teachers; an annual Girls in STEM conference; online courses; and summer camps. Girlstart focuses on girls of minority backgrounds, girls who live in low-income or non-urban environments, and/or girls who are considered at risk of academic failure. Girlstart's core programs foster STEM skills development, an understanding of the importance of STEM as a way to solve the world's major problems, as well as an interest in STEM electives, majors and careers. Girlstart is funded through private and corporate philanthropies, including Dell, Google, the Michael and Susan Dell Foundation, Motorola Solutions Foundation and Freescale.

Girlstart provides STEM activities at 43 elementary schools in Texas.

Indiana Afterschool STEM Initiative

INDIANA

Led by the Indiana Afterschool Network, the vision of the Indiana Afterschool STEM Initiative is that all Indiana school-age youth have access to science, technology, engineering and math experiences in out-of-school time programs that inspire them and prepare them for success in education and careers. The network has leveraged more than $1.5 million for STEM out-of-school time (OST) programming with partners over the past two years. This expanded STEM in 73 OST programs, provided training to more than 300 formal and informal educators and engaged more than 3,000 youth in STEM. The network defines STEM education as an intentional, multi-disciplinary approach to teaching and learning, in which students uncover and acquire a cohesive set of STEM concepts, competencies and dispositions that they transfer and apply in both academic and real-world contexts in order to be globally competitive in the 21st century. The network has developed and promoted after-school quality standards for STEM and nurtured partnerships among after-school providers and schools. Other priorities of the STEM initiative include: communication and policy; statewide quality system and professional development; and data collection and evaluation. The initiative receives funding from the C.S. Mott Foundation, the Noyce Foundation and other public and private sources.

New York City STEM Educators Academy

NEW YORK, NY

Launched in 2013 in four schools, The After-School Corporation (TASC) and the New York Hall of Science (NYSCI) have coordinated their expertise and resources to implement the STEM Educators Academy, an innovative professional development approach that prepares STEM educators to deliver an exceptional STEM learning experience to students living in some of New York City's most disadvantaged communities. Professional development and co aching supports educators from the formal and informal sectors to teach rigorous, inquiry-based and engaging curricula that is aligned with STEM learning goals and designed to spark the interest and passions of students and boost achievement. The Academy is funded by the Pinkerton Foundation. Participating schools and community partners commit to:

- Identifying teaching teams who will participate in 42 hours of joint professional development (including the summer institute and two mid-year seminars) and 16 hours of on-site observation, coaching and technical assistance. Teams consist of one science teacher and two community educators with interest in STEM.
- Providing an additional 100 hours of STEM learning in after school and during expanded learning time to a minimum of 40 students each year.
- Co-facilitating lessons once per week by teachers and community educators during the out-of-school hours to ensure alignment of instructional strategies and learning goals.
- Meeting weekly to discuss lesson plans, strategize future topics/activities, and share individual student successes and challenges.

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) and other community stakeholders (students, parents, teachers, businesses, science institutions and youth development providers) with a goal of improving STEM teaching and learning throughout Orange County, California. 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. One project of the initiative is a partnership with THINK Together (a non-profit provider of out-of-school time and expanded learning programs), 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. In 2013-14, the project is reaching 10,000 elementary school students in 20 school districts. 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 vision is that all students possess the requisite STEM skills to be competitive for 21st century jobs in Orange and surrounding counties. All educators and teachers are provided the tools and support to ensure their students are STEM competent and STEM literate. This effort is one of five regional partnerships in California providing support for STEM learning and teaching in after-school, summer and other out-of-school time programs through the Power of Discovery: STEM^2 statewide initiative.

SHINE Afterschool Program

CARBON AND SCHUYLKILL COUNTIES, PA

SHINE (Schools and Homes in Education) After School Program is led by Lehigh Carbon Community College serving 300 kindergarten through fifth graders and 150 middle school students in Carbon and Schuylkill counties in rural northeast Pennsylvania. SHINE partners with seven school districts, operating six elementary after-school centers and one middle school after-school center located at the Carbon Career & Technical Institute. SHINE emerged from Carbon County Child & Family Collaborative in 2004 to meet a priority of after-school programming for at-risk children and is funded by the federal 21st Century Community Learning Centers grant, private and state funds. Services include home visiting for kindergartners; 32 weeks of school-based after school and summer camp for at-risk children taught by schoolteachers emphasizing hands-on STEM in grades 1-5; and a middle school OST program and summer camp at Carbon Career & Technical Institute. Goals are: 1) Improve academic performance; 2) Improve student behavior and school attendance; 3) Increase STEM knowledge; 4) Facilitate family involvement in student learning and improve family literacy. SHINE also employs 15 community college students majoring in education as teacher assistant/interns in the after-school programs.

Students participating in the Orange County STEM Initiative enjoy a field trip to the Imaginarium.

SMILE Program

OREGON

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 under-served populations in the STEM fields. SMILE supports after-school clubs serving 650 students grades 4-12 in 35 schools in 13 rural communities throughout the state. Targeting low-income children of color, the clubs meet weekly and are led by 50 school-day science teachers. The SMILE Program has served more than 7,500 students and 365 teachers since its inception. 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 at OSU, and annual Math and Science Family Nights at partner schools for students and their families. SMILE is funded by Oregon State University, local school districts, federal grants, charter schools, and private philanthropy. SMILE was replicated in Rhode Island starting in 1994, with the University of Rhode Island as the lead.

Synergies Project

PORTLAND, OREGON

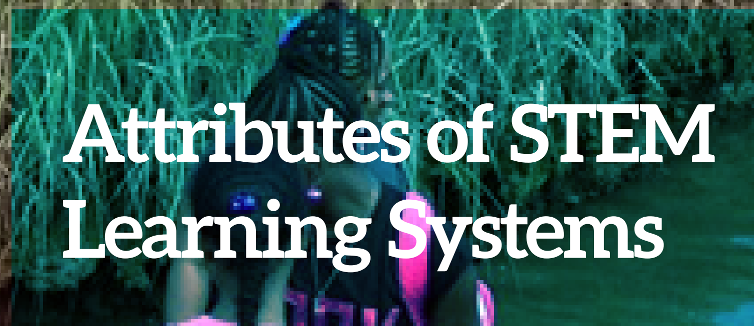
The premise of Synergies is that if one better understands how, when, where, why and with whom children access and use STEM resources across their lifetime, it will be possible to create a community-wide educational system that works more effectively and synergistically. Led by researchers at Oregon State University, the project has followed approximately 400 fifth graders from 2009 in the Parkrose neighborhood of Portland, along with their peers, siblings and significant adults in their lives. The first two years have been devoted to collecting baseline data and building community alliances, followed by continued data collection as well as community-wide “interventions” designed and executed by the community itself in years three and four. The project focuses on youth’s interest trajectories to determine how (physically and virtually) and why they utilize (formal and informal) community learning resources in order to engage with and learn about STEM. The community’s formal and informal STEM education providers, including Parkrose Public Schools, Multnomah County Library, Portland Zoo, 4H, Mount Hood Community College, Metro Parks, Portland Port Authority, Portland Children’s Museum, the Oregon Museum of Science and Industry, and other community-based organizations and businesses, are developing and testing a coordinated approach to facilitating STEM education. The long-term goal is to develop specific strategies and data-based tools to improve STEM learning in Parkrose that can be broadly applied to long-term improvements in STEM public education locally, nationally and internationally. The Synergies project is funded by the Noyce Foundation.

Urban Advantage

NEW YORK, NY

Urban Advantage is a multi-institution partnership program focused on improving middle school science teachers’ practices and students’ understandings about scientific inquiry through teacher professional development, student experiences at the partner institutions, and family outreach. The eight science-rich institutional partners include a natural history museum, a science center, an aquarium, two zoos, and three botanical gardens; they are joined by the New York City Department of Education. The program was launched in 2004 with 30 schools and 60 teachers and is currently serving over 170 middle schools and over 500 science teachers, reaching almost 53,000 students. Urban Advantage is supported by the Speaker and the City Council of New York and the New York City Department of Education. In 2010, the Denver Museum of Nature and Science received a five-year grant from the National Science Foundation to implement and study an Urgban Advantage program in Metro Denver, UA Metro Denver.

Photo credit: Tiffany Knight



Attributes of STEM Learning Systems

We found that the basic building blocks of a connected STEM learning ecosystem are:

1. K-12 school or school system with leadership who appreciates the value of collaborating with other learning environments

2. A robust after-school program, network or intermediary that has the capacity and credibility to work with other formal or informal learning environments

3. A strong STEM-expert institution, such as a science center, museum, corporation, or university that can provide essential resources like professional development for in- and out-of-school educators and hands-on STEM experiences for students and families

Sometimes the after-school network or provider develops into the role of the STEM expert as well. Funding support is needed not only for start-up, but ongoing capacity building, leadership and co-ordination necessary for long-term sustainability and impact. In addition to putting in place the basic building blocks, we found the initiatives we profiled for this report have developed the following set of common attributes:

- Anchored by strong leaders and a collaborative vision and practice
- Attentive to the enlightened self-interest of all partners
- Opportunistic and nimble

STEM learning ecosystems are anchored by strong leaders and a collaborative vision and practice.

Ecosystem building requires at least one organization to be the community influencer and champion who can articulate, persuade and lead the charge. Many initiatives among this group are fairly new, but are led by organizations that have stepped into this expanded role building on their record of accomplishment within their own realm of influence (for example, informal science programs and exhibitions, educator training, curriculum development, after-school system-building). They are marshalling diverse resources to give shape to these collaborations, enabling the vision and work to unfold.

Among the initiatives we identified, lead organizations were intermediaries, such as Boston After School & Beyond, Providence After School Alliance, or TASC; science-expert institutions such as the American Museum of Natural History, Museum of Science and Industry, Chicago, or the California Academy of Sciences; STEM-focused youth program providers such as Girlstart; or institutions of higher education such as Lehigh Carbon Community College in Pennsylvania or Oregon State University.

In our interviews, we found that organizational leaders often but not always bring both collaboration expertise and STEM expertise to the task. In some cases, ecosystem leaders are experienced system builders with a record of success guiding multi-sector education initiatives, but rely on others for STEM content and knowledge. Since the role of ecosystem driver is as much about creating the capacity for new ways of working as it is about understanding STEM learning, these more general system builders are bringing needed expertise to the challenge. Many ecosystem drivers are thinking big in terms of the depth and reach of their vision. They describe STEM learning goals broadly without separating how, when or with whom young people learn STEM. As John Falk from the Synergies Project explains, "Particularly in the 21st century, but actually always, learning begins and ends with individuals, not institutions. We need to build an education system of the entire community, not based on the structures of these institutions." As a result, coalition builders do not limit their vision for change in one setting, for example, improving formal science education during the school day or increasing the STEM confidence among after-school workers. Rather, they envision the student at the center, and recognize the need for individual learning pathways through STEM content and skills in a variety of settings over time.

In many cases, we found the actual on-the-ground programming supporting such a vision is in the very early stages or at a small scale, but the long-term goals are much larger and integrative. Programming differs from more typical cross-sector transactions, such as when a school district hires a community-based organization to lead science enrichment to students after school, a teacher attends a stand-alone professional development course at the local science center, or a school sends its fourth graders on a field trip to the local aquarium. All of these examples enhance STEM learning, but their parameters are determined by one party without significant or early input from the other. There is often an assumption that the service ends when the grant or contract runs out. In contrast, organizations embracing the ecosystem model are not vendors but collaborators, setting mutual goals and developing aligned strategies to deliver on those goals.

> "Particularly in the 21st century, but actually always, learning begins and ends with *individuals*, not *institutions*. We need to build an education system of the entire community, not based on the structures of these institutions."
>
> **JOHN FALK**
> SYNERGIES PROJECT

The organizational leaders are confronting the challenges of cobbling together a coalition where the members have uneven power dynamics – schools have more resources, more stability and more credibility, while after-school providers have more flexibility but are often battling outdated perceptions that staff education or experience levels preclude "real" teaching. Said one leader, "The school day people have a bias that they should be the authority because they are credentialed. A credential does not make you a teacher. What makes you a teacher is a desire to facilitate the learning of kids." On the other hand, educators from the informal settings can bring their own preconceptions of the classroom environment as rigidly structured and unimaginative. Each sector also has its own terminology, creating barriers to shared understanding. In our interviews, we found organizational leaders strategically working through these challenges.

Example 1

BOSTON SUMMER LEARNING PROJECT

To help provide a shared vision for Boston's summer learning project, as well as school-year collaborations, Boston After School and Beyond and Boston Public Schools co-led the development of the ACT framework, describing the formal and informal learning experiences that children need to Achieve, Connect and Thrive (ACT). This framework helps informal educators better articulate the value of their contributions, and helps to equalize the conversation at a partnership table that includes both schools and community-based educators. The framework ensures that all the partners providing STEM-rich summer learning have a common reference point for their shared activities.

Example 2

MUSEUM OF SCIENCE AND INDUSTRY (CHICAGO)

Andrea Ingram of the Museum of Science and Industry, Chicago (MSI) describes how MSI's conception of its role has evolved from a place people primarily come to experience science learning to a comprehensive educational institution. "MSI's leadership has revolutionized the way we work with students, teachers, families, communities and school systems. By taking a comprehensive approach to science education, we aim to connect MSI and the community in a sustainable partnership where learning takes place in many different locations." In the past several years MSI has scaled its professional development for teachers and after-school educators working with middle grade students. To weather constant district leadership upheaval, MSI interacts with teachers and principals, focused on creating cohorts of trained teachers and school leaders over time. Its exhibits and professional development emphasize cross-cutting concepts and scientific practices. "Scientific practice is a way of learning, speaking and approaching the world -- that is how we do what we do. It is the heart of the way we approach our work," said Ingram.

Example 3

SHINE AFTERSCHOOL PROGRAM (NORTHEASTERN PA)

The SHINE Afterschool Program in rural northeastern Pennsylvania was initiated in 2004 by the Carbon County Child and Family Collaborative to provide after-school programming for at-risk children. Over the past nine years, Lehigh Carbon Community College has led its partners to transform SHINE from a standard after school program offered in a handful of elementary schools to an emerging cradle-to-career STEM education pipeline for disadvantaged students in this 700-square mile rural section of northeastern Pennsylvania. SHINE partners now include local STEM businesses in addition to higher education institutions, school districts, and a career and technical high school. SHINE has developed curricula, trains in- and pre-service teachers, engages families, and pursues public policy and advocacy goals.

STEM learning ecosystems are attentive to the enlightened self-interest of all partners.

Coalition leaders pay attention to meeting the "enlightened self-interest" of their members, ensuring that their participation in ecosystem-building activities enables them to deepen their work toward their own organization's mission. If enlightened self-interest is not met, the result is episodic collaboration that is not sustained. Initiatives look for mutually beneficial activities, such as using resources more effectively — be they school classrooms, museum exhibits, parks and recreation centers, volunteer scientists, computer labs, curricula, or science kits. Or coalitions may work to leverage a new funding source through partnership, or collaboratively identify and fill gaps in the system. A belief that all parties are committed to meeting their mutual goals and bringing money, talent and time to a shared table grows the effort and creates shared power. Many initiatives began their ecosystem transformation by working in alignment with a partner and are moving along a continuum of integration, through both natural evolution and deliberate efforts.[13]

Example 1

SMILE PROGRAM (OREGON)

Oregon State University's SMILE program partners with 50 science teachers across the state to lead its after-school clubs. SMILE provides a robust professional development program for the teachers, which in addition to equipping them to run high-quality after-school clubs, provides tangible benefits such as science equipment and supplies, access to OSU faculty expertise, continuing professional development units/graduate credit, curricula resources, and membership in an ongoing community of practice populated by peers from across the state. Across the broad geography of Oregon, these resources are not otherwise easily available. Director Ryan Collay points out, "In some of our communities we are all that there is."

Example 2

URBAN ADVANTAGE, NEW YORK CITY

In Urban Advantage, the American Museum of Natural History leads a partnership of eight local science-rich institutions and the

New York City Department of Education to improve middle school students' understanding of scientific inquiry and investigations. Partner institutions recognize the benefits of working together to recruit schools and teachers, align resources with relevant core ideas in the science curriculum, and advocate for sustained City funding. One of the keys to strengthening the links among the institutions has been the collaborative work with lead teachers and partners to jointly design and facilitate professional development sessions using classroom teaching tools and resources offered by each institution. These common tools and professional development strategies create continuity and coherence across the program. Said Jim Short from the American Museum of Natural History, "Partnership and collaboration bring us all together. This work is more in-depth, gratifying and long-term than less intensive short-term involvement with teachers and schools."

Example 3

DETROIT AREA PRE-COLLEGE SCIENCE AND ENGINEERING PROGRAM

DAPCEP's collaborators include the Detroit Public Schools, area charter schools, eight universities, and several corporations. Each of the partners has specific interests met through the collaboration. Detroit Public Schools has dramatically increased its presence and success at the local science fair since DAPCEP designed an in-school course and teacher professional development focused on helping students to complete hands-on investigative science and engineering projects. DAPCEP provides teacher training and materials to DPS middle and high school teachers for the course. As charter schools have proliferated in Detroit, DAPCEP provides universities with a "one stop connection" to local K-12 students rather than obliging them to create partnerships with more than 60 separate schools and districts. Corporations share DAPCEP's goal of creating an educated, diverse pool of employees who are prepared with the complex knowledge and skills their jobs now require.

Collaborating organizations in STEM-learning ecosystems are opportunistic and nimble.

Many of the initiatives have the capacity to be flexible and adjust their own plans to seek common ground. They are opportunistic, taking advantage of funding, political will, others' flexibility, and available resources to make progress. They have evolved somewhat organically rather than by following a predetermined work plan.

Example 1

GIRLSTART (CENTRAL TEXAS)

Girlstart has grown from leading four school-based after-school programs in 2009 to 43 after school partnerships in 2013 (Girlstart After School includes after school intervention as well as wraparound programs such as family science nights, teacher professional development, and school-based science fairs). Said Executive Director Tamara Hudgins, "We are not afraid to try things. We have flexible staff who are totally dedicated to our mission of STEM education for girls. We are not in transactional relationships with schools – we bring our resources to the collaboration and we ask schools to bring their attention and time. We vet very seriously whether they have the capacity to be a strong partner with us. This is not about a vendor relationship but whether they view us as important to their community. This manifests itself in so many different ways, so we must be able to respond nimbly and flexibly to opportunities and challenges."

Example 2

AFTERZONE SUMMER SCHOLARS PROGRAM (PROVIDENCE, RI)

The Providence After School Alliance has relationships with a vast array of community providers, enabling it to respond to the needs of schools and the urban school district, and to the interests and desires of students and parents. By providing opportunities for teachers to try new instructional techniques with the support of educators from STEM-expert organizations and youth development providers, the AfterZone Summer Scholars program has also positioned itself as a way to train teachers. This has led the school district to fund the summer program as a professional development opportunity as well as a learning opportunity for students.

Example 3

ORANGE COUNTY STEM INITIATIVE

When the California Afterschool Network and the California STEM Learning Network announced the Power of Discovery: STEM^2 initiative to support partnerships among schools, community-based organizations, and STEM expert institutions, the OC STEM initiative jumped on the opportunity. Led by THINK Together, the Discovery Science Center, the Tiger Woods Center, and the Orange County Department of Education, OC STEM was chosen as a Regional Innovation Support Provider to support and equip after-school programs and schools in Orange and neighboring counties. OC STEM drew on lessons learned during the Jumpstart STEM statewide pilot the year before, when THINK Together had tested three approaches to enhancing and connecting STEM activities in its after-school sites. The most successful approach tested in that pilot was to provide programs with the Discovery Science Center's curricula resources and coaching strategies. For the scale-up required by the Power of Discovery initiative, OC STEM drew on that successful approach and also connected programs with additional experts and resources with the assistance of AmeriCorps VISTA volunteers. Said THINK Together's CynDee Zandes, "We want to build the capacity of programs and schools to integrate STEM everywhere, in and out of school, so that this is what they are doing anyway, after the external funding goes away."

Teachers in MSI Chicago science teacher education courses learning to connect content to real world phenomenon for students.

Strategies of STEM Learning Ecosystems

We asked initiative leaders to describe how they were approaching their work. We have identified six major strategies they are using to creating and connecting STEM-rich learning environments:

1. **Building the capacity of educators in all sectors, by tapping resources and expertise from STEM-expert institutions, schools, after-school/summer programs, and others.**
2. **Equipping educators from different settings with tools and structures to enable sustained planning and collaboration.**
3. **Linking in- and out-of-school STEM learning day by day.**
4. **Creating learning progressions for young people that connect and deepen STEM experiences over time.**
5. **Focusing curricula and instruction on inquiry, project-based learning and real-world connections to increase relevance for young people.**
6. **Implementing programs and public outreach to engage families and communities in understanding and supporting children's STEM success.**

1 STRATEGY

Building the capacity of educators in all sectors, by tapping resources and expertise from STEM-expert institutions, schools, after-school/ summer programs, and others.

The skills and knowledge of educators – regardless of setting – are critical to the quality of STEM learning experiences. Teachers need to know how to shift pedagogical practice and deepen their content knowledge as schools adopt new standards for what children and youth are expected to know and be able to do in STEM. Out-of-school time educators need training and support to confidently lead engaging STEM activities. The initiatives profiled here are linking their efforts to meet these imperatives, building their understanding of how cross-sector approaches can enrich outcomes for all.

They are also intentionally working on helping educators understand and make connections among STEM learning that occurs in different settings. According to the 2010 National Research Council report Surrounded by Science, it is "important for science educators to understand and appreciate the interconnections and to take them into account when creating and delivering science learning experiences for their audiences."[14] Practitioners and researchers are still uncovering the most effective ways to do this. A recent analysis of a study of connecting in and out-of-school science learning noted: "Teachers would benefit from greater training in supporting students to successfully integrate their learning experiences. In addition, better integration would occur if teachers were able to incorporate more out-of-school experiences into their regular practice such that students and teachers shared similar experiences and could build on them back in the classroom."[15]

We found that STEM-expert organizations are providing joint professional development to teachers and after-school educators, and schools and after-school providers are placing educators from one setting into another. For example, in-service and pre-service teachers are leading after-school or summer STEM activities. This practice was found in another recent study to effect "change in teacher candidate notions of teaching to ones involving more collaborative learning approaches, student-led learning, greater dialogue and greater confidence with both formal and informal resources."[16] As they implement these creative strategies, the initiatives are finding ways to overcome differences in the expectations, culture, language, and focus of educators from different settings.

Example 1

BOSTON SUMMER LEARNING PROJECT

Boston's effort is designed to immerse teachers and community educators in intensive summer-long collaborations. Cross-sector teams of educators co-lead groups of students through academic lessons and hands-on projects based around an essential question such as, "What does it mean to be living?" Teacher Christine Gottshall of Boston's Orchard Gardens K-8 school teamed with an educator from Outward Bound to lead a group of students in a science-focused summer experience at Thompson Island in Boston Harbor in 2013. Gottshall explains that she finds "… my students were performing at the same level academically that we would expect in the school year, but the difference was in the ways in which they were able to engage in the content, and for some of our kids there was a huge difference in behavior because they were able to be more active and be more hands-on throughout the course of our lessons."

The science-rich environment added value as well, especially for students who had never visited the islands before. Ms. Gottshall explained that the environment allowed her "to pull vocabulary words that connected to things we could see and experience together on the island, and it made it much more authentic and meaningful for them." Flexible lesson plans and a more creative space pays off particularly for students who "tend to think outside the box and are more creative thinkers," as Ms. Gottshall explains. Students who are "somewhat constricted by a traditional classroom setting were really able to take ideas and points of interest for themselves and really just run with them in a much more free way than…on a given school day with more time constraints and more physical space constraints."[17] Chris Smith from Boston After School & Beyond notes that the non-traditional space frees up teachers to try new instructional techniques as well.

Example 2

GIRLSTART (CENTRAL TEXAS)

Girlstart leads workshops, presents at teachers' conferences, and provides professional development to teachers on the value of informal science education. Girlstart also provides specialized professional development to teachers in its partner schools, focusing on hands-on activities linked to various units, such as marine biology, space or robotics. Anna Pedroza, principal of Ortega Elementary School in Austin, Texas, said, "My students, parents, teachers and I consider ourselves blessed to have Girlstart on our campus. We think of Girlstart as an essential program because the staff brings an area of specialization and resources that are difficult to find in an elementary school." Girlstart Executive Director Tamara Hudgins said, "With the pressure around test results, the reality for teachers is different than ours. But if we reach 500 teachers and 80 percent learn something they will use in the classroom, then we are making a difference." Girlstart also hires pre-service teachers from the UTeach program and STEM majors from the University of Texas Austin for its STEM CREW (Creative, Resourceful, Empowered Women) of after-school program leaders. "It's an easy collaboration with the UTeach program. We refine and extend the teacher training. We try to hire people from outside the school community because we want to design an experience for the girls that is not based on the 'I'm right and you're wrong' hierarchical structure. If that is the dynamic that is built during the day, it is not easily put away in the OST environment," said Hudgins.

Example 3

NEW YORK CITY STEM EDUCATORS ACADEMY

TASC and the New York Hall of Science designed a joint professional development experience to give middle school students a deeper and livelier immersion in science learning over the course of the school year. Five teams from four schools are each comprised of one classroom science teacher plus two youth development educators working after-school. The teams met for five full days of training in early August in a lab at the museum. They spent much of their time learning by doing the sorts of activities they might lead with students, like modeling the human digestive system and exploring motion by building balloon-powered cars. Each team devised lessons they would lead with students then presented them to the other teams for feedback and idea-sharing. By getting familiar with each other's terms, communication styles, and abilities, they prepared for the real-time planning they have been doing during the year to design the morning and afternoon science sessions. For example, at IS 206 in the Bronx, two community educators sat in on the science teacher's lesson on density, and helped with a short lab about why a can of diet soda floats when a can of regular soda sinks. In the afternoon, because they knew what vocabulary had been used and stressed and how far the groups were able to go during the morning, they were able to pick up right where the morning left off, adding a longer experiment using seven materials of different densities and use of the scientific equipment in the classroom. Based on the training over the summer and the focus on hands-on learning, one science teacher revised his lesson on DNA modeling to allow more freedom for students to create individualized approaches they then had to present and defend.

Example 4

MUSEUM OF SCIENCE AND INDUSTRY (CHICAGO)

Like many science-expert institutions, the Museum of Science and Industry, Chicago (MSI) offers professional development to teachers and training to out-of-school time providers. MSI has begun to connect these efforts within specific schools by establishing Science Minor Clubs in schools where cohorts of teachers participate in MSI's teacher courses. MSI's Andrea Ingram points to Sawyer Elementary on the West Side, which has been sending teachers to MSI professional development for more than five years and now has a Science Minor Club led by these teachers in partnership with community-based educators. Said Ingram, "The Science Minor Clubs are a different entry point for kids to the same science learning approach. There is excitement about science in school and after-school." Sawyer Elementary teacher Nicole Yakes said, "MSI has helped us change the entire science experience at Sawyer. The level of questions students ask – and the observations they make – get better every year." Fellow Sawyer teacher Laura Gluckman said her students are gaining critical skills, making meaningful connections and are thinking of themselves as part of a scientific community. "The MSI teacher courses embody the values that I think we all want to instill in our students – the values of lifelong learning and continuous curiosity about the natural world," Gluckman said.

Example 5

SMILE PROGRAM (OREGON)

The SMILE program provides between five and eight full days of training to the 50 science teachers who lead after-school clubs in 33 schools serving fourth through twelfth graders across Oregon. The majority of the teachers have been leading the clubs for between five and 12 years, creating what director Ryan Collay described as a close-knit community of practice. The professional development focuses on improving teacher's skills in the following areas:

1. Delivering inquiry-based integrated science/math curricula
2. Deepening content knowledge of science and math
3. Making connections to STEM career fields
4. Integrating technology into their teaching
5. Facilitating cooperative or collaborative classes and activities
6. Using culturally-relevant, equity-promoting teaching techniques

Said Collay: "We link our training to classroom practice and show teachers how they can use the after-school environment as a test bed to increase their own capacity to engage youth. We explore how the teachers can use SMILE to help young people become more successful students by building their non-cognitive skills, interest, engagement, and capacity to connect with what interests them. Another bonus is that the students see a different side of their teacher in the after-school space."

Example 6

URBAN ADVANTAGE (NEW YORK CITY)

This partnership among eight science-rich institutions and the New York City Department of Education aims to build middle school science teachers' capacity to lead students in completing scientific investigations and build their understanding of scientific inquiry and key science concepts. Through close coordination, the Urban Advantage (UA) partner institutions effectively align instructional resources and expertise to support a broad range of needs including the implementation of project-based learning as well as inquiry-based teaching strategies for conducting controlled experiments, field studies, design projects, and secondary research. Close coordination with the Department of Education has also spurred UA to increase its focus on integrating nonfiction reading and writing strategies into the science curriculum – a district priority through the Common Core. To maximize the benefits of the program, UA 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.

Example 7

SHINE AFTERSCHOOL PROGRAM (NORTHEASTERN PA)

SHINE, led by Lehigh Carbon Community College (LCCC), hires and trains teachers for its elementary-age, STEM-focused after-school program operating in six schools in a 700 square mile area of rural northeastern Pennsylvania. Each SHINE Afterschool Center is staffed by two teachers and two college education majors from the community college. SHINE Director Jeanne Miller points out, "the key to successfully integrating STEM into an after-school program is teacher buy-in." SHINE requires teachers to create a yearly professional development plan for their work in the program that includes training in project-based learning focused on STEM fields as well as the integration of reading, writing, business, and art. A total of 40 hours of intensive training are provided each year for SHINE staff, teachers and the pre-service teachers enrolled at LCCC who serve as interns in the program. "Once they know how to facilitate inquiry and lead project-based learning, teachers experience the impact they can have on students. It's not easy to integrate these techniques into the daytime scope and sequence that is aligned to testing, but teachers who work in our after-school program go back to their classrooms as better teachers and the principals are seeing this," said Miller.

> "We link our training to classroom practice and show teachers how they can use the after-school environment as a test bed to increase their own capacity to engage youth."
>
> **RYAN COLLAY**
> **SMILE PROGRAM**

Of the SHINE teachers who completed surveys for the program from 2008-2013, over half strongly agreed that their experience as an afterschool teacher in the SHINE program has improved student learning in their regular classroom, while nearly 60 percent strongly agreed that SHINE has helped them better understand and utilize assessments/data more effectively to improve student learning in their regular classrooms. One teacher noted, "I have incorporated more science lessons that are interactive and engaging" while another said, "SHINE has dramatically improved my teaching. It has given me a greater appreciation of the importance of communications with parents. The trainings have helped me better plan and utilize cooperative groups."[18]

Oregon students participating in SMILE program observe the collection and display created by other "student scientists."

2 STRATEGY

Equipping educators from different settings with tools and structures to enable sustained planning and collaboration.

It is difficult for schools and after-school programs, while they focus on the day-to-day needs of students, to find effective ways to connect their STEM curricula and instruction. A few initiatives offer tools and structures to guide these collaborations, with the goal of making it easier for educators to use precious time and resources effectively.

Example 1

ORANGE COUNTY STEM INITIATIVE

With the STEM expertise of the Discovery Science Center and system-building knowledge of the expanded learning/after-school providers THINK Together and the Tiger Woods Center, the OC STEM Initiative provides OST programs and their school partners with a framework for collaboration, including templates to use for needs assessments, sample Letters of Agreement and MOUs, guides for work plan development, and website materials and supports. Programs and schools choose a level of involvement based on their own readiness and capacity: STEM strong, STEM standard or STEM light. Depending upon the level the program chooses, OC STEM tailors its web-based and in-person professional development, evaluation and program support. The Initiative has also engaged three AmeriCorps VISTA members through partnerships with Maker Education and the Orange County Children and Families Commission to help identify new STEM resources for programs, including Maker activities and faires and pre-school STEM resources, and increased outreach to community partners and parents.

Example 2

CALIFORNIA ACADEMY OF SCIENCES (SAN FRANCISCO)

The California Academy of Sciences (CAS) supports after-school Science Action Clubs in San Francisco. The Academy trains the Club activity leaders – staff of community-based organizations operating the after-school programs at the school -- on how to participate in Citizen Science while leading hands-on science learning for young adolescents. In an effort to connect the interest, enthusiasm and scientific practice skills young people have developed in the club to the school day and to home, the Academy has created a Science Alliance Team at each of middle schools that host the clubs. The Team includes the Science Action Club activity leader, director of the community-based organization that runs the after-school program, a school science teacher, the principal or other school leader, and a parent/guardian. SAC Alliance Teams will provide a structure for science teachers to act as mentors to the activity leaders, students to deepen their learning and skill-building in the classroom, and families to get involved and provide support.

Example 3

THE AFTERZONE SUMMER SCHOLARS PROGRAM (PROVIDENCE, RI)

The Providence After School Alliance and Providence Public Schools take advantage of summer as a time for teachers, community educators, and PASA youth development specialists to collaborate on STEM learning for middle school students. Cross-sector teams spend nearly a week to co-develop a set of activities that connect STEM and literacy skills with hands-on field research for rising middle school students. During the planning time, team members learn from each other how to use an inquiry-based experiential learning framework. Said Providence Public Schools Superintendent Susan Lusi: "…there is a marriage of the youth development goals and expertise with knowledge of the standards and skills our students and teachers are held accountable for." A critical part of PASA's approach is encouraging educators to see one another as equal partners in the entire process, learning from one another through joint professional development, co-creating a curriculum, and leading the project together.

3 STRATEGY

Linking in- and out-of-school STEM learning day by day.

A 2011 study of connections among formal and informal learning experiences noted "The fields of informal and formal science education have both overlapping and divergent goals. The most critical implication for programs that operate in conjunction with one another is that they understand their goals and involve each other in the design and implementation of programs in which they will interact. It is essential that practitioners from both contexts discuss learning expectations for any planned event and are aware of the broader learning sequence present in the classroom."[19] The day-to-day work of connecting in- and out-of-school STEM learning often requires OST programs to shift their educators' schedules to enable collaborative planning and follow-through, and schools to welcome informal educators to their planning and leadership teams.

Example 1

ORANGE COUNTY STEM INITIATIVE

CynDee Zandes of THINK Together explains the three main ways after-school programs supported by the OC STEM Initiative integrate STEM experiences across settings for young people.

1. **Previewing.** The after-school program introduces a concept with a hands-on activity before it is introduced in class, so children are familiar with it and ready to build on their knowledge with the school unit. This approach requires planning and communication among teachers and after-school educators.

2. **Reviewing and Supporting.** In schools with less capacity for planning between the school day and after-school, the after-school program takes up a subject after the children cover it in class, providing review and support.

3. **Synchronous Teaching.** Schools that have classroom and after-school most in sync can address concepts at the same time with complementary curricula and activities.

Said Zandes, "From the 60 observations we completed in 2013, we know our two biggest challenges are building the science content knowledge of OST staff, and teaching them how to take a hands-on activity and make it 'minds-on.'" One of the ways OC STEM encourages coordination is to design out-of-school time staff schedules so they have time to attend science teacher planning meetings, and talk with schoolteachers. The OC STEM Initiative also practices cross-sector collaboration at the leadership level: the Orange County Department of Education Superintendent is a member of the OC STEM Board. Zandes: "We are moving from a mindset of 'They are my kids when I am with them and your kids when you are with them' to 'These are all our kids, all the time.' We are working on creating a coherent system that allows children and youth to integrate learning across all the environments they are in and maximize their opportunities."

Example 2

NEW YORK CITY STEM EDUCATORS ACADEMY

To ensure alignment between traditional school-day courses and informal science after-school, the STEM Educators Academy requires science teachers to co-teach in the afternoons four hours per month in addition to requiring four hours per week of enriched STEM in after-school hours. Although there is no requirement for community educators to join classes during the regular school day, at two schools, community educators spend an hour a week observing (and sometimes assisting) in regular school-day STEM classes. Building on a summer institute where educators jointly developed lesson plans, this time working alongside each other reinforces their mutual goals and real-time alignment of activities throughout the school year. They hear and can echo each other's use of scientific vocabulary, refer back to lessons, and ensure seamless transition from school to afternoon activities. They also align behavioral techniques and classroom management practices, which ensures a more coherent experience for students in science class. Over time, the school and community partner are committed to blurring the lines between school and after school across all content areas so that students experience a longer school day with a balanced curriculum led by school and community-partner staff.

Example 3

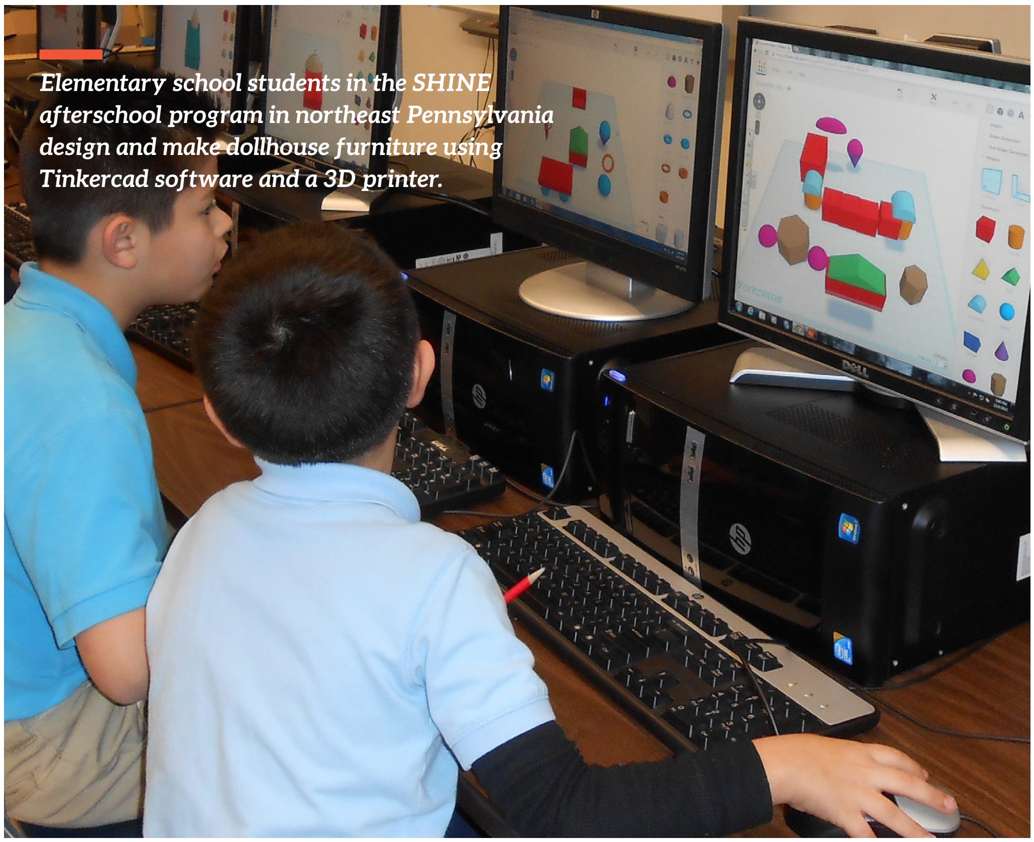
INDIANA AFTERSCHOOL STEM INITIATIVE

As part of a comprehensive effort to ensure all Indiana youth have access to quality STEM in out-of-school time programs, the Indiana Afterschool Network offers professional development in STEM curricula to educators in after-school programs. One of these curricula, NASA Ignite! is supported by WisdomTools, an education software and services firm that provides training as well as technical assistance, curriculum selection and alignment, STEM Kits, and, in some cases, expert educators to help with program implementation. In Cloverdale, a town of about 2,000 in central Indiana, and in Michigan City, a city of about 30,000 near Chicago and South Bend, school teachers were trained in the NASA curriculum for after school. In both districts, teachers wanted a more engaging approach for their school day instruction but lacked new curricula or training resources. They recognized that integrating the NASA curriculum during the day could be an ideal solution. WisdomTools helped to select appropriate and aligned activities so school-day and after-school lessons would complement one another.

4 STRATEGY

Creating learning progressions for young people that connect and deepen STEM experiences over time.

Several of the initiatives profiled are conceptualizing in and out-of-school STEM experiences as progressions that can build young people's skills and knowledge as they grow and develop. As they continue to articulate these STEM pathways, they are well-positioned to support the implementation of learning progressions as articulated in the Next Generation Science Standards, which note that students need "sustained opportunities to work with and develop the underlying ideas and to appreciate those ideas' interconnections over a period of years rather than weeks or months."[20]



Elementary school students in the SHINE afterschool program in northeast Pennsylvania design and make dollhouse furniture using Tinkercad software and a 3D printer.

Example 1

SMILE PROGRAM (OREGON)

SMILE Clubs span elementary through high school, beginning in fourth grade. Eight of the 11 districts have clubs at all levels, and the program is recruiting additional teachers and schools to fill in the pipeline where there are gaps. The program has articulated a progression of skills and attributes for students to demonstrate at each level. For fourth and fifth graders, the theme is "becoming scientists" and the program focuses on students developing observation, prediction, teamwork and presentation skills. At the middle school level, students are "growing into problem solvers" and the program focuses on students' capacity to identify and solve problems using their understanding of relevant content, then work as team members to generate a variety of ideas to address the identified problem. By high school, students are expected to "serve as informed voices in the community" by understanding the nature of their community and its needs; defining broader problems and identifying potential solutions; using evidence and science content to enhance their observations and improve their accuracy; connecting their understanding of relevant science content to the needs of and possibilities for a community; and formulating and delivering a persuasive presentation that shares with interested stakeholders related science content and possible solutions.

Example 2

CHICAGO AND DETROIT AREA PRE-COLLEGE SCIENCE AND ENGINEERING PROGRAMS

These programs provide rigorous STEM curricula to African-American and Latino children to prepare them to succeed in post-secondary STEM majors. They enroll children and their families beginning at age five. The newer Chicago effort currently serves kindergarten through fourth grade and is gradually building upward as its original cohort grows older, while the Detroit program serves kindergarten through twelfth grades.

Example 3

SHINE AFTERSCHOOL PROGRAM

SHINE begins by home visiting kindergartners and their families. Children enter the SHINE Afterschool program as first graders and continue through elementary school into a hands-on, career-oriented middle school program that feeds into placement for those who are interested in a local technical high school. SHINE leaders are building the pipeline further to the community college and eventually to Temple University's engineering program.

5 STRATEGY

Focusing curricula and instruction on inquiry, project-based learning and real-world connections to increase relevance for young people

The Next Generation Science Standards state: "As in all inquiry-based approaches to science teaching, our expectation is that students will themselves engage in the practices and not merely learn about them secondhand. Students cannot comprehend scientific practices, nor fully appreciate the nature of scientific knowledge itself, without directly experiencing those practices for themselves."[21] Many of the initiatives are integrating an active, hands-on approach to STEM learning into school and out-of-school time settings. They are also providing early and consistent emphasis on how the activities students are engaged in relate to their own lives, the world around them, and future careers.

Example 1

GIRLSTART (CENTRAL TEXAS)

Girlstart has developed a standards-based curriculum, called the Girlstart Method, for its after-school clubs and summer camps. The Girlstart Method is aligned with Texas science standards and is based on the five "e's" of engage, explore, explain, elaborate, and evaluate.[22] Girlstart chose this instructional model because it enables the activity leader to build on the girls' prior knowledge and experience and to take an active role in constructing the meaning of the activities for themselves. Girlstart summer camps are designed around a particular theme – for example, advanced video game development -- and provide a 40-hour immersion for the girls in each subject. Hudgins explains, "We set grand challenges for ourselves and the girls. We have been accused of expecting too much, but we believe setting ambitious challenges for girls in fourth grade is totally relevant. By setting those challenges early we set girls on a path to develop resiliency, creativity, and grit. We want girls to know that their ideas are valid. We say to girls: what can you do to solve world problems? Cap an oil spill using computer simulation. Clean an oil soaked animal. They are invested in solving real-world problems so that is where we channel their energy. We are always accessible to girls, parents, and teachers with fun, challenging activities that are connected to solving some of the big engineering global questions. Our belief is that connecting them to inquiry will maintain their interest."

Example 2

SHINE AFTERSCHOOL PROGRAM (NORTHEASTERN PA)

At the elementary level, all students enrolled in the SHINE Afterschool program across eight rural PA towns have been identified as needing academic support, so the STEM curricula maps closely to classroom skills and topics, with a key addition: "From the earliest age, we teach the children why math and science are important to their success and future and what STEM careers are all about – and this does not happen in school," said Director Jeanne Miller. Fourth and fifth graders take part in a 32-week STEM curriculum based on high-priority occupations in engineering, health sciences and green energy. The curriculum places an emphasis on developing critical thinking and problem solving skills, global awareness, and effective communication. Example topics include solar cars and houses, Rube Goldberg machines and hydroponics. Children from across the region feed into a centralized after-school program for sixth through eighth graders which takes place at the Carbon Career & Technical Institute, a vocational high school. The middle school curricula provides hands-on, project-based, career-connected experiences for students. The curricula was designed by a team of business and industry representatives, scientists and educators convened by the SHINE leadership. One project involves students building "The Car of the Future." Utilizing CAD, the students engineer and construct a life-size derby car, building it from scratch using precision-machined parts.

Example 3

THE AFTERZONE SUMMER SCHOLARS PROGRAM (PROVIDENCE)

Teaching teams consist of a community-based STEM educator, a district teacher, and an AfterZone staff member to ensure relevance and excitement. Community partners like SailZone Community Boating Center, Save the Bay or the Mechatronics Center for Dynamic Learning engage students in science research questions, like investigating the connections between sailing, weather, and mathematics or designing a solar-powered dune buggy. Twice a week students are out in the field engaging in hands-on learning, while on other days, they build mathematics and English language arts skills directly related to the field experiences. Students develop final projects, such as PowerPoint presentations or dramatic pieces, to demonstrate their learning.

Example 4

EXPANDED LEARNING NETWORK OF THE SOUTHERN TIER (CORNING, NY)

In rural New York, the Wings of Eagles Discovery Center in Horseheads started as the National Warplane Museum, but in the middle of the last decade, transitioned to a regional STEM academy with a focus on using aircraft and other flight-related objects as teaching tools. The transition was motivated by the dual realization that the old planes appealed mostly to members of an aging generation and that the center was in a strong position to help fill the gaps in STEM teaching to local children. The center now works in close collaboration with Corning, Elmira, and Horseheads school districts to use its 30,000-square-foot display hangar for science fairs and displays of students' projects. The center has also acquired five air traffic control consoles from the Federal Aviation Administration, along with computers and whiteboards from the

New York State's Boards of Cooperative Educational Services (BOCES) to add to the 36 planes it owns. These resources enable museum educators to lead lessons that focus heavily on projects rather than lectures. Alison Mandel, director of education at Wings of Eagles, witnessed the effect on third- and fourth-graders taking part in a two-week Marvelous Machines model-building project and saw how excited they became.

Example 5

CALIFORNIA ACADEMY OF SCIENCES (SAN FRANCISCO)

Science Action Clubs capitalize on the after-school environment to provide interest-driven, interactive science learning experiences for San Francisco middle school youth. The Academy trains after school activity Leaders and provides an essential supply kit and custom-configured iPad to each program. Students conduct hands-on science investigations and contribute data to ongoing research through Citizen Science projects.

Example 6

DETROIT AREA PRE-COLLEGE SCIENCE AND ENGINEERING PROGRAM

Through its partnership with local universities and corporations, DAPCEP provides access to a broad range of rigorous STEM courses beyond what is offered in school to fourth through twelfth graders in metro Detroit. Courses on tap for spring 2014 include robotics, video game design, 3D rendering, algebra, urban design, nuclear engineering, coding, and laboratory science. Children kindergarten through third grade attend five Saturday sessions alongside their parents focused on math, science, pre-engineering and reading. DAPCEP has also developed a course taught during the school day and after school by Detroit Public School teachers for middle and high school students focused on scientific investigations and projects leading up to the science fair competition. DAPCEP provides training, curricula and resources for DPS teachers leading the course. Said DPS teacher Sheryl Rucker, "I feel it's important for teachers to stay current on the best practices. I just finished [a DAPCEP training] learning about the engineering design process, which was more work than I would have ever imagined, but so informative on how I can engage my students to better prepare them with those skills that are sought after for engineers. DAPCEP in-school and on Saturdays really allows me to touch a lot of students in a positive way." Guadalupe Salazar, an 11th grader who has been in DAPCEP since kindergarten said, "DAPCEP has really shown me a lot of the real-life applications of the science. I have dissected a pig before, and opened up a heart of a sheep. I have done chemical experiments. I want to study engineering when I go to college."

6 STRATEGY

Engaging families and communities in understanding and supporting children's STEM success through programming, communications and public awareness.

Families and communities form a key part of the learning ecology for any young person. Families play a critical role in supporting their children to pursue difficult and rigorous STEM study, and they are also key to creating the demand that sustains out-of-school STEM programs over time. Yet engaging parents in understanding and supporting STEM learning is the least developed area of work among these initiatives.

Example 1

CHICAGO PRE COLLEGE SCIENCE AND ENGINEERING PROGRAM

Chi S& E is designed specifically to build parents' capacity to support their children's development through direct instruction side-by-side with the children; modeled instructional strategies for parents; at-home educational activities provided to parents; and lessons on technology for parents. In a focus group convened as part of an evaluation of the program's second year, a parent said, "Ever since I've been in the program I've found it less stressful working with my daughter because just doing the work refreshes your mind, having patience with them, and having methods to work with them. It just kind of improves things, on classwork and outside classwork."[23] Said Director Kenneth Hill, "Many people believe parent involvement is difficult, but we have found it is not if you have a good program and the kids love it. The kids love going to the Museum of Science and Industry on Saturdays. They get their parents up to go. The children's excitement drives them to do it!"

Part of Hill's family involvement strategy is to tap parents' skills and expertise to build organizational capacity. "We are building a parent organization. We have committees focused on curriculum, communications, and development. Parents are finding new support for the program, developing our social media strategy, helping to evaluate our impact, and involving other parents." Hill invests so much time and energy in parent involvement because he believes that parents are the key to the children graduating with rigorous science and engineering curricula. Said Hill, "Parents have to understand what their child is going through and support him or her because this journey is going to be very difficult."

Example 2

ORANGE COUNTY STEM INITIATIVE

Orange County STEM Initiative has a robust communications platform. Its website – ocstem.org -- is designed to publicize STEM in general: programs, events, partners, discussion boards, and news. The initiative also supports STEM-focused events and meetings to further build the STEM learning ecosystem. For example, in February 2012, the Synergy for Success in Science Education, in partnership with the National Science Resources Center, Science@OC and the Orange County Department of Education, brought together 15 leadership/district teams, consisting of superintendents, science educators, science curriculum specialists, and local business partners, to begin a dialogue and framework that addresses science education across their districts. In 2013-14, OC STEM, working with the Orange County Department of Education, launched the Lead STEM Practitioner Network. The Network consists of 25 prekindergarten to eighth grade teachers representing 22 school districts who are being developed as STEM leaders in their respective districts on STEM and Next Generation Science Standards.

> "Ever since I've been in the program I've found it less stressful working with my daughter because just doing the work refreshes your mind, and having methods to work with them."
>
> PARENT REFLECTING ON CHILD'S SECOND YEAR PARTICIPATING
> CHI S&E

Conclusion and Recommendations

This limited investigation into emerging STEM learning ecosystems in the U.S. uncovered tremendous activity, from urban centers to rural districts. Practitioners of all stripes are working to connect previously disparate settings in explicit ways that support STEM teaching and learning amoung educators, young people and their families. They have gone beyond binary, transactional arrangements, however they still face formidable challenges to moving toward the aspirational definition of STEM learning ecosystems offered in our introduction.

Challenges

1. **Accessing adequate, sustained funding.** Said Kenneth Hill of the Chicago Pre-College Science and Engineering Program, "The only reason we don't have 2000 children and parents yet [in our Saturday classes] is we need more money."
2. **Collecting data and assessing outcomes** in a comprehensive manner, across learning settings and over time.
3. Finding time and trust to successfully **navigate differences among formal and informal cultures**, including language and terminology, education and experience, accountability and vision.
4. **Successfully engaging families**, as efforts often fall short in attracting participation and assessing their impact is difficult.
5. Figuring out which organization or group of organizations is best positioned to **drive the ecosystem building effort**, and giving them the power to do so.
6. **Transitioning through leadership changes**, particularly in the formal education system, which can set back efforts.

We have identified some of the creative ways the initiatives we profiled in this study are addressing these challenges, but this emerging field of interconnected STEM learning needs to better share promising approaches, pilot new ideas, understand what lessons can be gleaned from efforts that did not work, and research the results of similar efforts in different fields.

In conclusion, we provide recommendations in the areas of practice, research and evaluation, and policy. These issues should be on the field's collective agenda, rather than faced by each initiative in isolation from others.

Recommendations

1 Practice | 2 Research & Evaluation | 3 Policy

1 PRACTICE

1. **Get ready to scale by learning more about what works and what does not.** Public and private funders should help emerging STEM ecosystems better understand how to scale their efforts, including how to integrate strategies for scaling into their design. Scaling takes skills that are different than those needed to make a smaller collaboration work well, including strong relationship-building, knowledge of multiple and aligned systems, and ability to marshal complex public-private funding. Strengthening intermediaries to take on these coordinating roles may help strong collaborative models to scale.

2. **Create a community of practice for STEM learning ecosystems:** National stakeholders, including Achieve, Inc., the National Academy of Sciences, Afterschool Alliance, Association of Science-Technology Centers (ASTC), the National Science Teachers Association, the Council of State Science Supervisors, and Every Hour Counts should support an ongoing community of practice for emerging STEM ecosystems to share innovative and effective practices, address the challenges specified above, and help to develop and grow their efforts. The community of practice could blend virtual communication platforms with face-to-face gatherings and should be supported by the STEM Funders Network members and other public and private philanthropies.

3. **Examine how STEM learning ecosystems can help realize the goals of Common Core mathematics, NGSS and the Framework for K-12 Science Education.** As the lead organization coordinating the development of the Next Generation Science Standards and the Common Core state standards, Achieve Inc. should integrate into its ongoing work an examination of the potential for STEM learning ecosystems to help realize the goals of Common Core mathematics, NGSS and the Framework for K-12 Science Education. This effort could focus on how interconnected STEM learning experiences provide a rich tapestry for teaching and learning cross-cutting concepts and scientific practices over the full developmental trajectory of preK-12. Partners for this effort should include the U.S. Department of Education and the Council of State Science Supervisors, and public and private funders and other stakeholders.

2 RESEARCH & EVALUATION

1. **Learn how to assess learning outcomes across settings:** To justify public and private investment over time, the ecosystem approach needs to prove its worth. Although many of these initiatives are quite sophisticated in tracking outcomes of individual program components, none of them have developed a way to track the impact of all the interconnections they are building among STEM learning experiences. Doing this will require tools that can assess a broad range of outcomes across learning settings, including interest, engagement and perseverance in STEM over time; STEM proficiency; participation and success in STEM study during the secondary and post-secondary years; adult STEM knowledge; and more. Useful tools that measure some of these things include the Dimensions of Success (DOS) and the Common Instrument by PEAR and 4H's YEAK (Youth Engagement, Attitudes and Knowledge) survey. Work by the Science Learner Activation Lab on how to activate children in ways that ignite persistent engagement in STEM and art learning and innovation, and by Daniel Schwartz and Dylan Arena of the LIFE Center on choice-based assessments using digital technologies contribute valuable knowledge and introduce new ways of thinking about these challenges.[24]

   An important, related challenge is the imperative states now face to develop assessments for the new Next Generation Science Standards. The National Research Council recently released the prepublication report of the Committee on Developing Assessments of Science Proficiency in K-12. The Committee was charged with "making recommendations for strategies for developing assessments that validly measure student proficiency in science as laid out in the new K-12 science education framework." The Committee pointed out that "measuring the learning described in the NGSS will require assessments that are significantly different from those in current use" and recommended "a developmental path for assessment that is 'bottom up' rather than 'top down': one that begins with the process of designing assessments for the classroom, perhaps integrated into instructional units, and moves toward assessments for monitoring."[25] The Committee also stressed the need for professional development and a gradual timeline for introducing assessments. The Committee's report may spur formal educators and education policymakers to think in new ways about designing and implementing assessments. Those who see the value of what children and youth can learn in many different learning settings have an opportunity to help push the conversation and the vision beyond conventional parameters of what happens in the classroom.

2. **Disseminate relevant research more broadly and across sectors.** We recommend that researchers, practitioners, and public and private funders work to make relevant research more accessible across the broad array of stakeholders involved in STEM learning. Communities undertaking an ecosystem-building approach to STEM learning need to understand, as much as possible, each other's evidence base, emerging findings, and current research questions. Different terminology, assumptions, and metrics can make translation across the formal and informal environments difficult. In addition, there is useful research investigating directly how formal and informal learning connect, and how to create conditions where learners transfer knowledge across disciplines, topics, or knowledge domains. These resources should be disseminated to formal and informal practitioners and systembuilders more broadly to encourage emerging ecosystems to build from the knowledge base of this growing field. For example, two reports were released in the past few years that in the course of examining deeper learning and non-cognitive skills, provide guidance to practitioners about instructional practices that encourage transfer.[26] These and other reports have great potential to inform practitioners and systembuilders using an ecosystem approach. We identified web resources that could encourage cross-sector dissemination of a common research base. None of our interviewees cited using these types of resources in developing their model. Broad dissemination of relevant research and existing resources could be part of the work of the learning community described above.

Resources for connecting research and practice

- Learning in Informal and Formal Environ-ments (LIFE) Center, www.life-slc.org
- Relating Research to Practice, http://relatingresearchtopractice.org/
- The Center for Informal Learning and Schools, cils.exploratorium.edu
- Learning Activation Lab, www.activationlab.org

3. **Increase opportunities to connect research and practice across sectors.** We recommend that public and private funders encourage researchers and practitioners to develop collaborative agendas that span across informal and formal environments. Robert Granger noted in the 2012 W.T. Grant Foundation annual report that "a stronger connection between research and practice is critical to improving youth performance and well-being" but in order to make that possible, the relationship between researchers and practitioners must become less linear

and more reciprocal, "with researchers and practitioners working together over time to improve understanding of persistent problems and test promising solutions."[27] In STEM learning ecosystems, this process is even more complex; researchers must work with practitioners across multiple sectors, including both formal and informal educators, to develop a reciprocal relationship that informs practice and builds the knowledge base for STEM learning ecosystems. Research agendas should build on the implementation and impact questions of both formal and informal learning. This collaborative approach to research and practice is a challenge within one STEM learning setting, so it will take extra effort to build research-and-practice models that address the entire STEM learning ecosystem.

3 POLICY

1. **Craft a policy agenda that identifies strategic levers at different levels to advance ecosystem building efforts.** Federal, state, and local STEM policies should explicitly state the importance of after-school and other providers in offering STEM in the non-school hours. One of the most effective ways to stimulate change is through the design of grant requirements. The U.S. Department of Education, state education agencies, local school districts and private funders can encourage or require formal educators to partner with community organizations and STEM-rich cultural institutions. Public and private youth development funders can encourage or require community partners applying for youth development funds to address STEM and connections to formal education. For example, New York City's OST initiative requires grantees to offer STEM and to identify a formal educator who will act as an "educational liaison" for the after-school program, ensuring connections to the school day.

   Schools and school districts, youth development providers and science institutions can also proactively select people for leadership positions who understand the value of collaboration and possess collaborative skills and experience. All sectors can integrate collaborative efforts into evaluation metrics for leadership positions and invite cross-sector teams to interview candidates for leadership positions. Changing policies in this way will lead schools, after-school providers and science institutions to value these skills in their leaders. Tamara Hudgins of Girlstart said: "There is the type of principal that is ready to collaborate and those that are not. We see a direct correlation between the most engaged schools and the STEM achievement of the girls. That is why we need to be purposeful about this."

2. **Take better advantage of the flexibility embedded in existing policies.** Many funding streams offer more flexibility than is currently used in practice. For example, federal training dollars may not stipulate that all trainees must be certified teachers, but the person or office administering that program may not be aware of that flexibility and therefore refuse to include after-school community educators in a publicly-funded training. Highlighting current uses of funds, such as Providence's innovative use of Career and Technical Education funds to support collaborative STEM learning during the summer, will help other sites to advocate to use those funds in innovative and more interconnected ways.

By separating recommendations into discrete areas, we do not mean to suggest that only some stakeholders should tackle any one of these recommendations. It will require a diverse range of stakeholders in each of these areas to make progress. Chris Smith of Boston After School & Beyond said: "Children are naturally curious and they love to build things. They often combine things in ways that are new and unconventional because their imaginations are not constrained by what has come before. That's the way we need to be as we put together the whole landscape of STEM learning. We need to be curious all the time. We need to do things in new ways, and imagine beyond what exists." Our hope is that the ideas of this report help spark the curiosity and imagination of all the stakeholders working to ensure that young people are engaged, inspired and prepared in the STEM disciplines as they develop into future scholars and leaders in our communities.

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Endnotes

1. For 2012 PISA results showing flat growth rates and average to below average results for American 15-year olds, see http://nces.ed.gov/surveys/pisa/pisa2012/index.asp.

   For the latest statistics on under-represented populations in post-secondary STEM studies, see the Women, Minorities, and Persons with Disabilities in Science and Engineering 2013 report by the National Science Foundation at http://www.nsf.gov/statistics/wmpd/2013/digest/ This NSF report points out that women's participation in engineering and computer sciences remains below 30% and women's shares of degrees in the physical sciences and mathematics remain well below those of men, particularly at the doctorate level. Additionally since 2000, underrepresented minorities' shares in engineering and the physical sciences have been flat, and participation in mathematics has dropped.

   A 2012 study by STEM Connector and My College Options noted that although overall interest in STEM majors and careers among high school seniors has increased by over 20% since 2004, 57% of the one million high school freshmen who declare interest in a STEM-related field will lose interest in STEM by the time they graduate from high school. http://www.stemconnector.org/sites/default/files/store/STEM-Students-STEM-Jobs-Executive-Summary.pdf

   Results detailing the poor showing of U.S. adults on the 2013 OECD Survey of Adult Skills can be found at http://www.oecd.org/site/piaac/.

2. Examples of school-focused STEM reforms include the 100K in 10 movement, http://www.100Kin10.org and STEM-focused schools, described in Erik Robelen's *Education Week* article September 13, 2011, "New STEM Schools Target Underrepresented Groups," http://www.edweek.org/ew/articles/2011/09/14/03stem_ep.h31.html

3. For more information on deeper learning, access the William and Flora Hewlett Foundation website at http://www.hewlett.org/programs/education-program/deeper-learning and for more information on competency-based education access http://www.competencyworks.org/.

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This report was commissioned by the Noyce Foundation and written by Kathleen Traphagen and Saskia Traill.

Acknowledgements

Our deepest thanks to the leaders and stakeholders of the 15 initiatives profiled in this study for giving freely of their time and sharing their stories with us, and to Ron Ottinger of the Noyce Foundation for his support, inspiration and guidance.

This report also benefitted from the comments and suggestions of Alan Friedman, Anita Krishnamurthi, Jay Labov, Jan Morrison, Ron Ottinger, Jennifer Peck, Sara Spiegel, Cary Sneider, Gerald Solomon, and Martin Storksdieck.

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