Building Resilient Communities

Exploring how libraries and community-based organizations can work together to mitigate environmental and health-related concerns due to climate change

# STEM Learning Ecosystems

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## Abstract

STEM learning ecosystems are collaborations among community members and organizations to foster STEM engagement and education in their area. They can support and amplify the efforts of individual organizations, such as libraries, helping them to achieve a greater impact. This report defines STEM learning ecosystems; reviews relevant theoretical background, strategies, and practice; describes common goals and provides examples of evaluation findings; and provides some resources for educators and organizations who are interested in learning more. There are many ways libraries can engage with STEM learning ecosystems, including joining an existing ecosystem, starting a new collaboration, and learning from the approaches that ecosystems use to broaden participation in STEM and create a thriving future.

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## Introduction

STEM learning ecosystems are intentionally designed, community-wide partnerships that enable people to actively participate in STEM (science, technology, engineering, and math) (Fig. 1). They encourage people to learn about and use STEM throughout their lives, both indoors and outdoors, at home, at school, and at work. Learning ecosystem partners can include educational and cultural institutions, public libraries, community and faith-based organizations, businesses, government agencies, and many more. These partnerships draw on expertise and resources across a community to create equitable access for learners of all ages. Place-focused STEM learning ecosystems are responsive to cultural, societal, and geographic contexts, creating experiences that are relevant to learners (Timko et al., 2022). Through their collaborative relationships, ecosystem partners strive to help learners find their own pathways for lifelong engagement in STEM.

## Theoretical Background

Ecological theories of learning (after Bronfenbrenner, 1979) emphasize the "dynamic interaction among individual learners, diverse settings where learning occurs, and the community and culture in which they are embedded" (NRC, 2009). In this view, STEM learning is the culmination of interactions that occur over time in diverse settings, shaped by the learner's own interests, dispositions, and values and by the surrounding community and culture (Bang et al., 2010; Banks et al., 2007; Bell et al., 2012). These ecological and sociohistorical perspectives help to support equity and inclusion because they focus on the context of learning and the interaction of learners with their environment.

There are different ways to conceptualize learning ecosystems. Some theoretical models of learning ecosystems emphasize and study the learning ecology or context surrounding the individual learner; others focus on the pathway of a learner among different experiences; and still others focus on the interaction of the component parts of the system (Hecht and Crowley, 2019), such as participating organizations.

Learning ecosystems are not just a theoretical model, however; they've become an important approach to STEM engagement and education in the U.S. Based on a fieldwide survey of research and evaluation on STEM learning, a National Research Council report (2015) supported this perspective and recommended that the U.S. move toward a community-wide, integrated STEM learning ecosystem approach. Today, there are likely hundreds of local, statewide, and regional learning ecosystems in the U.S.

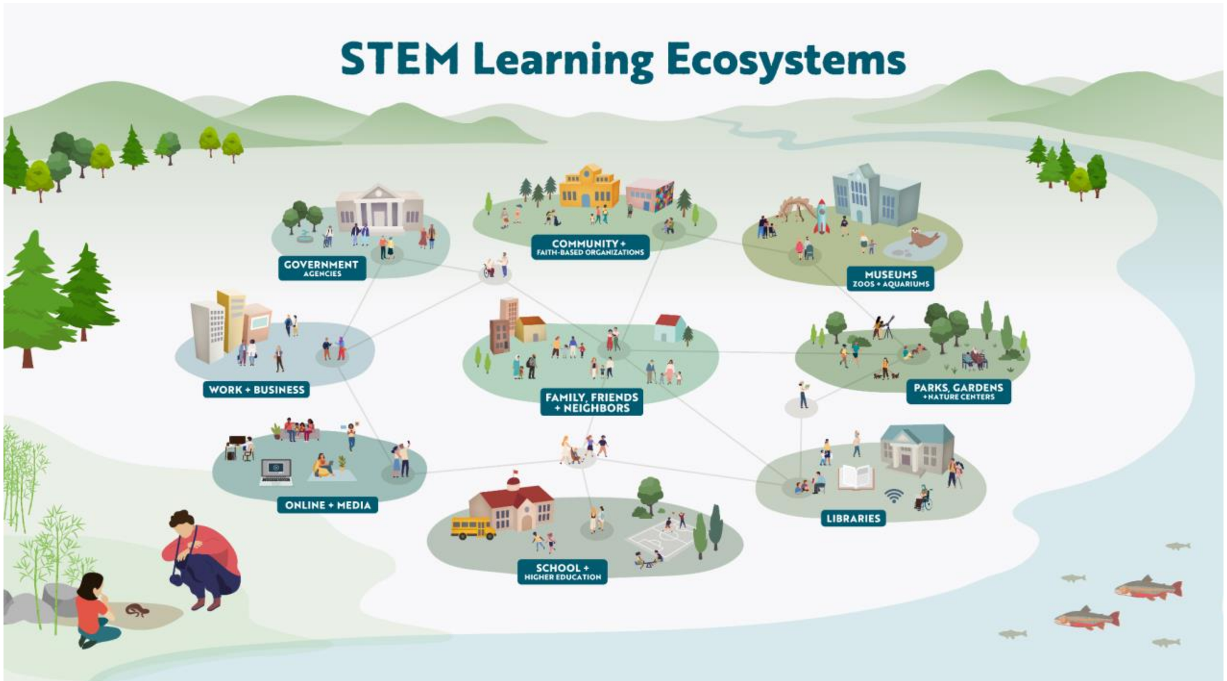

Figure 1. Illustration depicting the relationships in a place-based STEM learning ecosystem. (Arizona State University/NISE Network)

## Strategies and Practice

STEM ecosystems bring together people, organizations, activities, and resources to create STEM learning experiences that take place in varied settings. By developing mutually beneficial partnerships, leveraging local expertise and assets, implementing promising practices, and creating pathways among learning opportunities, STEM ecosystems can support individual learning and community growth.

Ecosystems can be organized in different ways: for example, some have a hub and spoke model, while others are hierarchical. STEM ecosystems can also interact with each other, whether they are nested, overlapping, or adjacent. They can also connect because they address common goals or have similar groups of participants. Connected ecosystems are sometimes called “ecospheres.”

A body of research and practice articulates the strategies that collaborators can use to develop, implement, evaluate, and continually improve STEM learning ecosystems. Here, we’ll summarize results from two studies that looked across several STEM learning ecosystems and found a similar constellation of attributes that contributed to their success. Traphagen and Traill (2014) studied 15 ecosystems, while Vance et al. (2016) studied 27.

These studies found several factors that help an ecosystem function and thrive. Strong learning ecosystems develop cross-sector partnerships focused on a clear mission among groups with aligned interests. They feature strong leadership that cultivates a collaborative culture and secures funding and other support. Partners work to build STEM programs and educator capacity that support the group's mutual goals. The ecosystem is committed to community engagement, particularly among professionals and caregivers who support learners. Healthy ecosystems are also flexible and able to change through time as they grow and mature (Traphagen and Traill, 2014; Vance et al., 2016).

The studies also identified several strategies that help STEM learning ecosystems create effective educational and engagement programs. They build the capacities of educators and provide tools and structures to enable sustained planning and collaboration across sectors. Their programs link school-day and out-of-school experiences that connect and deepen STEM learning over time. They feature active engagement (such as inquiry and project-based learning) and help learners connect STEM with their place, personal identity, and community concerns. Finally, ecosystems involve families, organizations, and communities in supporting learners' STEM success (Traphagen and Traill, 2014; Vance et al., 2016).

For example, the *Bay Area STEM Ecosystem* is a partnership that includes young educators, young people, and families in Sonoma, San Mateo, and San Francisco counties (CA). Partnerships with other nearby ecosystems and networks expand their impact into Santa Clara, Marin, Contra Costa, Alameda, Napa, and Solano counties. Many of these regional ecosystems are also part of the larger California STEM Network. Ecosystem members comprise a wide variety of partners, including K-12 schools, higher education institutions, industry partners, museums, youth organizations, public library systems, and municipal agencies. The ecosystem has a lead organization for overall coordination of the collaborative, Children Now, and a steering committee made up of a rotating group of partner organizations. Ecosystem members meet as a large group three times per year and collaborate on projects year-round. (Children Now, n.d.; Kekelis & Sammet, 2019; STEM Ecosystems, n.d.).

## NASA Science Activation

The *SciAct STEM Ecosystems* project is a collaboration of five groups that are funded through NASA's Science Activation (SciAct) program, which focuses on broadening participation in authentic earth and space science: Arctic and Earth SIGNs, led by the University of Alaska Fairbanks; Learning Ecosystems Northeast led by the Gulf of Maine Research Institute; Rural Activation and Innovation Network currently led by Arizona Science Center; Smoky Mountains STEM Collaborative led by Southwestern Community College in North Carolina; and the National Informal STEM Education Network, led by Arizona State University (also the project lead). The group conducted several cycles of inquiry, integrating evidence from multiple sources: publications, through a targeted literature review; wisdom from practice, through interviews with professionals and community connectors who participate in STEM learning ecosystems; and insights from experts, through interviews and reviews with project advisors and SciAct collaborators (ASU, 2024).

Figure 2. Young people participating in “Creek Week” activities in North Carolina, Smoky Mountains STEM Collaborative. (Swift Creek Media/NISE Network)

The study identified key elements of learning ecosystems that are intentionally designed to broaden participation in authentic STEM learning:

**Community:** STEM learning ecosystems are built and sustained through intentional practices, principles, and activities; thrive through reciprocal relationships; and are grounded in their geographic and cultural context.

**Belonging:** Ecosystems can broaden STEM participation by cultivating genuine relationships among individuals and organizations; creating a flexible and transparent culture; sharing programming and resources; and prioritizing diversity, equity, accessibility, inclusion, and belonging.

**Engagement:** Authentic STEM engagement starts with understanding what is relevant to learners and communities, then creates connections to content through active learning experiences.

## Goals and Activities

STEM learning ecosystems are responsive to local contexts. As a result, their goals and activities vary along with their organizational structure and key partners (Fig. 2).

Many learning ecosystems seek to **improve STEM education and learner outcomes** in their region. Their goals might be to improve performance in formal educational settings (such as high school graduation rates or the number of students entering STEM programs in college) or to create more opportunities for learning outside of school. To address these goals, these ecosystems include a range of educational organizations, build programs that engage learners in a variety of settings, and develop pathways to connect formal, informal, and higher education opportunities.

There are also many learning ecosystems that seek to **create economic growth and prepare learners for STEM careers**. In addition to educational institutions, these ecosystems can include economic development agencies, social service agencies, organizations focusing on workforce development and training, and local businesses. Their programs develop interest and skills related to local industries, encouraging entrepreneurship and attracting STEM talent to the area. To accomplish their mission and goals, ecosystems develop a variety of initiatives, including programs and action efforts.

These goals allow ecosystems to align activities with a variety of local priorities (such as environmental justice or health equity). Ecosystem partners can coordinate to leverage their diverse strengths to respond in creative ways to unexpected events (for example, providing not temporary shelter and educational activities for families during an extreme weather event). By responding to both long-term priorities and specific events, learning ecosystems can contribute to the overall resilience of a community.

Learning ecosystems also often have a cross-cutting goal to **broaden participation,** to ensure that all learners have opportunities to take part in STEM and that the community benefits from increased capacity. STEM learning ecosystems might seek to eliminate disparities in learner outcomes or career pathways among different groups (such as racial/ethnic or socioeconomic groups) or geographic regions (such as urban, suburban, and rural areas). In order to broaden participation, STEM learning ecosystems must be intentionally designed with diversity, equity, accessibility, inclusion, and belonging (DEAIB) in mind (e.g., Falk et al., 2016). If not, they may reinforce, rather than overcome, existing inequities (Bevan, Calabrese Barton, and Garibay, 2020; Penuel, Clark, and Bevan, 2016; Pinkard, 2019).

Ecosystems that prioritize broadening participation are responsive to DEAIB in all aspects of their work: their structure and organization, approach to collaboration and engagement, and programs and learning experiences (ASU, 2024). In a learning ecosystem, a DEAIB-centered approach includes creating partnerships that include multiple stakeholder groups; developing strong ties among individuals, groups, and organizations; and paying attention to representation and power dynamics. These ecosystems articulate shared goals, then identify and leverage the complementary expertise and assets of diverse experts, educators, community members, and organizations to achieve them. They often co-create initiatives together with focal audiences and implement programs with mentors, role models, and "brokers" who help learners identify with STEM and make culturally relevant connections.

Finally, they present STEM as one way for people to create the personal and societal future they want to live in (Bevan, 2018; Penuel, Clark, and Bevan, 2016).

The *Bay Area STEM Ecosystem,* introduced above, works to increase equity and access to STEM learning opportunities for all youth in the greater San Francisco Bay Area (CA), with an emphasis on addressing the needs of underserved communities like South San Francisco. An early success of the ecosystem was a series of summer STEM programs in South San Francisco made possible by the collaboration of 13 partner organizations including neighborhood schools, summer camps, and libraries (Children Now, n.d.; Kekelis & Sammet, 2019; STEM Ecosystems, n.d.).

## Evaluation

STEM learning ecosystems are intentional about setting goals, evaluating their progress, making evidence-informed changes, and communicating their value to stakeholders. An ecosystem might measure outcomes and impact at three levels: the individual learner, the program, and the community (NRC 2015). Two ecosystems, described below, that use data to help them thrive and provide impactful programs are *Remake Learning* (greater Pittsburgh) and the *Tulsa Regional STEM Alliance* (Tulsa, OK).

*Remake Learning* provides an example of how innovative programming and strong relationships have transformed education in the greater Pittsburgh area. The ecosystem's mission is to promote "engaging, relevant, and equitable learning practices in support of young people navigating rapid social and technological change." Its strategies are to help people connect, exchange knowledge, collaborate on new ideas, improve their practice, and find funding to support their activities.

*Remake Learning* recently summarized its impacts. First, the learning ecosystem has changed how participating adults interact, creating a community of practice where people from different fields (such as educators, scientists, and municipal leaders) know each other, share information, and work toward common goals. Second, organizations (such as schools, museums, and public libraries) create deeper partnerships and take advantage of community resources. Third, educational systems have restructured, adopting new practices, sharing resources, and gaining shared financial support. Finally, families and children are better supported by schools and find more opportunities for learning out-of-school (for example, at special events and at a constellation of play sites located within a half mile of a local library). Beyond Pittsburgh, the ecosystem has emerged as an inspiration and model for others (Remake Learning, 2024; see also Remake Learning 2015, 2023).

The *Tulsa Regional STEM Alliance* (TRSA) in Tulsa, Oklahoma, provides an example of a multi-level STEM learning ecosystem evaluation. The ecosystem's mission is "to ensure every student has access to the best possible STEM education." Its strategies are to cultivate cross-sector partnerships; create and connect STEM learning programs; provide educator training; and support youth learning pathways.

TRSA works with the Partnerships in Education and Resilience (PEAR) group to evaluate its ecosystem. PEAR examines outcomes for learners, programs, and community-wide partnerships and makes its evaluation tools available to others. The Common Instrument Suite (CIS) is a self-report survey that measures STEM-related attitudes, including interest/engagement, career knowledge, and STEM identity. The Dimensions of Success (DoS) tool measures STEM program quality, providing data to inform improvement. Finally, the Data Narrative Analysis (DNA) studies programs and relationships through time, providing information for planning and decision-making (Lewis-Warner et al., 2019a, 2019b; see also TRSA, n.d.).

## Other Types of Partnerships

As learning ecosystems share some characteristics with other kinds of partnerships, in addition to having distinct qualities, it is important to consider your goals and capacities when considering what kind of collaboration is best. Your partnership goals may also change through time, such as a project-based partnership evolving into a learning ecosystem.

STEM learning ecosystems are usually intended to be lasting partnerships that can include several individual initiatives, rather than a discrete project that several organizations might undertake together. Learning ecosystems typically include members from a variety of sectors (such as K-12 schools, public libraries, and businesses), and therefore are different from professional associations, communities of practice, and networks that connect people in the same field or profession. Learning ecosystems are usually place-focused, drawing on local assets and responding to local priorities. Their sensitivity to local context results in diverse structures and participation, making learning ecosystems different from partnerships whose structure and participation might be mandated by an organizing body. Learning ecosystems are similar to connected learning partnerships (Ito et al., 2013), but the latter tends to emphasize online and technology-enabled interactions, while learning ecosystems are broader in the types of interactions they support, and often emphasize in-person activities.

Although they are different from these other types of groups and partnerships, learning ecosystems can include and/or collaborate with all of them. For example, a learning ecosystem might be coordinated by faculty at a community college and partner with and include members of a state library association, a regional park, a school parent-teacher organization, a local astronomy club, scouting groups, and more.

Designed collaborations (such as ecosystems and networks) can be organized for different purposes and therefore find different principles and practices useful. Some learning ecosystems use or are influenced by a *collective impact* approach, where members commit to systemic change by adopting a common purpose and evaluating their success using the same measures (Kania and Kramer, 2011). These partnerships often have a designated “backbone” organization that provides infrastructure and coordinates the activities of its members. *Networked improvement communities* (Bryk, Gomez & Grunow, 2011) use methods from improvement science to address specific problems of practice and create organizational change; they might include learning ecosystem members but are different in purpose and approach.

## Opportunities and Resources

There are opportunities to join or create a learning ecosystem almost anywhere, whether in a city, suburb, or rural environment. To find out if there is an existing learning ecosystem near you–or to gauge interest in starting one–try these methods:

- Talk with well-connected people you know, especially if they are in fields that often participate in learning ecosystems, such as education and youth development; nonprofit and community organizations; or business, neighborhood, and workforce development;
- Connect with organizations that are likely to participate in a STEM learning ecosystem, such as school districts, colleges and universities, science centers and museums, public libraries, and afterschool program providers;
- Check with local and national professional networks and communities of practice that connect learning ecosystems and their members, such as your state library network or the national STEM Learning Ecosystems Community of Practice (https://stemecosystems.org/); and
- Search the internet and social media, using terms such as your state/region and "learning ecosystem" or "educator network."

There are many resources available to support new and existing learning ecosystems (and similar networks and partnerships). The STEM Learning Ecosystems Community of Practice has free resources online, as well as virtual and in-person convenings (https://stemecosystems.org/). Some ecosystems have created tools and guides to help others plan (e.g., Black, McCloud, and Zimmerman, 2019; Carraway, Rectanus, and Ezzell, 2012; NISE Network, 2024; Remake Learning, n.d.) and evaluate their efforts (e.g. Morrison and Fisher, 2021; Traill and Traphagen, 2015). The NRC report on out-of-school learning also provides a useful framework to guide evaluation of STEM learning ecosystems (NRC, 2015, pp. 31-40).

TRSA makes various evaluated program resources, such as its STEM camps, available for free use by educators (TSRA, 2022). Networks such as the STAR Library Network (https://www.starnetlibraries.org/), the National Informal STEM Education Network (https://www.nisenet.org/), and Howtosmile (https://www.howtosmile.org/) offer free educational resources, including STEM activity guides and professional training videos, that support STEM engagement and education activities.

## Conclusion

STEM learning ecosystems are partnerships among diverse organizations that collaborate to support learning and participation in STEM, and ultimately to create thriving and resilient communities. They are internationally organized to leverage strengths and assets across a community or region and amplify the efforts of their partners. Ecosystems are greater than the sum of their parts: by working together, members of a STEM learning ecosystem can have a greater impact. There are many ways libraries can engage with STEM learning ecosystems, including joining an existing ecosystem, starting a new collaboration, and learning from the strategies that ecosystems use to accomplish their goals.

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