California Tinkering Afterschool Network

Pilot Year Evaluation Report, March 2013

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Executive Summary

SRI International conducted an evaluation of the pilot year of the California Afterschool Tinkering Network. Launched in 2012 by the Exploratorium with funding from the Stephen D. Bechtel Jr. Foundation, the network aims to promote the expansion of high-quality STEM-rich tinkering activities into afterschool programs serving children from low-income communities. The network includes five key collaborating organizations that worked in partnership with over 20 afterschool or summer programs in their local communities to serve more than 2,000 children, extending the reach of the network through a hub and spoke system across the state. All five hub organizations participated in three two-day professional development workshops organized by the Exploratorium to provide resources for implementing programs and building capacity at partner sites. Highlights of the network's activities and accomplishments are summarized here.

The Network Developed a Shared Vision for High-Quality Tinkering Programming

One of the goals of the California Afterschool Tinkering Network in the pilot year was to begin to develop a shared vision for tinkering activities in afterschool programming. From prior research, collaborative discussion, and documentation of network hub activities, network members worked to articulate how tinkering activities best promote learning and development in the afterschool setting. In conjunction, drawing on evidence from network activities and site observations, the evaluation team constructed a candidate model that illustrates features of high-quality programming and links these features to several of the STEM practices and learner dispositions they support. Exhibit 1 illustrates the alignment of key programming features, such as contact

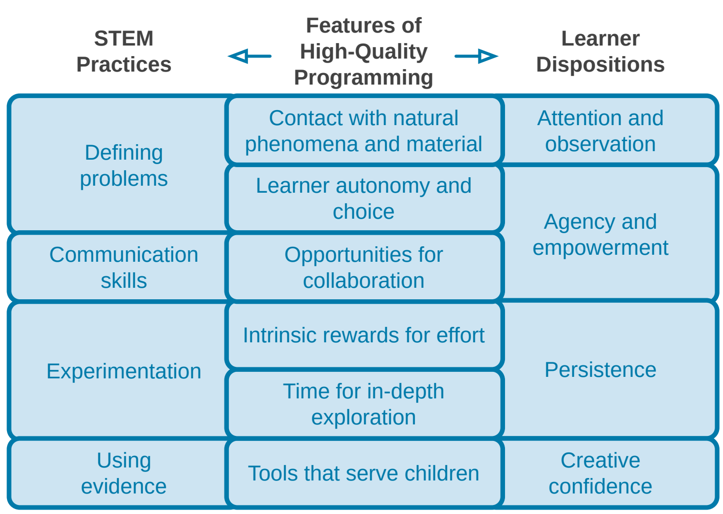

Exhibit 1. Relationship of high-quality tinkering activities to learner outcomes in STEM practices and learning dispositions.

with natural phenomena and time for in-depth exploration, with practices and dispositions that promote STEM learning. We note the relationship between the STEM practices in our model and those described in the Common Core Math and Next Generation Science Standards.

The Network Offered Professional Development for Hub Staff That Developed Local Capacity

The pilot year focused on professional development for hub leadership and staff to both build local capacity to implement high-quality tinkering programs and identify local strengths as well as needs that could guide future activity. The Exploratorium hosted three professional development workshops, identified and posted online resources, sponsored intervisitation among sites, supported program documentation, and codeveloped a Phase Two plan, all of which served to expand the reach of high-quality afterschool STEM programming in localities throughout California.

Hubs Partnered Locally to Offer a Variety of Learner Programs in Each Region

The pilot year activities described in this report include numerous examples from successful learner programming supported by hubs working with local partners serving low-income communities. These examples illustrate the diversity of approaches, partners, and participants across programs, indicating the relevance the network has to a wide range of afterschool settings and the potential for the network's impact on a larger scale.

The Network Has Established a Strong Basis and Promise for Expansion Beyond the Pilot Year

The network holds promise going forward and has several areas for potential expansion based on results from network activities and needs identified during the pilot year. We recommend that, in the future, network activity include (1) drawing on experiences across sites to refine the vision for tinkering in afterschool settings, (2) distributing critical resources for providing high-quality opportunities in low-income communities, (3) developing documentation processes that provide evidence of the value of tinkering in out of school time, and (4) sustainably expanding the network to broaden the reach of programming for children and youth.

Contents

I. Introduction

In 2012, the Stephen D. Bechtel Jr. Foundation awarded the Exploratorium a grant to pilot the California Tinkering Afterschool Network,[1] a statewide initiative undertaken in collaboration with the Community Science Workshops, Techbridge, the Discovery Science Center, the California Afterschool Network (CAN) and the California STEM Learning Network (CSLNet). The initiative was designed to test a sustainable, adaptable, and scalable model for providing educationally rich tinkering opportunities for children attending afterschool and summer programs in low-income communities. The network provided resources and supports for five organizational hubs that worked in partnership with local afterschool and summer programs to implement tinkering activities across the state.

The specific aims for the network during the pilot phase were to

- Develop a common vision and plan for how best to integrate activities into local afterschool programs that intensively serve children and youth from high-poverty communities.
- Create mechanisms for sharing resources, activities, and know-how across the network, building local capacity to sustain the effort.
- Develop a statewide evaluation plan focused on learner outcomes.
- Support and document prototype tinkering partnerships between science rich educational institutions and local afterschool programs that
  - surface opportunities and barriers to sustainability and scale-up and
  - provide examples that can inspire and encourage others to join the network.
- Launch a statewide call for science-rich educational institutions and afterschool programs to join and help build the network.

The network has pursued these aims with a dual strategy of extending tinkering activities to diverse out-of-school-time (OST) programs and using these experiences to develop means for scaling up network efforts in

[1] The network was originally called the California Informal Science Educator's Makers Network.

the post-pilot phase. During the pilot, the hubs and their local affiliates succeeded in bringing tinkering activities to more that 2,000 children in OST programs.[2]

The network initiative is taking place in the context of three broad and related considerations:

1. *Implementation of Common Core Math and Next Generation Science and Engineering Standards*. A key question for network members during the pilot was how to make connections between afterschool STEM tinkering activities and the new standards. Members recognize that afterschool programs have the potential to expand children's opportunities to learn in ways that can contribute to a standards-based vision of what constitutes scientific literacy.
2. *Research on learning in afterschool settings.* This research includes literature detailing both the developmental possibilities of afterschool settings (which typically bring together the socioemotional and disciplinary dimensions of learning) and the structural constraints that include irregular attendance and limited staff training and material resources. A shared commitment is that high-quality tinkering activities must be designed and implemented with these aspects of afterschool settings in mind.
3. *Evidence-based understanding of the features and key design dimensions of high-quality tinkering activities*. Building on prior research, discussions among network members, and documentation of hub activities, the evaluation team has identified key design features of STEM-rich tinkering activities as exemplified in network programming.

What is Tinkering?

STEM-rich tinkering in an educational context consists of activities in which children work with carefully selected sets of STEM phenomena, tools, concepts, and questions to design and build without a pre-determined set of steps or outcomes. Tinkering differs from *making*—or it is a type of making that entails extensive improvisation and problem solving (as opposed to following step-by-step instructions to construct or make an object). As the term is used here, tinkering entails a central aspect of the learning that can occur through making, which encompasses a broader range of activities associated with the maker movement that often results in a specific intended product of the maker's design. Tinkerers can explore a particular phenomenon such as electricity by building circuits, asking themselves throughout the process questions such as, What would happen if I tried two batteries? Why won't the bulb light up? How can I make a bell built into the circuit ring at the same time? When these STEM-rich activities are grounded in children's own

[2] Differences in how each organization accounted for participation in tinkering programs prevents us from aggregating attendance numbers across sites. Some sites counted unique participants throughout the year, regardless of the number of program days or events they attended, while other sites documented the number of attendees for each program day or event, counting individuals more than once. We estimate that at least 2,000 children participated in network-affiliated programs, but the number may be much higher.

questions and goals, tinkering activities “provide singularly accessible opportunities for learners to engage in [meaningful] scientific and engineering practices” (Petrich, Wilkinson, & Bevan, 2013).

Tinkering in Afterschool

As the number of U.S. children in afterschool programs has increased over the past decade, interest in expanding STEM learning opportunities into afterschool settings has also grown. A shared emphasis on collaboration and authentic hands-on activities, create what Hussar et. al (2008) called “philosophical overlap” between the leading edge of science education and afterschool fields. Yet much of STEM learning in afterschool remains worksheet or kit based, frequently with step-by-step instructions. While there are good reasons to include such activities in afterschool settings (to reinforce and relate to school STEM or simply to provide STEM learning opportunities for children who may have little time on science at school), a premise of the California Tinkering Afterschool Network is that there is also good reason to provide more open-ended, creative, and playful activities in afterschool settings, particularly for low-income youth, who disproportionately attend schools with narrow, text-based curricula. Indeed, afterschool engagement with STEM activities that excite and empower children may be critical for preparing them for school science.

At the same time, growing interest in tinkering, making, and the Maker Faire movement has sparked the development of numerous resources—from kits and materials to special equipment, events, and guides—that support increased possibilities for STEM learning for those with ready access to these resources. Museums, clubs, informal affinity groups, well-funded schools, and, of course, families of means are creating opportunities for more and more children to experience the joys and benefits of making. But such opportunities are inequitably distributed, resulting in yet another dimension of our national educational divide. While afterschool settings are strategically important for bringing tinkering and making opportunities to low-income youth, to date little has been done to systematically address how to support rich tinkering learning activities in these settings, both in terms of direct investment and in-depth research into promising, scalable approaches.

Drawing on data from the pilot year of the California Tinkering Afterschool Network, we provide four examples to illustrate the character and breadth of afterschool and summer program offerings at partner sites—which incorporated tinkering approaches to varying degrees in and varying ways, depending on the nature, objectives, and capacities of the programs involved. Thus, in addition to indicating the potential for learning from tinkering activities, these examples indicate the potential needs that the network can address to build capacity across the state.

Tinkering with Sewn Circuits in a Community-Based Club Setting

Source: the Exploratorium Tinkering Studio Blog
Exhibit 2. A child working on a sewn circuit.

One network hub provides tinkering programming for children who regularly attend summer and school-year sessions at a local Boys & Girls Club. Since the children return each week, activities are designed to build on one another. A characteristic set of activities centers on providing children firsthand experiences with electrical circuits. After two or three initial experiences with bulbs and batteries, children work with conductive thread and fabric to create sewn circuits (Exhibit 2). Building on ideas from exemplars, children stitch wearable items such as armbands with LED bulbs powered by small batteries. When the armbands are snapped closed, the lights turn on. Children's work with these circuits provides them first hand, tangible experience with phenomena that illustrate fundamental concepts about electricity. The challenges that arise are as meaningful in this regard as the successes. For example, when their conductive thread crosses itself, children see that the LED lights fail to turn on.

Making a Boat in a Drop-In Community-Based Setting

Source: Screen shot of video collected by Fresno Community Science Workshop staff.
Exhibit 3. Girls building a canoe with staff help at a workshop site.

At one hub site, afterschool and summer participants drop-in as they choose to a workshop stocked with a variety of tools and materials and facilitated by young adult staff. As summer approached, a group of three girls decided that they would like to build a boat for use during an annual field trip to a nearby river. The girls explored materials and, over the course of several days, designed and built a canoe by constructing a rigid frame and then covering it with overlapping segments of duct tape (Exhibit 3). The girls, working with their youth facilitator, designed the duct-tape layers working with several tested iterations to ensure strength of the material. Later, the girls took the canoe on the field trip and successfully used it to boat on the river. The site facilitator who helped the girls reported that they took great pride in their product, especially since initially not everyone believed that duct tape could be used to create a water worthy boat.

Experimenting with Propellers in a Summer Camp

One hub directly translated activities from the network workshops into week-long summer camps implemented through partnerships with local colleges and school districts. The camps progressed through a series of activities with electricity, circuits, and motors, giving children free rein to construct their own devices from a wide array of materials on the final day. Children worked to build all manner of contraptions, several groups attempting to create flying machines of one type or another. A pair of 12-year-old boys worked for hours on a helicopter-like design and eventually hit on an idea: Why not try to generate spin enough to launch something? What the boys tried to launch was some of the dodecahedrons and other origami sculptures that were displayed around the room (Exhibit 4). The leader of this camp warmed up the kids each morning with a mathematical paper-folding challenge, such as “who could make the largest and the smallest stellated octagon.” Bringing the origami together with the tinkering, the boys worked out relationships between the size of a sculpture, the speed of the propeller spin, the potency of their batteries, the type of attachment between the motor and the sculpture, and the timing of the launch. For each try, they cleared a space in the classroom, set the sculpture spinning, and decided what changes they would make for their next attempt.

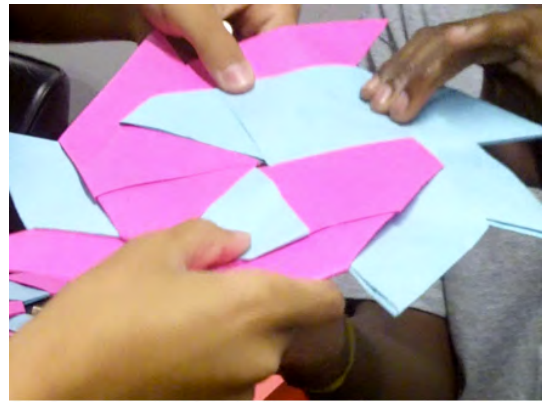

Exhibit 4. Boys creating an origami launching device.

Creating Small Toys in a School-Site Afterschool Program

Several hubs partnered with providers by taking materials and activities to afterschool programs serving youth on school campuses. These programs are typically funded by federal 21st Century or California After School Eduction and Safety (ASES) grants to provide youth in low-income communities enriching experiences in a safe environment. In one such program, hub staff bring materials and work with the same group of children each week to implement sequences of activities illustrating complex concepts. On this day, children built small propellor-driven flying toys pulled by a string, following step-by-step instructions to create them (see example in Exhibit 5). A carefully designed diagonal fold ensured that the thick paper propellor spun when the toy was pulled through the air. Although the

Exhibit 5. Example of the type of propellor toy made in the program (partly built).

children were able to embellish their products individually before going outside to fly them, the approach to designing the toys did not include the exploration, improvisation, problem-solving of tinkering, suggesting the type of positive impact the network might have in the future. Throughout the process, the college-student facilitator talked about the flow of air across the toy and encouraged children to question, hypothesize, and search for evidence regarding why pulling the device forward with string causes the propellor to turn.

The Evaluation

To understand the potential value of the California Tinkering Afterschool Network model, SRI International was contracted to conduct an external evaluation of the pilot implementation. For the pilot year, the evaluation was specifically aimed at

1. Documenting hub and local partner activities undertaken with network support, including
    - The nature of learning activities in prototypical pilot sites
    - The reach of the network in terms of demographics, participation rates, and organizational types
    - Modes of engagement and models of outcomes for children and youth participating in activities at different locations.
2. Articulating the network's vision for high-quality tinkering, including
    - Specific features of this type of programming
    - The STEM practices and learner dispositions that align with these features.
3. Evaluating the feasibility of the network as a scalable and sustainable approach, including
    - The kinds of professional supports and resources needed by and provided to network partners
    - The structural challenges that make it difficult to implement tinkering in typical (non-science-specific) afterschool programs
    - Network solutions to these challenges and the feasibility of scaling tinkering across the state.

The evaluation entailed several different types of data collection and analytic approaches. SRI researchers observed and documented the three two-day network workshops held at the Exploratorium and attended by staff from all five hub organizations and staff from their partner afterschool program providers. Researchers from SRI visited each of the network hubs and several of the local afterschool partner programs, observing and documenting programming supported by each hub at multiple local sites and talking with facilitators and hub leadership. Additionally, SRI carried out phone interviews with staff at each hub after the site visits, collected additional information via email from hubs throughout the year, and coordinated video and photographic documentation at each site.

SRI's analysis of the offerings at each partner site and the interactions between them enabled us to characterize the features and outcomes of tinkering activities that the network hubs offered to their afterschool partners in accord with the evaluation objectives. Overall, this report is the result of reviewing all data sources and analyzing them systematically in relation to one another.

In the following sections of this report, we present a candidate model of tinkering features and outcomes illustrated with examples of programming from the pilot phase. This is followed by a description of activities carried out during the pilot year, including three professional development workshops hosted by the Exploratorium and learner programming carried out by hub organizations in partnership with local afterschools, schools, and community organizations. The report concludes with potential future directions for the network based on the network's contributions and needs identified during the pilot year.

II. A Vision for High-Quality Programming

The California Tinkering Afterschool Network brought together a community of OST practitioners working to innovate science learning activities in afterschool programs serving children from low-income communities. Participants included both program leaders and veteran educators as well as young facilitators new to their teaching role. Through face-to-face and online interactions, the network enabled a rich dialogue and idea exchange regarding tinkering as an OST activity. Network participation led to new programs at each participating site. By studying this programming and the perspectives of network participants and other staff, the evaluation has identified common features of tinkering activities across the network representing an underlying shared vision for what constitutes high-quality STEM-rich tinkering activities. These distinct features bring together tinkering's STEM learning and youth development possibilities.

The features and impacts we focus on are outlined in Exhibit 6 and described in further detail in this section. We also provide video illustrations of the features and impacts in a Prezi presentation designed to accompany this report.[3] Note that even though Exhibit 6 shows STEM practices and learner dispositions aligned with individual activity features, we envision a complex set of relationships in which each feature of tinkering programming can contribute to a variety of learning outcomes for children.

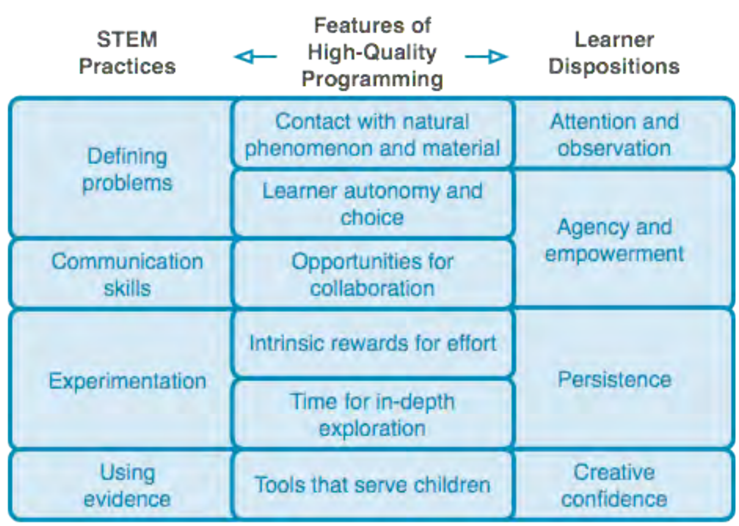

Exhibit 6. Relationship of high-quality tinkering activities to learner outcomes in STEM practices and learning dispositions.

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[3] For access to the Prezi presentation connected to this report please contact Bronwyn Bevan (bronwynb@exploratorium.edu) or Julie Remold (julie.remold@sri.com).

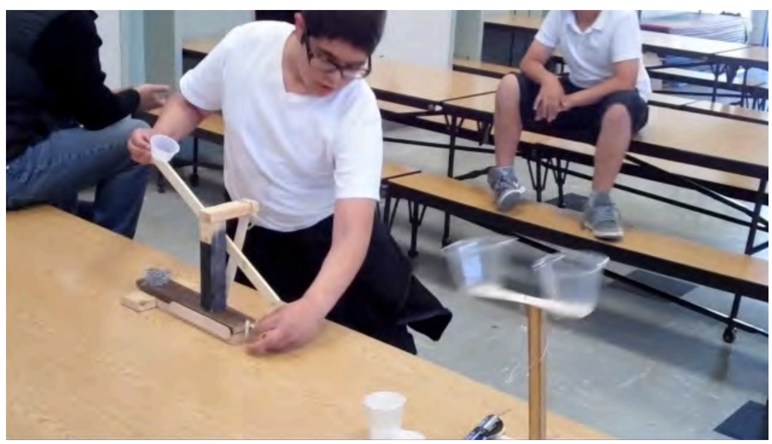
Features of High-Quality Programming

SRI has identified the following key features of tinkering as core to students' experiences across the network's hubs. Each of the features contributes to a number of STEM practices and learner dispositions. Exhibit 6 shows a simplified model of the relationship between the features described below and the STEM practices and learner dispositions described later in this section.

Direct Contact with Natural Phenomena and Materials

In tinkering, learners follow a hands-on approach to problem solving that includes direct contact with natural phenomena. Constraints are defined by a mix of participant goals and the limits of the phenomenon itself, the contact with nature providing an authentic feedback loop. Unlike a situation in which work is evaluated and controlled by an adult, participants in tinkering activities can evaluate their own work based on the outcomes of their efforts: if a circuit is not closed, the light will not go on; if a boat is denser than water, it will not float. Moreover, many of these activities provide direct connection to everyday experiences—such as cooking, gardening, playing, fixing broken things, and riding a bicycle—allowing youth to leverage these experiences in their creations.

Exhibit 7 is an image from a video collected at one of Community Science Workshop Watsonville's school-based partner sites. In the video, Raphael describes a toy catapult game he has created with wood and plastic cups. He also explains the reasoning behind several of his design decisions, including how considerations regarding its use shaped the design of his toy to ensure that it is "not too hard" and "not too easy." Raphael discusses the way the size and shape of the cup that holds the paperclip affect the speed at which it is launched and therefore the difficulty of the game.



Source: Screen shot of video collected by Community Science Workshop Watsonville staff (video available in Prezi presentation)**.**
Exhibit 7. A young maker from Watsonville showing a catapult game he built

Raphael's direct contact with natural phenomena and materials enable him to explore the complexity of his design decisions, experimenting with different materials and configurations. Through this process, he has developed ideas about how the weight and shape of objects affect the catapult's performance. This hands-on exploration of science phenomena is characteristic of the kind of experience kids have when participating in tinkering activities. The firsthand insights serve as resources for Raphael's ongoing engagement with scientific phenomena both in out of school and school settings.

Autonomy and choice

In tinkering projects, participants are typically allowed to make choices about their own methods and goals. The low-stakes nature of their exploration means that participants can experiment with approaches that are not proven because not every attempt has to be a success. Even when products or materials are well-defined or highly specified, high-quality activities allow participants to make decisions about processes or details along the way. In many cases, tinkering activities are offered in contexts where participants opt in and therefore each participant has choice regarding whether to participate at all.

Learner autonomy may be an important contributor to empowerment, engagement, and self-efficacy of participants in high-quality programs. Researchers have linked autonomy and choice with greater well-being and application of learning to new settings and approaches (Ryan & Deci, 2006; Schwartz, Bransford & Sears, 2005; Strauss, 1984).

The image in Exhibit 8 is taken from a video collected at one of the hub sites. In the video, a teenager explains her decision to make a large piñata in the shape of Hello Kitty. Making the piñata involved scaling, measuring, and modeling the objects frame to resemble the iconic symbol. The teen's design choice was based on personal circumstances, including her aesthetic preferences for her upcoming birthday. Others in the activity similarly followed their interests in creating their products. This example illustrates how open-ended tinkering activities can promote engagement by allowing learners to freely explore their own interests and create products that relate to their personal histories.

Source: Screen shot of video collected by Community Science Workshop Watsonville staff (video available in Prezi presentation)**.**
Exhibit 8. A teenager describing her Hello Kitty piñata creation.

Opportunities for Collaboration

Because tinkering activities include opportunities to draw from a broad range of personal experiences, youth bring different expertise and perspectives to their work. This helps support authentic collaboration in which youth learn through experience how working together can enrich their efforts.

Unlike many collaborative school activities in which youth are assigned a partner and given specific partnership goals, high-quality tinkering environments enable youth to make choices about working alone or with others. This fluidity allows participants to consult with one another on an as-needed basis or join projects along the way to completion, directly experiencing the benefits of working on creative endeavors with others. Collaboration in these environments resembles collaboration as it occurs in much of real life, shaping choices about processes, products, and ways to address challenges that arise. Moreover, it provides participants the opportunity to learn specific problem solving, communication, and other skills through the interactions the process generates (Roschelle & Teasley, 1995; Zurita & Nussbaum, 2004).

Source: Screen shot of video collected by Exploratorium staff (video available in Prezi presentation)**.**
Exhibit 9. One boy teaching another how to sew.

Exhibit 9 was taken from a video collected at an Exploratorium-led workshop in a Boys & Girls Club. The children are working on sewn circuits, using conductive thread, batteries, and LEDs to create wearable digital art. The video shows one boy teaching another how to sew, exemplifying collaboration between children without mediation by an adult. One child uses sewing skills developed at home to help his peer make a sewn circuit, serving as a mentor and leader in this activity. The blending of social and learning interactions in support of one another is common in tinkering activities, often happening through ways that might be deemed off topic or immaterial for learning in a formal classroom setting.

Intrinsic Rewards for Effort

Built into tinkering activities are multiple features of learning experiences that provide inherent rewards: collaboration, autonomy, discovery, problem solving, pursuit of interests, pride, and even hope (Dweck, 2000; Malone & Lepper 1987; Pekrun, Elliot, & Maier, 2006; Poortvliet & Darnon, 2010). This notion of clear and relatively short-term rewards for engagement, attention, and effort encourage hard work and dedication even when a process may be challenging and frustrating. Participants experience the consequences of cutting corners or ignoring details with products that do not turn out as hoped. With care and attention, tinkering activities typically result in tangible products that children can literally own, enjoy, and be proud of. The products can also facilitate later reflection on the experiences.

In the image shown at right (Exhibit 10), two Techbridge participants describe their propeller plane project to their group. The girls highlight the value of each other's work, even though the propeller of one plane and an LED light in the other do not function. This program was intentionally explicit about the central role of experimentation, accommodating failure and the development of workarounds, solutions, and new understanding in the practice of scientific investigation. The girls' tone clearly shows their enthusiasm and positive affect in relation to the opportunity to collaborate and share their work and the creative process itself. Taking pride in effort, independent of the final outcome, is a common characteristic of tinkering activities.

Source: Screen shot of video collected by Techbridge staff (video available in Prezi presentation)**.**
Exhibit 10. Still image of video collected by a network hub showing two girls presenting their work.

Time for In-Depth Exploration

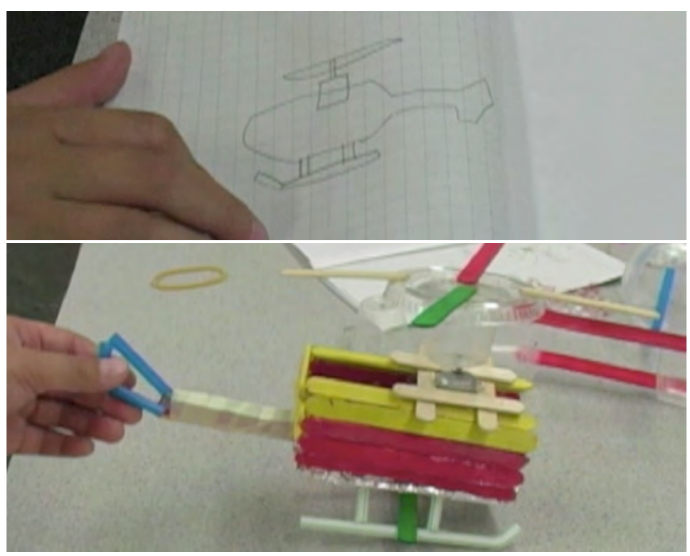
In tinkering activities participants have time for exploring a problem or approach in depth. Time is not scripted with specific activities, goals and expected achievements for each time period. Learners are encouraged to explore solutions independent of their final outcome and are allowed to work on projects over extended periods of time, often over several days. Allowing sufficient time gives learners chances to work iteratively, improving on prior efforts, experimenting with new approaches, and drawing on personal and cultural funds of knowledge (Gonzalez, Moll, & Amanti, 2005). Deliberate search for connections, drawing on a prior experience to inform a new situation—what Salomon and Perkins (1989) call high road transfer—requires that learners have time to explore and think.

Source: Photo taken by Fresno Community Science Workshop Staff.
Exhibit 11. Images of one of Community Science Workshop Fresno's SAM Academy programs showing two an example of an extended project.

In Exhibit 11, taken at the Community Science Workshop Fresno's SAM Academy Young Makers Science Camp, we see children beginning to make airplanes in the photo on the left in a project centered on the dynamics of flight. The second photo shows children using what they have created in an outdoor activity, having been given ample time to test the properties of their airplanes they had built in an extended session of experimentation. Allowing children time to plan, work, and reflect is an essential characteristic of high-quality tinkering, without which other features of learning experience are undermined.

Tools That Serve Children (and Not the Other Way Around)

Many children are used to doing things because they are told to; they are asked to demonstrate competence in using tools provided by adults (e.g., algorithms for basic mathematics) rather than being provided with opportunities to use tools in support of their own purposes. Tinkering activities provide opportunities for children to think about their own goals and choose tools (both physical and conceptual) to advance their efforts. By allowing space for learners' personal interest and facilitating more open-ended processes, youth can integrate the resources available in their environment into their problem solving activities.



Source: Screen shot of video collected by Discovery Science Center staff (video available in Prezi presentation)**.**
Exhibit 12. Photos show a plan drawing created by a child participant and a helicopter toy built using the drawing.

Exhibit 12 is from video collected by the Discovery Science Center. In the video, two children show the toys they have built using a spinning motor—in one case (shown) the motor spins a helicopter's propeller, and in the other it spins a windmill. Both children have used their journals to plan and then use their designs as blueprints for their toys. In these activities, children are not presented with goals regarding how or what tools they use; they are not expected to develop proficiency with blueprints, glue guns, or soldering irons. Instead, common tools used in STEM practices—field notebooks and diagrams—are taken up by students as means for achieving their own goals.

STEM Practices Supported by Tinkering Activities

In addition to acquisition of specific content knowledge outcomes connected with individual activities, such as concepts of electricity embedded in circuit projects, tinkering contributes to the development of STEM practices that align with those in the most recent draft of the Next Generation Science Standards (NGSS).[4] The following outcomes have been identified by SRI as key STEM practices that are supported by the kinds of tinkering activities promoted by network hubs.

Defining Problems

Throughout the course of participation in tinkering activities, participants address issues that arise in their work. While some problems might be posed to them by facilitators, others arise in the course of activities as a result of emergent goals and practical challenges. When this happens, learners must define problems and constraints for themselves before they can develop solutions. Several features of quality tinkering activities contribute to learners' opportunities to define problems. Direct contact with materials and natural phenomena puts youth in a position where, in addition to looking for answers or solutions, they must think about which questions matter. One element of the autonomy and choice in tinkering is the ability to define project goals; these open-ended experiences afford learners more chances to define problems as well. Additionally, time for in-depth exploration allows facilitators to avoid specifying all problems in advance for learners.

Framing a problem, establishing the constraints that shape the search for a solution, and linking challenges to available resources help prepare learners for success in open-ended settings where activities are not externally directed.

[4] The Next Generation Science Standards will be available for download in spring 2013 at http://www.nextgenscience.org/next-generation-science-standards

Source: Screen shot of video collected by Fresno Community Science Workshop staff (video available in Prezi presentation)**.**
Exhibit 13. A participant describing her project plans and challenges she anticipates.

Exhibit 13 shows a girl at a Community Science Workshop partner site explaining her strategy and the challenges she anticipates for creating a hat with a motorized spinning propellor. The plans she explains in the video suggest that the girl has several underlying questions about how she will create a circuit that meets her requirements. She recognizes that she will need to attach the propeller to the "hat" (a plastic cup), connect the two ends of her wire in appropriate places, and create a complete circuit that also has a switch—a clothespin she has dedicated for the purpose. In a subsequent video, she details the difficulties she had gluing the propellor an the alternative plan she came up with. She also shows the shortcomings of the plastic cup serving as a hat, very specifically describing the problems and the means by which she has dealt with them.

This skill of defining problems connects with "asking questions and defining problems" from the NGSS.

Communication Skills

Tinkering activities place learners in a position where social interaction and communication with others is key to developing successful solutions. Sharing the results of their work is part of the enjoyment of the experience. Exchanging ideas and receiving feedback from others require children to verbalize and in some cases document their thoughts, even if they are not yet fully developed. Such situations require learners to become more specific in their descriptions, often leading to their adopting technical vocabulary as they describe their projects to others.

Several features of tinkering activities contribute to the development of communication skills, including direct contact with phenomena, opportunities for collaboration, and embedded rewards that help learners develop enthusiasm to share their work with others.

Source: Screen shot of video collected by Fresno Community Science Workshop staff (video available in Prezi presentation)**.**
Exhibit 14. Parent describing what her daughter taught her about how circuits work.

The image in Exhibit 14 comes from a video showing a mother participating in a tinkering workshop at a Discovery Science Center partner site. Her daughter participated in the same workshop the day before and, based on what she learned, has explained to her how a circuit works. The mother, in turn, describes how a circuit works to the interviewer using technical language (e.g. positive and negative) and analogies (e.g., "it's like a circle") that she learned from her daughter. This example shows shared development of STEM concepts and language, and is one indication of the daughter's developing STEM proficiency, reflected by her mother's understanding and verbalization of the ways electric circuits work.

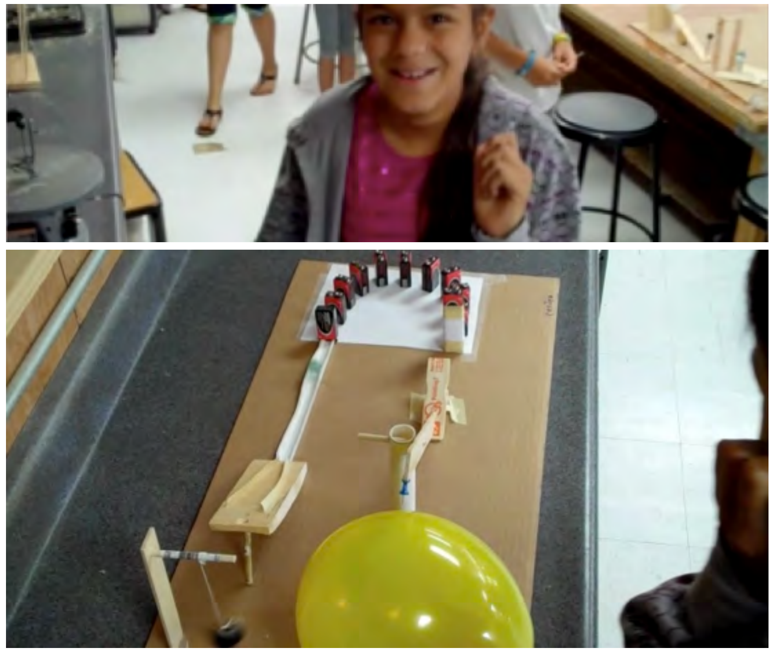
Communication skills are connected with "obtaining, evaluating, and communicating information" and "engaging in argument from evidence" from the NGSS.

Experimentation

Tinkering activities encourage children to experiment and test solutions to problems. Success is when a product works in a way participants are satisfied with (which is not necessarily as originally planned). Experimentation is supported by several features of quality tinkering activities including direct contact with natural phenomena, autonomy and choice, embedded rewards for effort, and time for in-depth exploration.

Through experimentation within tinkering projects, learners develop not only the skill of experimentation itself, but also several key dispositions discussed such as attention and persistence. These are described in more detail in the next section

Exhibit 15 shows one of several children testing their chain reaction machines in front of a camera. The chain reaction activity requires students to design a machine with four different actions (falling marble, tipping dominoes, etc.) culminating in the popping of a balloon. Children must experiment with the cause-and-effect relationships among the materials (what slope of the ramp provides enough speed for a ball to knock over a domino) and refine, measure, and retool the machine so that the balloon is popped. The videos demonstrate an atmosphere of patience with the machines not working as expected and persistence seen in the ongoing modifications.



Source: Screen shot of video collected by Community Science Workshop Fresno staff (video available in Prezi presentation)**.**
Exhibit 15. A participant demonstrating the continuous motion machine she made as a result of extended trial and error effort.

Exhibit 16 shows three cousins from Fresno demonstrating their chain reaction machines. Although their first two tests captured on this video fail, they do not become discouraged and continue with a trial-and-error approach to problem solving. In fact, they do succeed in getting their contraption to work, which the project team witnessed but did not capture on video.

Source: Screen shot of video collected by Community Science Workshop Fresno staff (video available in Prezi presentation)**.**
Exhibit 16. Children demonstrating their iterative efforts in developing continuous motion machines.

The skill of experimentation is related to the science practice skills of “Planning and carrying out investigations” from the NGSS.

Using Evidence

Participation in tinkering activities gives children opportunities to use feedback loops to inform their projects, using evidence from one iteration to inform decisions about the next. The feedback that comes from trying things that may not work the first time gives children firsthand experience with interpreting and weighing evidence. Use of evidence is fostered by several characteristics of high-quality tinkering. Direct contact with natural phenomena gives children opportunities to collect evidence from the real world, while autonomy and choice concerning activities helps ensure they are motivated to think about how they can use evidence to achieve their own goals.

Exhibit 17 comes from a video in which Raphael from Watsonville presents his catapult game, which challenges players to launch a small object so it lands in one of two spinning cups. In the video, Raphael explains why he used two batteries instead of one to operate the motor. Through experimentation and the evidence it provides, he learned that the number of batteries he uses affects the speed of at which the cups spin and therefore the difficulty of his game.

Source: Screen shot of video collected by Community Science Workshop Watsonville staff (video available in Prezi presentation)**.**
Exhibit 17. Battery compartment from Raphael of Watsonville's project. In the associated video Raphael explains how he used feedback from prior trials to learn how many batteries were needed to drive his motor..

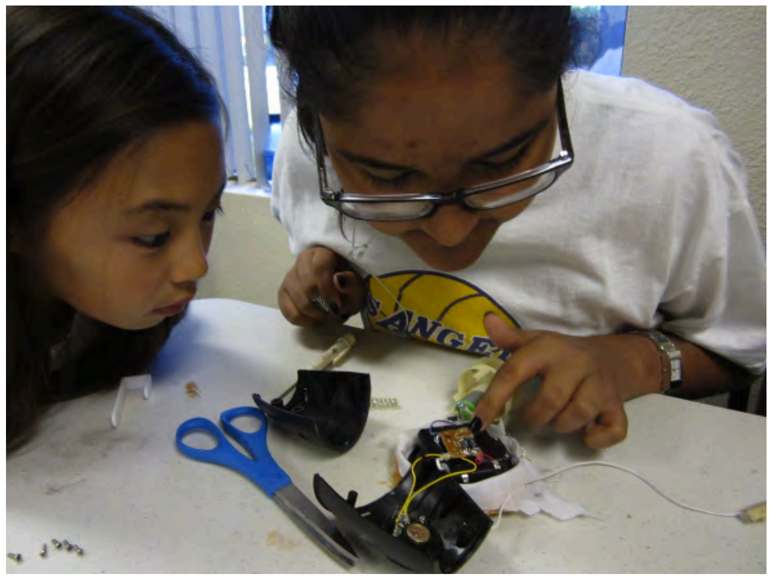
The skill of using evidence is related to "Analyzing and Interpreting Data" and "Engaging in Argument from Evidence" from NGSS.

Learner Dispositions Supported by Tinkering Activities

Tinkering supports the development of the types of productive dispositions that can influence STEM learning outcomes (Gresalfi & Cobb, 2006). Aligned with youth development principles (e.g., Mahoney et al., 2005), participants come away from their tinkering experiences with a changed sense of their own capacities. By encouraging learners to take on responsibilities within their projects and rewarding their persistence and care, tinkering activities contribute holistically to the development of children's sense of themselves as STEM learners. These new dispositions and capacities bolster the possibilities for future STEM learning in OST and other settings.

Attention and observation

In tinkering activities, participants' attention is minimally guided. Participants must themselves decide what matters to the success of their project. This provides learners with the experience of directing their attention to elements of their work that matter most. The skill of figuring out what matters is one that school activities provide students few chances to develop. A learner's opportunity to figure out where to direct his or her attention emerges naturally in tinkering as a consequence of open-ended tasks.



Source: Photo taken by Techbridge staff (video available in Prezi presentation)**.**
Exhibit 18. Two girls attentively engaged in a toy dissection activity.

Learners' attention to the details of their efforts becomes especially important when they encounter challenges and need to solve problems. Exhibit 18 illustrates what this type of close attention can look like. These girls have just taken apart an electronic toy and plan to remix its parts with other materials to create something new, a toy of a different sort that emerges from their tinkering. At this point, they are focused on understanding how the electronic elements work and determining what latitude they have for reorganizing them.

Many features of quality learning activities provide children with opportunities to develop observation and attention skills. This disposition is particularly closely linked to learner autonomy and empowerment. Learners who set their own goals are invested in outcomes, leading to extra effort in monitoring their own progress and attending to the particulars that support it.

Agency and Empowerment

In tinkering activities, learners have opportunities to observe what is and is not working and take in feedback from the physical world. Scientific concepts and complexity are intrinsic to the activities. Questions like "*Is this going to be on the test?*" have no place as participants explore concepts through processes they control in pursuit of goals that they have set. In these environments, learners take on increasing responsibility, from choosing the goals for a project to redesigning after initial failure.

Tinkering activities have been described as *learning that you can see*. This inherent transparency can help learners develop the capacity to think strategically about their own progress, charting their own course toward longer term goals. In tinkering, children can repeat activities or build on their skills by elaborating and deepening them over time. They can look at the tangible results of prior progress and think about their own learning trajectories, and they can look to their project goals and think about what capacities are needed to achieve them.

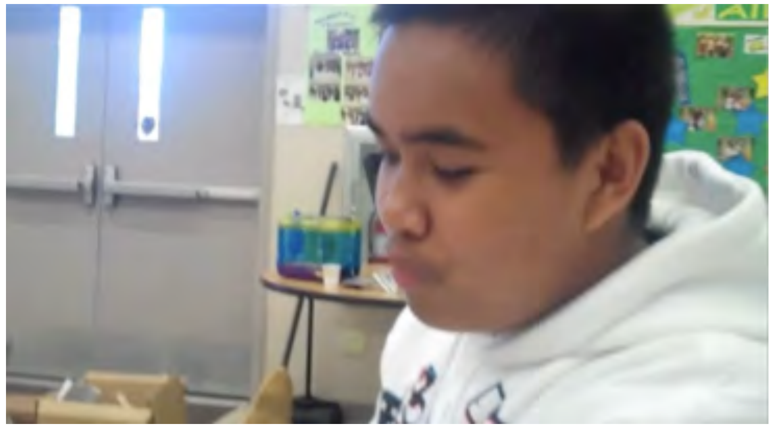
All key characteristics of high-quality tinkering projects contribute to learner agency and empowerment. Exhibit 19, from a video taken during a Boys & Girls Club workshop, shows a child named Michael demonstrating a toy he calls Thinking Bear that he has created with conductive Play-Doh, batteries, and light bulbs. Michael's uses the central metaphor of thinking as "lights turning on" and playfully holds up a small Play-doh lightbulb to indicate that his bear is thinking. Michael explains that he learned that two batteries make for brighter lights. He also has learned about conductivity and circuitry. Michael's experience shows that in these types of activities children are empowered to use their creativity rather than worry about being right or wrong.

Source: Screen shot of video collected by Exploratorium staff (video available in Prezi presentation)**.**
Exhibit 19. A participant explains his creative process when building what he called a Thinking Bear from

Persistence

Success for children engaged in tinkering activities requires persistence—almost by definition since it is through ongoing engagement with materials that tinkering occur. These activities also entail a basic degree of trial and error; participants learn through overcoming frustration and mistakes. Extended and open-ended opportunities to work on projects of personal interest provide opportunities to develop persistence. Having set their own goals, learners become committed to their projects and become interested in seeing projects through to completion despite setbacks. Experienced participants can come to see failed attempts as part of the process rather than as mistakes or failures. By providing open-ended learning opportunities in a supportive environment and encouraging children to approach problems iteratively, tinkering activities reward persistence.

Exhibit 20 shows Arthur from Watsonville, who demonstrates how a small garden fountain he has built works. He talks about his inspiration for the project and some of the challenges he encountered along the way, such as water spraying in unexpected directions. Arthur's pride in his work is evident; he plans to put his fountain in his garden at home for other people to see. This case illustrates that tinkering activities encourage youth to see their projects through to completion, even when they face challenges that take them away from their original plans—which in Arthur's case was to design a wave-making machine like he had experienced at a water park.



Source: Screen shot of video collected by Community Science Workshop Watsonville staff (video available in Prezi presentation)**.**
Exhibit 20. Still image of video collected by a network hub showing a participant proudly describing a garden fountain project.

In tinkering activities, learners experience direct rewards of hard work. The rewards can come from the benefits of literally being able to take a project home after completion or from the pride that results from developing a solution to a difficult problem. People deeply engaged in tinkering activities can come to see engineered solutions differently and find inherent beauty in elegant solutions to problems or value in new approaches to overcoming constraints. All the features of high-quality activities can contribute to persistence for learners.

Exhibit 21 shows three girls from Community Science Workshop Fresno who planned and built the duct tape canoe. The girls are motivated by their interest in having a boat that they can use but throughout the video their enthusiasm makes clear that they are additionally motivated by the process of the work itself, confronting challenges along the way and developing solutions to thorny problems.

Source: Screen shot of video collected by Fresno Community Science Workshop staff (video available in Prezi presentation)**.**
Exhibit 21. Three girls describing a long-term project.

Creative confidence

Tinkering activities encourage learners to explore objects and the world around them as part of the resources available for their creative process. Through these kinds of experiences, tinkerers can come to see things in the world around them as malleable. They develop a sense that they can capture, remix elements, and make improvements in many different types of activities and settings.

Exhibit 22 shows a girl taking apart a battery-operated toy to see the mechanisms inside. The girl opened the toy to access its internal components. These kinds of experiences, looking under the hood, give participants access to thinking about how similar products could be made. The girl is confidently exploring the ways the toy works and goes to her peers when she needs help.

Source: Screen shot of video collected by Techbridge staff (video available in Prezi presentation)**.**
Exhibit 22. A girl exploring the hidden mechanisms behind a toy.

Exposure to the hidden working of the toy can help participants imagine how they might create something of their own design.

Overall, the aggregate of the features of high-quality tinkering and tinkering environments create the kinds of learning experiences and outcomes illustrated by the examples in this section. For some learner dispositions and STEM practices, it is easy to envision direct lines to the specific features of the environment that support them—such as learner persistence developing from the intrinsically rewarding efforts promoted by high-quality programming. The relationship between environmental features and outcomes, however, should not be regarded as a set of one-to-one correspondences. Instead, multiple characteristics of high-quality tinkering and tinkering experiences contribute to each of the impacts we have described in this section. Allowing children adequate time for in-depth exploration, for example, encourages both experimentation and persistence. In-depth exploration also can lead children to define problems as they iterate through versions of a product or to a stronger sense of agency and empowerment as they set their own timelines for their work. In this way, features of high-quality environments, STEM practices, and learner dispositions must be regarded as having complex, interconnected relationships.

While the flexibility of afterschool environments allows for ongoing and adaptive efforts to create the type of high-quality programming illustrated in this section, actually achieving the level of quality that promotes the practices and dispositions identified in this section is not easy. This is the challenge the network was created to address.

III. Pilot Year Network Activity

As noted in Section I, the network framed the goal of expanding STEM-rich tinkering in afterschool programs around the intersection of three broad facets: (1) connecting to the Common Core Math and Next Generation Science Standards, (2) the developmental affordances and structural constraints of typical afterschool programs, and (3) an emerging vision of high-quality STEM-rich tinkering activities as entailing both the development of scientific practices and youth development learning dispositions.

In this section we describe the activities of the network and how they supported local afterschool programming led by the hubs. We then summarize the activities provided by each hub.

During the pilot year the network included five hub organizations. Three had significant experience in tinkering, one had a rich history of construction and engineering activities, and one was new to tinkering. Network activity included three professional development workshops that were attended by staff from all hubs. The network also experimented with an online blog focused on tinkering and organized inter-visitations among network members as well as program documentation and Phase Two planning.

The professional development workshops focused on developing and disseminating activities and know-how across the network and provided support for on-site documentation of programming and impacts. Workshops were organized around firsthand experiences doing and observing others doing tinkering activities, and then reflecting on the design, facilitation, and learning outcomes experienced and observed in the activities. Direct experiences in the hands on activities anchored subsequent discussions about such topics as materials, facilitation, and learner agency. Participants from different hub organizations were invited to plan and facilitate discussions and activities on various topics. Network meetings were designed to:

- Equip participants with concrete tinkering activities that hubs could implement in their programs for children,
- Provide first-hand experiences for learning through tinkering to reflect on and raise awareness of key dimensions of high-quality activity design and facilitation strategies,
- Discuss frameworks for positioning the tinkering programs in the context of the forthcoming Next Generation Science Standards, specifically referencing the engineering standards and learning outcomes,
- Develop and agree upon documentation strategies for hubs to use both to visually capture programs for stakeholders and evaluators and to use in reflective staff development about student learning,
- Promote new relationships with one another to support information sharing, professional development, ongoing collaboration, and efficiencies inherent to a learning network.

Workshop 1. Orientation to the Network (January 25-26, 2012)

The goals of the first meeting of the California Tinkering Afterschool Network were for hub organizations to get to know each other and find out what each partner brought to the network, to develop shared goals for the network activities, and to begin a conversation about evaluation and outcomes focused on how activities support children's development of scientific practices and learning dispositions.

As part of the introductions, representatives from hub organization provided information on their prior tinkering work along with background on their local contexts and partners. There was also discussion of the shared goal of turning tinkering into something less rarified bringing it to larger numbers of youth, especially youth from high-poverty communities. All of the hubs were already working with afterschool programs in low-income communities, with the exception of the Exploratorium, which as part of this Bechtel-funded project, expanded its existing tinkering programs for community-based school events to a regularized partnership with the San Francisco Boys and Girls Clubs in the Mission and Visitacion Valley sites.

Leaders from the Community Science Workshops (Community Science Workshop) in both Fresno and Watsonville described their history and approach with a full complement of out-of-school and school-based programming that included field trips, summer programs for migrant children, and afterschool programming at ASES and 21st Century sites. Subsequent discussion focused on the importance of having time for activities, backtracking when activities do not work, and providing children the right level of challenge.

TechBridge representatives shared their work on engineering design activities with middle school girls, which included activities centered on taking things apart and a extended green design project. They described the advantages of and special considerations when working with a single group of children over a long period of time. They also discussed the career orientation of their programming. The Discovery Science Center introduced preliminary work and plans for extending out-of-school programming with local partners. Exploratorium staff presented their approach to implementing tinkering programs in the community and also described the way in which science concepts develop gradually over time through carefully selected sequences of activities. Discussion focused on the development of identity among participants from underrepresented groups, concerns about avoiding a deficit-oriented approach when offering programming in low-income communities, and strategies for building connections with families and communities.

The Exploratorium described its work in designing and implementing tinkering over the prior decade, including the development of a framework, called the MAPDD framework, that it used to guide staff reflection and analysis of tinkering programs. This framework focused discussion on (1) activity design, (2) facilitation strategies, and (3) environmental features. For each of these dimensions, the Exploratorium presented a set of design principles (such as designing activities to include multiple pathways for participation, or organizing the environment so that learners could benefit through cross-pollination afforded by easy visual and physical access to the ideas and tinkering approaches adopted by others).

This first workshop then shifted to attendees' hands on engagement with a tinkering activity. A circuit activity led by Exploratorium staff was followed by a reflective discussion that used the MAPDD framework to unpack what the activity meant to participants, the ways participants experienced the activity, and how the facilitation approach supported the process. Everyone generally responded very positively to the experience, though many wanted more time to work on it. Everyone generally responded very positively to the experience, though many wanted more time to work on it. This led to further discussion about the importance of adequate time for this kind of work.

In the afternoon, workshop participants then took turns, in small groups, visiting the Exploratorium's Tinkering Studio and observing Tinkering Studio visitors engaged in the same activities they had just done in the workshop. Subsequent discussion about participant observations in the Tinkering Studio was organized around the MAPDD framework

Reflecting on both the work of the hub organizations and the Tinkering Studio observations, attendees then discussed staffing and staff capacity in out-of-school settings. This discussion included general characteristics of afterschool programs and staff and the strategies hub sites had developed to improve capacity. For example, the Community Science Workshops have sought to improve continuity and stability by expanding the responsibilities of school-year staff to summer programming. They reported that providing year-round employment makes the sites better able to recruit and retain staff.

The workshop closed with a discussion of the importance of documenting the work that happens at hub sites, both to help the network demonstrate to outsiders the nature of tinkering and to provide opportunities for reflection for facilitators, other program staff, and participating children. Discussion focused on common approaches to documentation such as demonstration fairs and opportunities to make documentation more reflective such as through participant journaling. SRI facilitated a short discussion about where we might look for and document evidence that participants in tinkering programming are learning.

Workshop 2. Implementing Tinkering in Afterschool (March 29-30, 2012)

At the second workshop, each hub attended with a cohort of 2-5 partners from local afterschool sites. The second workshop was organized around introducing the hubs and their afterschool partners to the rationale for doing tinkering in afterschool programs.

The meeting began with a review of the goals of the network, the MAPDD framework for thinking about tinkering, and a discussion of standards, which included contributions by representatives of the California Afterschool Network who introduced some of the current policy context for science in afterschool. They noted that changes in the language arts standards may influence afterschool offerings because of new emphases on reading and writing in subject matter areas..

A discussion was then led by Shirin Vossoughi, Exploratorium Post-doctoral Researcher, on questions of equity in opportunities to learn and engaging underserved children in STEM. Discussion questions included:

- How can after-school programs expand how we see and think about "what counts as" science and science learning?
- What kinds of opportunities do after-school programs provide for young people to engage in personally and culturally meaningful science learning activities?

- How can tinkering activities create pathways for historically under-represented communities to see themselves as part of STEM fields, and to see these fields as transformable or open to change?

Later in the morning, Exploratorium facilitators led a hands on activity, again using basic circuitry components and open-ended exploratory prompts, this time with more materials and opportunities for greater complexity. In later discussion, they highlighted elements of the facilitation that supported productive exploration by pushing people to see what they could do and come up with new challenges of their own.

Exhibit 23. Network hub staff member working on a toy dissection)

In the afternoon leaders of the Community Science Workshop led another circuitry activity, in which learners were provided step-by-step instructions on how to wire circuits to create moving objects. This activity was followed by a discussion of the kinds of learning opportunities that emerge from tinkering experiences and the kinds of evidence that reveal that learning is taking place.

On the second day, an extension of the circuit activity from the previous day was used to explore the idea of engaging children with particular phenomena over the course of several different afterschool sessions. This activity, toy dissection, involves removing the battery-powered mechanisms from stuffed animals and repurposing the mechanisms to create new moving objects. At the end of all of these activities, the group discussed how the individual activities built on one another and how the facilitation fostered connections between each activity.

At the end of the second day, participants built their own circuit board kits which they could later use with children in the local afterschool programs. Each hub organization took one complete kit back home.

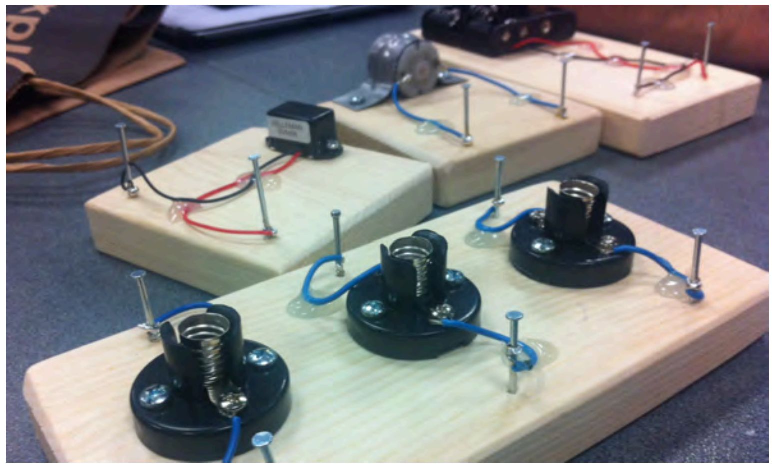


Exhibit 24 . Circuit kit components made at Exploratorium by hub staff for use in local programming.

Throughout the two-day workshop, formal and informal discussion among participants focused on comparisons of implementation models and local community characteristics. Participants identified features of the shared activities that seemed important; for example, several people commented on the value of having extended time to complete activities. Participants also showed interest in thinking about what kinds of evidence for learning can be captured unobtrusively in tinkering environments.

Workshop 3. Documentation and Hub Network Leadership (October 11-12, 2012)

The third and final 2012 meeting of the California Tinkering After School Network was organized around recognizing and leveraging leadership from each of the hub sites. The agenda of the two day workshop was organized around themes identified by hub leaders through an email poll in advance of the meeting. Based on their interests and leadership, teams of two hub leaders were paired to address topics they felt were important to implementation, including gaining an understanding of the distinctive features of afterschool science, recognizing the features of high-quality facilitation for tinkering, and finding ways to effect positive STEM career mentoring.

Using the MAPDD framework, Exploratorium staff initiated a conversation about learning through tinkering. They presented the results of a prior and ongoing study that identified four dimensions of learning through tinkering, and how each could be observed in programming settings:

(1) Engagement - active participation, persistence,

(2) Intentionality - variation of approaches, personalization, self-direction and initiative,

(3) Innovation - repurposing of tools and methods, redirecting efforts, growing fluency with tools, concepts and processes; increasingly sophisticated questions and use of tools, solutions, and

(4) Solidarity - helping, borrowing, sharing tools; building on one another's work.

A whole group discussion on learning environments centered on questions about differences between activities carried out in dedicated spaces such as the Tinkering Studio and activities that happen in lunchrooms or other spaces that must return to their usual use at the end of the day.

The workshop continued with sites reporting on their work since the previous meeting.

The Community Science Workshop, Fresno reported on developments in their SAM academy, including summer programming in community sites, a new museum partnership, and the involvement of staff in collecting video documentation of their summer work.

Techbridge staff described a video game development activity (digital tinkering) and motorized toy making using boxes of material from RAFT. Their documentation included interviews with young makers while they worked.

The Exploratorium described their work with Boys and Girls Club partners, which added two new elements, science journaling and a partnership with youth facilitators from the Xtech program.

The Discovery Science Center reported on a more traditional one-week summer camp model which they reconfigured to incorporate tinkering. The Community Science Workshop, Watsonville discussed the school-site afterschool programming they offer and introduced their mobile workshop approach to the group.

Next, Paul Pooler of the Discovery Science Center and Meg Escudé of the Exploratorium discussed needs and challenges related to sequencing tinkering activities when there is ongoing programming. They highlighted the use of science notebooks for reflection as a support for enhancing the value of thoughtful sequencing. Other workshop participants were interested in how language skills and challenges are best approached when using science notebooks.

Techbridge representatives presented to the group about their extensive experience with adult mentors who serve as role models for participants. They outlined specific strategies and provided detailed materials on recruiting and working with adult mentors to provide real examples of science and engineering career paths.

The Community Science Workshop, Fresno shared experiences with an extended, youth-driven summer project creating a boat from duct tape and other materials (described in the introduction to this report).

The group again visited the Exploratorium Tinkering studio where visitors were making paper circuits. The discussion that followed focused initially on facilitating paper circuitry activities and then on some of the resource-intensive aspects of organizing and carrying out tinkering programming. Several meeting participants were interested in hearing how other sites handled logistical concerns such as backordered supplies and costs of key materials.

The workshop closed with discussion about the kinds of activities participants would want to see in the network in the future. Some were interested in the network becoming an institute of workshops. Another well-received suggestion was that the network could support staff from hub organizations exploring different approaches through visits to one another's sites. Finally, several participants were interested in how the network could provide logistical support for carrying out activities (e.g. through materials collections) and documentation.

Documentation and Reflection

The network supported hubs in documenting the work they do with children in an effort to promote communication among hubs, foster reflection at all stages of the tinkering process, and support efforts to document student outcomes. A major interest of the network was whether or not the hubs could use video documentation as forms of evidence of learning and/or impact for (1) stakeholders (funders, parents, school personnel) and (2) program assessment (for use in staff reflection). A goal was to make these documentation activities "embedded" in the normal routine of programs since it was clear that they did not have the capacity to add on to their work entire documentation and assessment components. Hubs expressed interest in investigating the ways in which documentation could be incorporated into the activities themselves. Ideas that were discussed included having children "tell the story" of their projects as they completed them, having children interview one another, and having children use Powerpoint to describe the "natural history" of the objects that could be shared as a final part of the project.

Each hub collected video documentation of programming captured live and video interviews with participants. Products, photographs, and participant journals also supported the documentation efforts, providing insights into the particulars of local programming. SRI staff used documentation provided by hubs as well as documentation collected during site visits (e.g., photographs of projects) along with other data such as field notes from network meetings and staff interviews in the development of this report.

Video documentation

Hub staff collected video footage of participants engaging in activities. This video was collected primarily with simple handheld cameras and attempted to capture everyday practice. The video footage was used during workshops to spark conversation and invite comparisons across settings.

Video interviews

At several sites hub staff asked a sample of children to participate in video interviews about their projects once the projects were complete. Hub staff were provided with an interview protocol designed by SRI and the Exploratorium. The protocol was designed so that a peer could conduct the interviews (though some were conducted by adults) and interviewers were encouraged to use the protocol only to the degree that it was helpful. Protocol topics were:

1. The thing they/you made
    a. How they/you decided to make that?
    b. How does it work?
    c. What makes it do that? (whatever it does)
2. The idea for making this.
    a. the plan at the start
    b. different ideas along the way
    c. how it ended up
    d. Are there plans to do more work or build another one?
3. Surprises when making it
    a. Did it work they way they thought it would?
    b. Any people they worked with or people who helped on the project?
    c. Favorite things about making it
4. Any advice for somebody else wanting to make something similar (parts that were hard or easy)
5. Where will the project be kept?

Each hub provided some examples of video interviews for use by evaluators, for reflection within sites, and for presentations at network hub meetings.

Other documentation

Hubs also collected additional documentation of their work with children, some of which was shared at network meetings and with SRI evaluators. Several sites used participant notebooks to guide children's reflections and in some cases notebooks were preserved for reflection on the program as a whole. Many sites collected exemplars of student work or photos of finished projects that could be used participants, staff, network peers, and evaluators.

Review of Pilot Year Network Activity

Several aspects of network activity in the pilot year are worth further comment. First, hubs developed insights regarding successful tinkering programming and partnerships by taking into account evidence from both research and practice. They were able to analyze features of high-quality programming through a combination of research-oriented presentations on learning combined with reflections on the actual practice of implementing activities with children. A case in point is support of learner collaborations in hands on activities.

Second, network members extensively discussed types of variations in the design and implementation of local programs. Many of these variations depend on whether features of programs are more stable and permanent or more fluid and temporary. For example, hub staff observed contrasts between programming offered in permanent workshop settings versus programming provided in school-based sites. Similarly, differences in relationships with partner organization staff depend on whether they are based on long-term, established collaborations or day-by-day assignments. Finally, hubs observed differences between programming offered to stable cohorts of children, programming offered with a more flexible cohort model (e.g. optional participation from a stable group), and drop-in programming. Hub participants recognized the importance of designing programming with attention to these variations and expressed interest in ongoing opportunities to learn how others managed these issues.

Third, several hubs had specific expertise that they offered to others in the network. For example, during one workshop (January 26, 2012), staff from both Community Science Network hubs discussed how they combined multiple programming formats to better support partnerships with districts and afterschool sites and to provide job stability for staff. In another workshop (October 12), Techbridge staff offered a presentation on working with career role models related to their programming. In many cases, these kinds of presentations led to discussions and informal problem solving during breaks among staff from different hubs. Hub participants expressed continued interest in both the structured and facilitated sharing of special expertise, on the one hand, and less formal opportunities to problem-solve together, on the other.

IV. Learner Programming Supported by Network Hubs

Network hubs offered programming at their own sites, at local schools, and at other sites in the community such as museums and community centers. Programming at each of the hub sites varied considerably depending on the human and physical resources available, the established and nascent community partnerships in place, and the needs of the community.

Some programming was offered to stable cohorts of participants for sessions lasting up to 12 weeks while other programming was offered on a drop-in basis. Hubs worked with a wide range of facilitation strategies. At some sites hub staff facilitated programming directly, in many cases with the help of youth workers from the community, while other programming was offered with the support of local site staff, including teachers at school sites and permanent staff members in community-based settings. Much of the programming targeted narrow age ranges, spanning three to five years. Programming served children as young as age kindergarten age and as old as 8th grade, with high school students often participating as youth facilitators.

The activities carried out by network hub organization at local sites in 2012 are summarized in Exhibit 25 and described in more detail in this section.

Techbridge	**Tabletop activities at school-based afterschool programs** (spring)**.** 36 days of programming across sites with STEM role models from local community.
	Summer workshop on electrical engineering (summer). Three full-length days; program held at Techbridge classroom site in Oakland office.
Exploratorium	**Xtech training for volunteer youth corps members** (summer). Two weeks of tinkering activities for volunteer youth corps members (8 days, 4 hours a day)**.**
	Drop-in Summer tinkering activities (summer)**.** 10 or 11 weeks of drop-in tinkering activities offered at two Boys and Girls Clubs.
	Afterschool tinkering activities (fall). 11-week cumulative curriculum of skill building tinkering activities offered at two boys and girls clubs after school.
Community Science Workshop Fresno	**Maker Summer camps.** Offered at five different sites (Fresno Art Museum, three elementary schools and a Community Science Workshop). Fresno Art Museum also included teacher professional development.
	Teacher professional development (summer). With Fresno art museum camp
	Drop-in workshop programming (spring and fall). Afterschool and weekend programming at two workshop sites.
	Family Days (fall and winter 2012). For parents and their children, offered at six different sites.
	Tabletop activities at school-based afterschool programs (Spring and fall). Structured tabletop activities offered at 10 school sites. In some schools activities/content was carried over into school programming.
	STEM Support for Teachers (fall**).** In-school program at two sites providing STEM support for teachers requesting help.
Orange County Discovery Science Center	**Summer camp.** Two sessions, one week each. Session 1 served 150 kids with the 10 teachers trained at the beginning of the Summer. Session 2 served 42 kids with facilitation by partner staff (from higher education institutions) with help from pre-service college students.
	Parent component of session 1 Summer programming. Parent programming was attended by 20-30 parents. of Summer camp participants Programming was coordinate with the first camp sessions.
	Teacher Training (summer). Two-day teacher training program for 10 classroom teachers**.**
Community Science Workshop Watsonville	**Summer Camp** 11-week drop-in structured tabletop activities at Boys and Girls Clubs.
	School Site After School Programing (spring and fall). Structured tabletop activities in afterschool programs at some sites with mobile workshop offered at others. Drop-in programming in five school sites.

Exhibit 25. Overview of programming offered in the pilot year of the network.

Community Science Workshop Fresno Programming

The Community Science Workshop (Community Science Workshop) in Fresno offered community-based programming in community centers, its own workshop spaces, and in other community spaces, including a museum and a garage. Programming was facilitated by Community Science Workshop staff. These staff also offered afterschool programming and teacher professional development in schools. Detail on this program offerings supported by the network are below.

Community-Based Maker Summer Camps

Community Science Workshop Fresno carried out five tinkering-oriented Summer camps for 565 participants at the following 5 sites in high-poverty communities:

- Three camps in elementary school sites served 225 participants with 6 hours of tinkering per person.
- A camp at the Fresno Art Museum serving 240 participants offered 35 hours of tinkering programming per participant (5 full days). 70% of participant in this camp was funded through network scholarships while the other 30% paid tuition. This programming was offered with facilitation help from museum staff and it featured a teacher professional development component.
- A camp at the Granny Park Community Science Workshop site served 100 participants with 20 hours of programming per participant.

Drop-in Workshops

Drop-in programming was offered at Community Science Workshop's main and satellite workshop sites and available 20 hours per week (afterschool and Saturdays), 45 weeks per year. Drop-in workshops are staffed by Community Science Workshop Fresno Staff and youth staff. Network funds supported drop-in services for 60 participants who were supported by youth facilitators.

Family Days

Family days attended by 6,000 parents and their children were offered at six different sites, including the Fresno Art Museum, school sites, a church, a street fair, and a medical clinic. Family days events were facilitated by Community Science Workshop Fresno staff.

Programming in Afterschool Settings

Structured tabletop activities were offered within afterschool programs at 10 low-performing or high-poverty school sites. Afterschool programs served 800 students in the spring and fall of 2012 and were facilitated by Community Science Workshop Fresno staff and youth workers. At some school sites, activities and content from the tinkering programming was carried over into the school day.

STEM support for Teachers

The Community Science Workshop Fresno offered an in-school program providing STEM support for teachers who requested help. The program served 50 teachers working in low-performing school sites and was facilitated by Community Science Workshop Fresno staff.

Community Science Center Watsonville Programming

The Community Science Workshop Watsonville hub offered community-based programming in their own workshop spaces as well as community center sites. They also offered afterschool tabletop programming and a mobile workshop at several school sites. More detail on the programming they offered under the network grant are provided below.

Community-based Summer camps

During the Summer of 2012, Community Science Workshop Watsonvile offered 11-week Summer camps programming featuring drop-in structured tabletop activities at Boys and Girls Clubs in the community. The Summer camps were facilitated by regular hub staff and youth mentors.

Walk-in programming

Community Science Workshop Watsonville offered open-ended, unstructured, walk-in afterschool and Summer programming in their own main site and at satellite site locations in the community. They also used a mobile workshop to offer afterschool walk-in programming at five school sites. Programming is facilitated by Community Science Workshop staff and youth.

Programming in afterschool settings

Structured tabletop activities were offered within existing afterschool programs such as 21st Century or ASES sites in the community. Programming in afterschool settings was facilitated by Community Science Workshop Fresno youth staff supervised by adult staff.

Discovery Science Center Orange County Programming

The Discovery Science Center (DSC) in Orange County offered tinkering programs during the Summer of 2012 based directly on the activities and approaches developed and disseminated during the first two network meetings (January and March, 2012). The DSC programs supported by the network grant are described below.

Teacher Training

Working with teacher trainers from UC Riverside and San Bernardino Community College, 22 teachers from the Ontario-Montclaire Unified School District participated in a two-day training the week before the Summer programming in June. Most of the teachers were immediately engaged and interested in the activities, with a few warming more slowly to the open-ended and student-centered approach. These teacher received supplies that they took back to their classrooms.

Summer Student Programming

Summer programs using the activities from the network meetings were offered at school sites in June and July 2012. The first Summer camp was held in the Ontario-Montclaire Unified School District. The primary staff were the newly trained elementary teachers from the district who were supported by the teacher trainers from UC Riverside and San Bernardino Community College. The camp ran for five days and served 175 students, primarily Latino and mostly fifth-graders but spanning the ages of 10 to 14. The camp progressed from basic circuitry activities to building more complex devices of students' own design based on their experience with circuits. It also included rocketry and science career activities. The majority of the programming was built on the circuitry activities in the California Tinkering Afterschool Network meetings.

The second camp was held with 42 students for four days in a middle school in the Rialto school system. The activities were similar to the earlier camp, but also included complex origami-based mathematics. The camp was staffed by the instructors from UC Riverside and San Bernardino Community College with undergraduates from UC Riverside assisting. The undergraduates felt that the experience was highly valuable for their own growth as educators and for their conceptions of the way that STEM can be learned. The participating students were all sixth to eighth graders, primarily African American and Latino.

Parent Programming

Simultaneous with the student programming for the June session, the staff also ran a parent program in which parents were able to engage in the same tinkering activities as their children. Several parents and students reported discussing the activities at home, sharing ideas regarding how their creations worked and what they learned.

Exploratorium Programming

With network support, the Exploratorium initiated a new partnership with the SF Boys & Girls Club. The Exploratorium worked with staff from the Boys & Girls Clubs Mission programs to hire a new bilingual educator, Meg Escudé, to lead this work. Escudé worked in two sites in the Mission district, employing teen youth from the Exploratorium XTech youth program to work as paid tinkering assistants in the afterschool programs. Exploratorium programming supported under the network grant is described in more detail below.

Summer Programming

During Summer 2012, the Exploratorium offered drop-in Summer programs at a Boys & Girls Club for children aged 6-12. The tabletop activities were offered to groups of 15-20 children per session. Participants were African American and recent Latino and Asian immigrants in a low-income neighborhood. Programming was facilitated by Exploratorium staff with the support of teen Xtech interns. Despite being drop-in, there was a core group of frequent participants.

Programming in Afterschool Settings

In fall of 2012, the Exploratorium offered programming similar to its Summer programming for children at three Boys & Girls Club locations. Groups were divided serving younger and older children separately with different sets of tabletop activities. As with the Summer programming, a core group of participants attended regularly.

XTech Summer Program

The Exploratorium hosted a group of 10 middle schools students from low-income communities in San Francisco recruited through the First Graduate and Aim High programs to participate in a two-week training. After training, XTech interns joined Exploratorium staff facilitating afterschool and Summer programming at Boys & Girls Club locations.

Techbridge Programming

Techbridge incorporated tinkering into much of its Bay Area school-site afterschool programming in the spring and fall of 2012. It also offered a three-day Summer program in Oakland. The Techbridge tinkering programming supported by the network grant is described in more detail below.

Techbridge Afterschool Programming

Techbridge is a direct provider of afterschool programming for girls in grades five through eight. Programming is offered at school sites with high percentages of the students eligible for free and reduced price lunch and English language learners. 180 girls participated in the programming—75 students at 3 sites in the spring and 105 students at 5 sites in the fall. Each program is facilitated by Techbridge staff with support from one local school teacher at each site. Programming included the participation of adult role models in STEM careers from the local community to establish links between the activities and future STEM careers.

Summer Programming

In the Summer of 2012, Techbridge offered a three-day program for 15 fifth through eighth grade girls at the Techbridge site in Oakland. Summer programming was facilitated by Techbridge staff.

V. Beyond the Pilot Year

There is widespread interest in expanding tinkering and making activities into afterschool programs. The pilot year revealed that this work entails many issues related to local capacity to design, implement, and support high-quality STEM-rich tinkering activities for children. This may be especially true in afterschool settings that are subject to multiple requirements (homework help, snack time, etc.) and may have fewer resources than programs designed by or for STEM learning specifically.

The observations, interviews, videos, and other data collected during the pilot year suggest multiple ways that the network can continue to support the expansion of high-quality programming afterschool sites. Hubs expressed an interest in learning from one another on a broad range of topics, from logistical concerns (e.g. obtaining materials) to building capacity with local partner staff. While all the hub organizations valued the network and their participation in it, two hub organizations in particular mentioned that without the network they would not have been able to incorporate high-quality tinkering activities into their programming.

The evaluation data collected suggest that, in the future network activity might include (1) drawing on experiences across sites to refine the vision for tinkering in afterschool, (2) distributing critical resources for providing high-quality opportunities in low-income communities, (3) developing documentation processes that provide evidence of the value of tinkering in OST, and (4) sustainably expanding the network to broaden the reach of programming for children and youth.

Refining the Shared Vision

The network has already developed a shared vision for tinkering activities in afterschool. Continued work can help further articulate criteria for success across the varied types of afterschool settings serving low-income youth.

Ongoing meetings and communication among hub members will help hubs develop new goals and address common challenges. Indirectly, much of this work will support the goal of creating compelling documentation of the value of hub activities. A common vocabulary and framework for thinking about the benefits of tinkering will support the hubs and the network itself in articulating the value of the work to outside audiences.

Distributing Critical Resources and Know-How

Activity Designs

Staff from several hub organizations were interested in continuing to collaborate on activity designs to learn more about the variety of tinkering projects taking place in the network. In the pilot year, several concrete examples of partner site activities served as resources for other sites. For example, one staff member from Community Science Workshop Watsonville was surprised by what she saw in a video of a collaborative activity from another site. She wondered if children in her community could work together in the same way and planned to experiment with new forms of collaboration.

Network workshops provide a rich platform for hubs to compare activity designs and gain insight on how to improve their local offerings. Future work by the network might include providing a shared repository where hubs could document and exchange specific activities. Additionally, understanding how each hub adapts the same activity to their specific requirements would enable a better understanding of how different local settings can be best served by the network.

Successful Afterschool Partnerships

Network hubs had varied types of local partners, including community centers, individual schools, and teachers on school campuses. Some relationships between hubs and local partners were new and some better established. What mattered to hub leadership varied from one hub to another; for example, some hubs preferred and negotiated to work with the same site staff on a consistent basis while others showed less concern for staff continuity. Similarly, some considered other factors such as programming space or stability of the participant cohort to be important. Several sites reported advantages to thinking through these kinds of partnership parameters in advance and including them in early discussions with local site contact persons.

Working with local staff to develop and negotiate partnerships was a significant effort for all hubs, more so for those with substantial recent growth. In the ongoing efforts of the network, hubs might benefit from opportunities to learn from one another about strategies for managing successful partnerships.. Elements of the partnerships that mattered to hubs include staffing models, participant recruitment, time allotment, program space, and materials.

Efficient Resource Management

Hub organizations with more extensive tinkering experience have expertise to offer concerning obtaining and managing resources, including materials, staff, and activity designs.

Staff from different hubs consistently expressed interest in hearing how others addressed logistical and supply challenges, such as the difficulty of operating in settings where materials must be put away each day and the problem of back orders or managing shipping costs when materials come from many suppliers. Staff were concerned about the balance between human and financial resources. Finding lower cost supplies takes significant staff time and most programs are too small to buy in bulk. Striking the right balance between time and money is an example of a resource management problem that concerned several hubs.

Several hub staff expressed interest in having the network provide centralized resource management in the form of a physical repository for supplies or a digital bank of activity designs, video documentation, and supplies lists. An information bank could also be a clearing how for tips on working with youth staff and developing local partnerships.

Documenting the Work to Promote its Value

The network worked with hubs in the pilot year to collect documentation of the programming each organization offers. This documentation has helped hubs reflect on their own work and describe it to others, including at network meetings. The evidence collected by hubs has been a key element in the network evaluation and has helped hubs make a case for tinkering as they communicate with outside audiences, such as potential partner sites.

Moving forward, the network can support hub organizations and OST programs to brand activities, fundraise, and consolidate evidence for the value of tinkering. The network can develop resources of value for member organizations as a whole in their efforts to champion tinkering activities for outside audiences. Members would benefit from a comprehensive literature review of the relevant theory linked to design elements that could be used in proposals or in communication with OST programs and other potential stakeholders to make a case for the value of tinkering.

Similarly, the network can support hubs in their effort to communicate specific ideas to outside audiences. For example, by demonstrating the amount of staffing investment required for successful programming, the network can support sites' effort to build a case for adequately funded programming.

Network Expansion

A key issue regarding the network's effort beyond its pilot year is its growth and scale-up. During the third workshop (October 2012), discussions were held about the ways the network should grow and how to include potential future partner organizations. Two models seem possible. One is to invite new hubs to join the network in its existing form while the other is for current network members to become hubs for subnetworks that serve specific local communities. These options are not mutually exclusive; short-term growth could involve strategically adding new partners to the network, and then a second long-term phase could launch local partnerships where existing hubs become leaders of smaller networks. Scaling the network through local leadership would allow each partner to leverage network resources according to the needs of each community and would promote the organic growth of the network.

Tinkering holds tremendous promise to bring exploratory, improvisational, problem-solving characteristics to STEM in afterschool settings. Several key features of high-quality tinkering activities, as we have observed, serve to promote STEM practices related to the new science standards and to nurture development of learner dispositions that can be carried across activities and settings to support success in STEM. In its pilot year, the network developed a shared vision for high-quality programming, increased the capacity of hubs and partners to implement tinkering activities in their regions, supported new and diverse programs, and established a strong foundation for expansion of the network throughout California in future years.

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