

# Afterschool Matters

Number 17 • Spring 2013

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VOICES FROM THE FIELD

## WELCOME

Which ball drops faster from the Leaning Tower of Pisa? In what kind of soil do green beans grow taller? Does adding sugar to a vase of flowers delay wilting? Ask a second-grader! I did, at a recent science fair, and was reminded of the excitement children and youth can experience when they take on the role of scientist, experimenter, inventor—and expert.

We are most grateful to the Noyce Foundation for supporting this issue of *Afterschool Matters* focused on STEM in out-of-school time (OST) settings. Lifting up the ongoing contribution of OST programs to STEM learning is an important exercise for the field. Dimensions of STEM learning such as investigating, reasoning, analyzing, concluding, and explaining can regularly be part of OST learning content. Enriching and engaging STEM learning experiences can build skills intimately related to school and career success.

Through various organizations and initiatives, the momentum for enhancing STEM learning in OST programs is growing. Recently the Afterschool Alliance produced the report “Defining Youth Outcomes for STEM Learning in Afterschool,” which helps to identify what STEM learning outcomes afterschool programs could help to achieve, what the indicators of progress toward such outcomes might be, and what types of evidence could be collected by afterschool programs.

We hope that this issue of *Afterschool Matters* pushes the conversation forward. Whether the subject is cryptology, biology, or March Madness bracketology, the OST program lab is open! We encourage all to come in.



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# where it gets interesting

## Competing Models of STEM Learning After School

by Bronwyn Bevan and Vera Michalchik

*In an afterschool science program in a mid-sized city in the South, 12 sixth-grade students are about to make battery-operated motors using copper wires, paper clips, magnets, tape, and 9-volt batteries. Before starting the activity, one of the two classroom teachers leading this weekly program passes out ice cream cones to the children, who sit in two rows of desks facing the front of the class. Leaning back in her chair with her own ice cream, the other teacher makes small talk for several minutes before asking Investigation Club members what they know about motors.*

*The children and teacher casually converse about their experiences at home with their parents' cars, boats, or lawn mowers. The teacher shares what she learned from her own father, "a shade-tree mechanic," about fixing car engines. During the conversation the teacher calls out several components of car motors—air, oil, gasoline, batteries—when the children mention them.*

*After about 30 minutes, with all the ice cream consumed, the teachers pass out the activity worksheet and ma-*

*terials. They ask a student to read aloud the step-by-step instructions and then instruct the children to begin, working individually at their desks. The teachers roam through the room to assist them. The students hunch over their desks as they assiduously assemble the materials, carefully coil the copper wire around the battery, and affix the paper clips to the terminal nodes. As they work, they engage in casual side talk, giggles, and commentary. Concentration is in the air. Individuals ask for assistance: The copper wires keep springing off the battery; a connection can't be made. The teachers come over to hold the batteries or pinch the paper clips. Children continue good-naturedly to work at wrapping and*

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*rewrapping the wire, which just won't hold. Maybe the paper clips are too loose? There are some groans of frustration but no recrimination, and nobody gives up. As the hour nears 5 p.m., parents start to drift in to pick up their children. Nobody has gotten a motor to work. "Maybe it was the wrong gauge wire," says a teacher. She tells the children to write about what happened in their science notebooks. A single student picks up her notebook and starts to write. The others start packing up their bags and begin to leave one by one.*

This description of an observation in May 2009 is representative of many science activities we have observed in afterschool settings serving middle school children. The setting is school-like, with desks in rows and teachers at the front of the room. The mood, featuring ice cream cones and casual conversation, is relaxed; the activity is materials-based; and the pedagogical context is spare, using untested activities and limited materials with minimal instruction and reflection. This particular project was one of 16 programs we studied as a part of a federally funded initiative on science learning in out-of-school time (OST).

No operating motors were built during the two hours we observed the Investigation Club (a pseudonym), but many other things happened. Students identified and shared what they knew about motors and batteries from everyday life. They swapped stories and jokes with their teachers and with one another, solidifying their membership in a science-focused community. They undertook the science activities with alacrity and persisted despite frustrations. They gained familiarity with materials including copper wire, batteries, and clips as they assembled a multi-component apparatus. They directly experienced practices of science that involve building, tinkering, and refining toward the goal of constructing an operational instrument.

### **How Connections Happen—or Don't**

Two days later, in the school-day science class, another teacher began the sixth-grade electricity unit. Four of her 24 students were part of Investigation Club. When she asked for examples of electricity in students' daily lives, one of the Investigation Club students gave the example of a car battery, whereas other students all referred to items that are typically plugged into a wall. The teacher called on the Investigation Club students to describe an

electric circuit as she sketched it on the blackboard. They were also asked to distribute the materials for a fruit-battery activity and to demonstrate to their peers how to coil the copper wire to complete a circuit. This time, with the correct materials assembled, the Investigation Club students successfully completed the circuits—more quickly than did many of their peers. The teacher asked them to assist other students. Most but not all of the sixth-graders successfully completed a circuit before the end of the activity time. The teacher then led a discussion about the ways in which trials and failures are an intrinsic part of the scientific process. One of the Investigation Club children recounted how the club's earlier activity hadn't worked and described what he thought the problems

might have been. The class discussed the variables that made it easier or harder to complete the circuits. The teacher led the students through a review of the key ideas, terms, and processes of the activity, moving into a six-week unit on electricity.

This classroom teacher was aware that some of the students had recently attempted to complete circuits. She knew of their interest in science and their affiliations with the Investigation Club program. She called on them to spark group conversations, to demonstrate, and to assist other students. In this way, she leveraged their interests and growing capacities both to support their own learning and to advance the productive engagement of the whole class. She even knew that the afterschool activity had not unfolded as planned, so that the students' grasp of concepts might be tenuous; thus she took on the diagram sketching herself, with their verbal input leading the way.

Actually, this classroom episode didn't really happen, at least as far as we know. The afterschool program we observed was conducted in a school, with schoolteachers working as afterschool club leaders. However, because the design of the program was grounded in the assumption that interest sparked in one place—afterschool—would automatically generate interest in another setting—school—the afterschool program leaders did not make special efforts to connect to the classroom. The underlying model of learning was that interest is a steady construct. If it gets stoked in one place, it will catch fire in another. The research that documented the effects of the afterschool program, therefore, focused solely on what happened during afterschool hours and

*Use of this additive model of learning, we argue, may lead to missed learning opportunities for all children, and perhaps especially for children from high-poverty communities.*

how it supported engagement. The study design did not test assumptions about how concepts and experiences in the afterschool setting would manifest in the school setting. We don't know if they did, if they didn't, or even if they had opportunities to do so.

This narrow focus is, we contend, a problem. It arises from a model of learning that views interest, engagement, and learning as context-free. Use of this *additive* model of learning, we argue, may lead to missed learning opportunities for all children, and perhaps especially for children from high-poverty communities. These children are more likely than children from higher-income communities to attend afterschool programs that are funded by government and private foundations. These funders often require programs to collect data that is informed by the additive model of learning—for example, pre- to post-program changes in interest or attitudes or in school-day grades or test scores. Use of these data in turn shapes afterschool program designs and possibilities.

### Competing Theories of Afterschool

Afterschool programs are currently conceptualized in two ways. One is represented by *expanded learning*, which includes a wide range of content-rich opportunities in the hours outside of school, including summer camps. The operating assumption is that, in structured OST programs, children can learn concepts or develop capacities or interests that will later enhance their engagement in everyday as well as academic settings. Some of these programs are science-specific. They might be based at science museums, like the XTech program at the Exploratorium, or in youth development programs devoted to science, like Project Exploration in Chicago. However, most expanded learning programs are not science-specific. For example, most 21st Century Learning Community Centers and equivalent district or county programs encompass a range of activities, including play, snack, homework time, and academic enrichment. Though most of the academic activities focus on reading and mathematics, increasingly afterschool leaders report that they are interested in incorporating science activities into their offerings.

That program relied on what we term the *additive model* of learning, which posits that providing children with rich science experiences in one setting is like filling a beaker. Students' levels of science interest, capacity, and commitment rise and should therefore remain equally high in other settings such as school, home, and other OST programs.

The other model is *extended learning*, in which afterschool aligns more closely with the school curriculum. Interest in extended day models is growing as many communities seek more time to improve students' academic performance, generally measured by standardized achievement tests. Some argue that extended day programs can be organized so that learning activities are markedly different from school activities and yet directly reinforce key ideas or concepts from the school curriculum.

The *extended* school day, because it is clearly a part of the school curriculum and strategy, may be most logically assessed through school measurements such as test scores, attendance, and grades.

The *expanded* school day is more complicated. Its premise is that time after school might be fundamentally different from school time. Expanded afterschool programs might address subject matter, practices, terms, and instruments that are not included in the school curriculum or that are covered at more advanced grade levels. For example, expanded programs might include taking care of animals in a life sciences program based at a zoo, learning about complex systems through computer-based modeling at a local research agency, or participating in a youth research team associated with a local municipal agency's water quality studies.

The viability of expanded day programs in the eyes of policymakers and funders rests partially on the assumption that students who are engaged in high-quality OST science programs will build their interests, capacities, and commitments to science in ways that will carry over to enhance engagement in school science. Indeed, this premise informed the federal program that funded Investigation Club. That program relied on what we term the *additive* model of learning, which posits that providing children with rich science experiences in one setting is like filling a beaker. Students' levels of science interest, capacity, and commitment rise and should therefore remain equally high in other settings such as school, home, and other OST programs (Bevan & Michalchik, 2012).

Many researchers value the ways in which high-quality expanded day programs productively engage

children in science practices, communities, and learning. Research shows that, in these settings, children access resources—objects, instruments, expertise, settings—not otherwise available to them (Barron, Wise, & Martin, 2012). They expand their social networks through new relationships with one another, with science or mathematics professionals, and with other adults (Khisty & Willey, 2012). They expand their identities as achievers in the context of science (Barton & Tan, 2010; Fusco, 2001; Rahm, 2002). They take on new responsibility for and authorship of their science understanding (Vossoughi, 2012).

Although this research makes a compelling case that powerful science learning can occur in youth development contexts, as researchers we struggle with how to document and assess *at scale* the contributions such experiences represent for children. We emphasize *scale* because we know that STEM education funders, policymakers, and program leaders need documentation of program effectiveness and student learning. The evidence must be obtained in ways that are at once efficient, in that they do not require detailed and costly observations and interviews, while also being non-obtrusive, for example, not “ruining” the OST experience by requiring school-like paper-and-pencil tests.

Moving documentation and assessment to scale is, we argue, critical to ensuring that the expanded day continues to be an option in the face of the growing interest in extended day learning. We fear that, in the absence of demonstrated evidence of learning, extended day models, because they are easier to document through existing school measures, will be used with students from high-poverty communities, while harder-to-document expanded day opportunities will be reserved mostly for students from more wealthy communities, where science scores are of less concern. To date, efforts to develop effective expanded day assessment models that can scale up have been hindered by the assumptions of the additive model of learning.

### **Limitations of the Additive Model of Learning**

The additive model of learning assumes that if children participate in afterschool STEM programs by  $x$  amount, their overall interest, capacity, and engagement in STEM—and particularly in school STEM—should rise by an amount equivalent to  $x$  (Bevan & Michalchik,

2012). We argue that the additive model limits attempts to understand learning across settings and timeframes in several ways.

First, even the most passionate science learner emerging from an OST setting can become bored or confused in a badly conducted school science class. It is equally true that even the most deeply committed school science student can be turned off during boring OST activities. However, in the additive model, if students attending OST STEM programs do not perform better in school science than children who do not attend, both the value of the OST program and the development of the learners are questioned. (See Kane, 2004, for a synthesis of four different program evaluations, though none are science-specific.)

A second problem stems from assumptions about how children categorize activities. The additive model presupposes that children who have a positive experience

in a given science activity should later respond positively to other science activities. Children who like robots ought to like chemistry. This view suggests that children carry around a unified feeling about “science,” regardless of whether their interests are in animals or planets, gadgets or gardens, illustrating plant life or watching things explode. In fact, researchers have documented the ways in which children’s interests in science are domain-specific

(Azevedo, 2011).

Third, the additive model discounts the value of positive engagements with OST activities that may not directly link to school science but that may open the door for ongoing future engagement with science, including in the school setting. Such positive experiences might engage children in noticing specific phenomena, developing skills on which they can later draw, or establishing peer or adult relationships that make science more appealing. Generally, OST programs offer time, tolerance, safety, choice, and flexibility for intertwining emotional, aesthetic, and social elements into learning activities in ways not as easily accommodated by schools.

Fourth, the additive model underplays important contemporary paradigms in the learning sciences (Lave & Wenger, 1991; Rogoff & Lave, 1984; Sawyer, 2006). This research shows that, in order to make useful connections between their OST and school experiences, children benefit from clear points of articulation between

This view suggests that children carry around a unified feeling about “science,” regardless of whether their interests are in animals or planets, gadgets or gardens, illustrating plant life or watching things explode.

the two. In this view, the construct of “interest” has little meaning apart from activities that directly relate to that interest. Practical experience is the basis on which children make connections among learning activities across settings. This reality has many pedagogical implications for the design and delivery of programs that seek to make these connections (Ito et al., 2012).

The additive model does not take into account the fact that a given context or activity system that provides for successful learning is not, at its core, the same as the next. A child engaged by the configuration of people, ideas, tools, tasks, processes, and possibilities in the afterschool setting will face a different configuration during the school day. Each evokes a different “fit” between the child and the activities at hand and therefore draws forth a different set of responses.

Though people do carry with them continuously developing sets of interests, proclivities, and passions (see Gutiérrez & Rogoff, 2003; Holland, Lachicotte, Skinner, & Cain, 1998), how these interests and proclivities manifest themselves is not so simple. We posit that the additive model of learning is overly simplistic, to the point that it obscures what may be happening across settings. The persistence of this model may be one reason for the exceedingly mixed results in large-scale studies of afterschool learning (James-Burdumy, Dynarski, Moore, Deke, & Mansfield, 2005; Kane, 2004). Its use threatens the viability of expanded day programs, especially for children attending high-poverty schools.

### **Contextual Model of Learning**

In contrast to the additive model of learning, we posit a *contextual* model. In using this phrase, we follow a long line of scholars who have documented the ways in which learning, identity, interest, and participation are related to context (Esmonde et al., 2012; Gutiérrez & Rogoff, 2003; Holland et al., 1998; Lave & Wenger, 1991; McDermott & Varenne, 1998). Rather than counting on the direct transfer of knowledge, skills, or interests from one setting to another, researchers must identify the multiple and contingent ways in which children express their growing fluencies with diverse scientific practices. These fluencies will look different in different settings and may not appear at all when conditions do not support them.

In recent years, education researchers have begun to pay progressively more attention to learning across settings. Scholars argue for the need to conduct cross-setting studies both to understand how children develop interests and expertise over time and to discover the social arrangements and opportunities that exist—or do not exist—to support learning (Gutiérrez, 2012; Lee, 2008). Many thus undertake this research to advance educational equity (see Banks et al., 2007) because, as inequitable outcomes reveal, educational settings appear to vary in their ability to leverage learners’ existing interests and resources (Bell, Bricker, Reeve, Zimmerman, & Tzou, 2012).

In-depth documentation of learning in a given setting is important (and especially informative for program leaders), but it may be limited when used to predict whether one approach or another is “more effective” unless it is contextualized across the settings of the learning ecologies in which it exists.

From an educational perspective, cross-setting research may reveal how and where children develop interests and capacities to productively engage in science, thus enabling program leaders to

better leverage and coordinate learning resources. From a learning sciences perspective, research that follows children across settings, especially when it addresses non-dominant communities that are frequently underrepresented in the literature, can strengthen our understanding of learning and human development and how these vary culturally by expanding the body of data to be more inclusive and therefore more complete (Bell et al., 2012).

Scholars argue for the need to conduct cross-setting studies both to understand how children develop interests and expertise over time and to discover the social arrangements and opportunities that exist—or do not exist—to support learning.

### **Investigation Club Revisited**

We return to the Investigation Club. Because it was part of a larger federally funded program called SCiStar (a pseudonym), the effects of participation in the Investigation Club were measured in part through pre- and post-program pencil-and-paper surveys to see if children’s attitudes toward science changed. The assumption, following the additive model, was that, if attitudes changed during SCiStar participation, the changed attitudes would also play out in school, home, and other OST settings—and even possibly in career interests.

The surveys asked about children’s prior experiences with STEM generally and with OST STEM; they also used

an instrument designed to assess attitudes toward science (Weinburgh & Steele, 2000). Analysis of the data showed that children's positive attitudes in science, which started high on a five-point scale, held steady during the middle school years. This finding runs counter to the widely documented drop in positive attitudes and interest in science during middle school (George, 2000; Zacharia & Calabrese-Barton, 2004). Indeed, when we compared students participating in the 16 SCIstar projects with non-participating students matched for demographics and levels of interest in STEM, we found that attitudes toward science dropped in the comparison group but held steady for the youth in SCIstar (Bevan, Gallagher, Michalchik, Remold, & Bhanot, in review).

The evaluation of SCIstar involved other elements in addition to the surveys, notably extensive on-site observations and interviews. However, in none of the 16 projects did local project leaders or evaluators take a cross-setting approach to understand if and how SCIstar experiences might be showing up in other settings, such as home, school, or other OST programs. As the external evaluators of the program, we did not have institutional review board clearance to conduct this research ourselves.

If the program had been based on a contextual model of learning, the situation would have been different. Cross-setting approaches would have been used to design, develop, and document the Investigation Club project. From the beginning, school and OST leaders would have developed a shared set of goals for the students. Program design and evaluation would have included determining how to follow children in home and other settings. Program leaders would have identified ways to document growing STEM interest or capacities during the school day. Documentation would not have been limited to grades and standardized test scores; it might have included the nature of student participation, questions, leadership, and engagement in STEM activities in and out of school. Depending on the focus of the activity—in the case of Investigation Club, energy and earth systems—a study could have determined whether key concepts as well as scientific practices were carried into the school day.

This method of research is not simple. It requires coordination across multiple systems and stakeholders (see

A contextual model of learning and a cross-setting model of research design would enable the field of informal science education to look for power where it actually exists and to locate breakages in the line that keep children from getting the full benefit of STEM experiences—in and out of school.

Penuel, Fishman, Sabelli, & Cheng, 2011). However, simpler forms of research are not providing the field with useful information. We are looking for a broken power line on our property because that is where we live, but the power line could be broken anywhere in the entire network. Also, there could be power at the house next door or in the community across the river, but we have not had the inclination or wherewithal to look. A contextual model of learning and a cross-setting model of research design would enable the field of informal science education to look for power where it actually exists and to locate breakages in the line that keep children from getting the full benefit of STEM experiences—in and out of school. Such approaches would inform the work of educators, researchers, and policymakers.

### Fostering an Ecology of STEM Learning

The additive model of learning not only runs counter to the contemporary understanding of learning but also undermines the potential of OST programs to support youth engagement in STEM learning. It leads to use of false measurement strategies, such as holding OST STEM programs accountable for school outcomes. These documentation strategies in turn shape—and potentially narrow—program design and implementation. Moreover, the additive model diverts attention from the central issue of making rich learning opportunities more equitably available across local learning settings. A single powerful science learning opportunity—whether at home, in afterschool, or at school—can be exciting and memorable. However, unless it is embedded in an ecology of further opportunities that include higher-level mathematics, feature role models of all kinds, and offer increasingly advanced and complex learning, the single science learning opportunity is likely to remain singular.

In contrast to the additive model of learning, we posit a contextual model that conceptualizes learning as a process that takes place over time and across settings, in response to specific people, ideas, tools, and opportunities. This process can also be shut down or diverted when opportunities and connections are not made available or comprehensible (Barton & Yang, 2000; Bell et al., 2012).

The distinction between *additive* and *contextual* models is not a minor or semantic issue. The additive

model represents a fundamental misconceptualization (see Stetsenko, 2009) that can undermine the developmental power of the OST setting. For example, the assumption that interest carries across settings independent of the types of opportunities available can lead policymakers to devalue or even defund powerful OST programs whose effects don't register on school measures. The school itself—not the OST program, which has no control over the school day—should be accountable for how young people perform on school measures.

To better understand and capture the complex processes of learning, research in OST STEM needs to take a longer view of how OST fits into a larger learning ecology. It needs to attend to the specific contexts of STEM learning and clearly tie the measures of learning to the models of learning. Taking such an approach implies that:

- School measures should be considered as relevant to OST programs only when robust connections between school and OST have been designed and implemented.
- Better (and embedded and naturalistic) measurements of learning must be developed for OST STEM programs, especially when they have different, and perhaps richer, goals for learning than do many school science programs (see Michalchik & Gallagher, 2010).
- Research frameworks that better account for learning as it develops across settings and time must be developed and incorporated into studies of OST learning.
- More STEM OST programs should be supported and made more equitably available. We suggest that this need for more, and more equitable, high-quality STEM learning opportunities applies equally in school settings.

Only when the entire STEM learning ecology is taken into account, and when young people have access to high-quality STEM learning opportunities, can the results of studies of children's STEM interest be fully interpreted and appropriately applied.

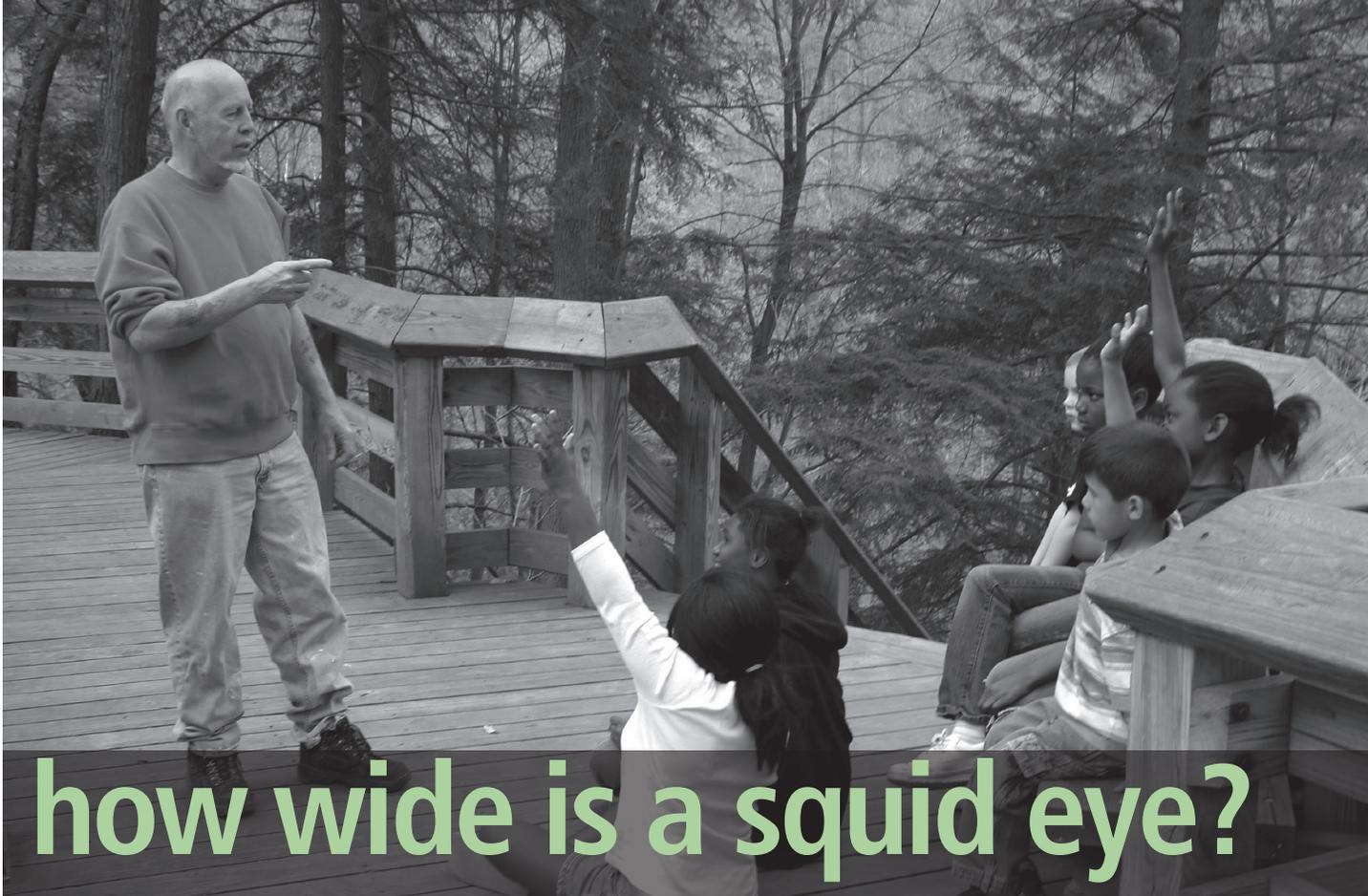
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# how wide is a squid eye?

## Integrating Mathematics into Public Library Programs for the Elementary Grades

by Marlene Kliman, Nuria Jaumot-Pascual, and Valerie Martin

*The chart in Figure 1 (page 10) is affixed to the wall in the children's room of a public library branch in a large city. A group of 8–11-year-old children, having posted their own information on the chart, watch with excitement to see how the data set evolves as passersby contribute. Lashawnda is hoping that the next person to add a dot increases the height of the "bump" around 9, while Jamal is rooting for more dots near 5, to form two "bumps," a bimodal distribution. Maximilliano wonders if anyone with a name longer than his will post a dot, further extending the range.*

*As children reflect on the growing patterns of responses, their afterschool group leader, Markeshia, guides them to consider sampling: If we collect 100 more responses from this library, do you think the overall shape of the data will remain the same? What if we collect responses from a library branch across town? from a different part of the U.S.? from another country?*

*Each week, children in Markeshia's group explore a "question of the week." Sometimes children choose the question; sometimes Markeshia selects a question to mesh with a theme she wants children to explore. Whatever the topic, she*

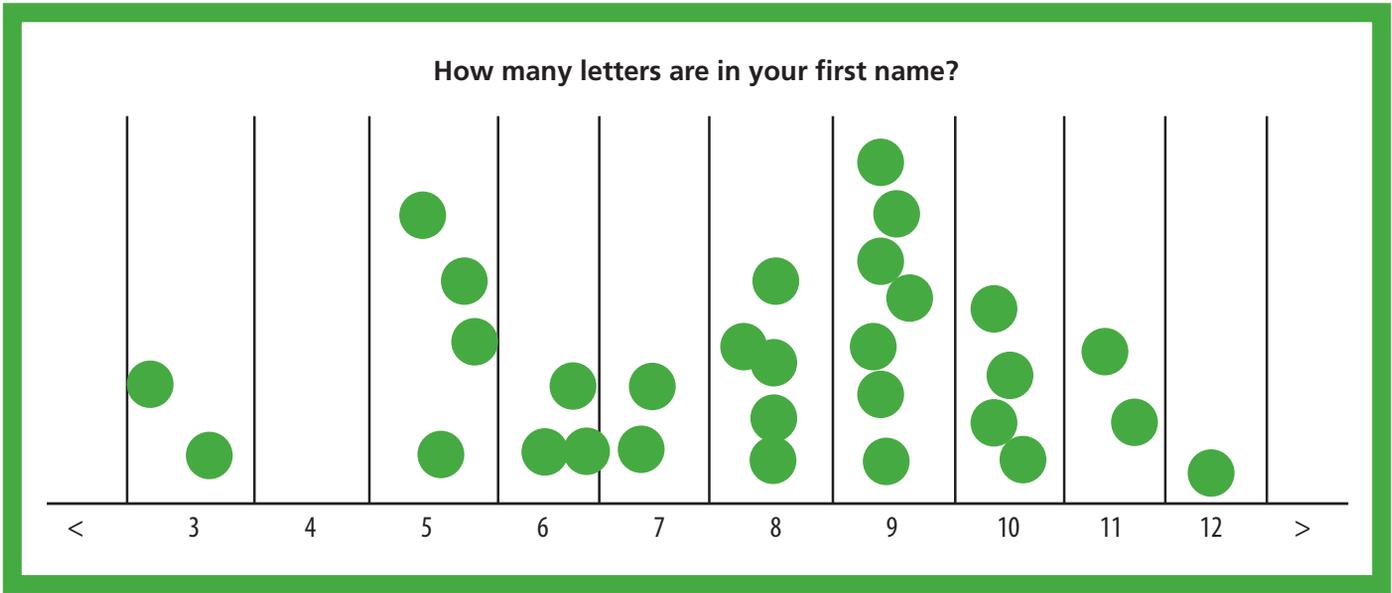
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**NURIA JAUMOT-PASCUAL**, senior research associate at TERC, leads informal math workshops, professional development programs, and webinars in English and Spanish. She has worked for more than 20 years as a teacher and staff developer in Spain, Central America, and the U.S. She is currently a doctoral student in education at the University of Georgia.

**VALERIE MARTIN**, senior web and graphic designer at TERC, specializes in conveying math and science concepts in a clear and visually appealing manner. On the Mixing in Math projects, she ensures that web and print resources are accessible and engaging to a wide range of readers, whatever their math background.

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**Figure 1. Math off the Shelf Activity**

*always embeds data analysis, guided by resources that show her how she can infuse math into her work with children.*

Although public library programs for the elementary grades offer explorations in a wide range of topics, scenes like this one, in which mathematics plays a role, are all too rare: Mathematics offerings are typically limited to homework help (Char & Foote, 2009; U.S. Department of Education, 2003). However, when informal educators incorporate mathematics into their project-based offerings, children stand to gain. Participating in out-of-school activities that embed mathematics in authentic ways bolsters children's skill development, appreciation of the relevance of mathematics, and mathematics attitudes (Guberman, 2004; Harris Interactive, 2011; Nasir, Hand, & Taylor, 2008).

Informal educators, from afterschool providers to librarians, care deeply about children's mathematical success, but they often are math-avoidant themselves and thus shy away from doing mathematics with children (Gasbara & Johnson, 2008; Intel, 2009). Like many adults, they lack confidence and comfort with mathematics, and they view mathematics as being devoid of context. In everyday life, adults estimate, measure, and navigate, but they don't think of these activities as mathematics and do not share strategies with children (Esmonde et al., 2013; Lange & Meaney, 2011). Even as awareness of science as a cultural and social activity is growing, adults of all backgrounds often view mathematics as a context-free topic consisting of facts and algorithms (Allexsaht-Snyder, 2006; Martin, 2009a, 2009b).

To provide informal educators in library settings with an alternative vision of mathematics, the authors, based at TERC, a STEM education nonprofit, initiated Math off the

Shelf (MotS) with funding from the National Science Foundation. MotS involved two phases: resource development and dissemination with evaluation. In the first phase, we worked with library-based informal educators (LBIEs, including children's librarians and library-based afterschool educators) to create interdisciplinary mathematics resources tailored specifically to their needs. In the second phase, we made the resources available to a wider group of LBIEs and investigated results: Did access to these resources lead LBIEs to make any changes in their practices? in the way they interacted with children? in their own views of mathematics?

In this paper, we describe resource characteristics and key findings. We chose to focus on LBIEs because families are increasingly relying on public libraries as free, safe places for children in the absence of other out-of-school care (Newman & Celano, 2006; Public Agenda, 2006). Given the wide range of informal educators based in libraries, our findings suggest that informal educators can integrate mathematics into their offerings if they have access to resources that readily mesh with their own program goals and formats.

### **Designing Math Resources: What Works in the Library?**

For the first two years of MotS, we worked with several dozen LBIEs in four regions in the northeastern U.S. (Queens, New York, and locations in Connecticut, Massachusetts, and Westchester County, New York) to create interdisciplinary mathematics resources. The majority of our LBIE partners were based in urban areas with significant low-income Latino/a or African-American populations. As community-based informal educators, LBIEs know their audience well: They craft programs to fit the interests and needs of the local

population; they are familiar with formats and themes that draw in neighborhood crowds; and they build strong rapport with the community. Thus, we sought to develop ways for them to infuse mathematics into what they already do successfully and confidently, rather than create a separate, stand-alone mathematics program.

### Design Process

We employed an interactive and iterative design process. First, we solicited from LBIEs upcoming programming themes, such as animals or healthy snacks, and special events, such as Earth Day or Chinese New Year. We also asked them about their needs when no programs are available; for example, they need games children can play quietly by themselves. Next, we developed activities designed to be embedded in these existing contexts and themes. After our LBIE partners chose among the activities, implemented their choices, and gave feedback, we revised and then invited a wider group to try the activities. Our process continued until we had a varied bank of about 200 well-vetted activities in English and Spanish, including dozens each of crafts, projects to last an hour or more, games, and short activities designed to fill 5–10 minutes. Many of the activities are appropriate for the full elementary grade range, with suggestions for increasing or reducing challenge; others are geared for particular grade levels. For example, the activity that introduced this article could be made simpler for younger children by using a yes-or-no question such as “Did you eat fruit today?”

Throughout the process, we spent hundreds of hours communicating with LBIEs in person, by phone, and by e-mail to better understand their realities, the opportunities and constraints in their varied library settings, their goals and joys in work-

**Table 1. Typical Children’s Public Library Characteristics**

LIBRARY CHARACTERISTIC	COMMON?	CORRESPONDING MotS CHARACTERISTIC
Setting allows for substantial noise, movement, mess; provides separate activity space	No	Provides a resource bank; LBIEs choose what fits their setting
Books are available	Yes	Includes activities that make use of library resources
Setting serves as a public space; substantial foot traffic	Yes	Capitalizes on public audience with data-collection activities and museum-type displays
Programs, boards, and displays follow a monthly or seasonal theme	Varies	Offers activities that can be readily customized to a theme (e.g., animals, weather, planets)
Participants may walk away mid-activity, leaving the program or building	Yes	Provides guidance on drawing out the mathematics mid-activity, rather than only at wrap-up
Drop-in attendance: number, age, and abilities of participants not known in advance	Yes	Includes information on selecting and adapting for different needs, abilities, ages, and audiences
Children present when program or adult supervision is unavailable	Yes	Offers activities children can do without adult facilitation
Informal educators have paid time for professional development	Varies	Designed to be accessible without training
Informal educators have autonomy in designing programs	Yes	Resources are accessible and visually appealing to draw in math-avoidant adults
Informal educators comfortable leading mathematics activities	No	Draws on adults’ everyday math skills by focusing on content that arises from authentic situations (e.g., measuring to create a poster)

ing with children, and their reasons for choosing to use particular resources. Table 1 summarizes characteristics common to their settings and ways that we shaped MotS resources to accommodate their needs.

### Example Activities

The resource bank includes a broad variety of activities. Some are appropriate for almost any type of out-of-school program, including crafts projects and games children can play quietly. Others are designed to capitalize on unique aspects of most library settings. Often LBIEs customized activities to fit local interests and needs.

### Library as Venue for Gathering Public Opinions

As the opening anecdote on name length illustrates, libraries can be an ideal venue for collecting and displaying data from a wide range of passersby. LBIEs have used the MotS data-collection activity “Quick Questions” (<http://mixinginmath.terc.edu/activities/quickquestions.php>) to explore community data on everything from languages spoken at home to favorite vegetables to opinions about changes to local bus service. LBIEs choose the question to match children’s interests, address a timely community issue, or align with a monthly or summer reading theme.

### Library as Forum for Exchanging Problem-Solving Strategies

Patrons of all ages bring different opinions, experiences, and backgrounds to the library; they also bring a variety of mathematical strategies. Museum-type displays, in which patrons are confronted with a puzzle or problem and asked to record their solution strategies, provide a way for children to share ideas with and learn from many others. In one such activity, children and other library patrons share strategies for estimating. LBIEs place two identical jars out in a public area. They fill one jar with large objects, such as beads, pasta shells, or pompoms, and another with identical smaller ones. Next to the jars is a sheet on which passersby record the number of objects they estimate to be in each and, most importantly, how they made their estimates (Figure 2). As with Quick Questions, this activity, Mystery Jars (<http://mixinginmath.terc.edu/activities/mysteryjars.php>) can be readily adapted to different themes. For instance, LBIEs have used large and small beads to launch an arts-and-crafts monthly theme and bottle caps of two sizes in honor of Earth Day.

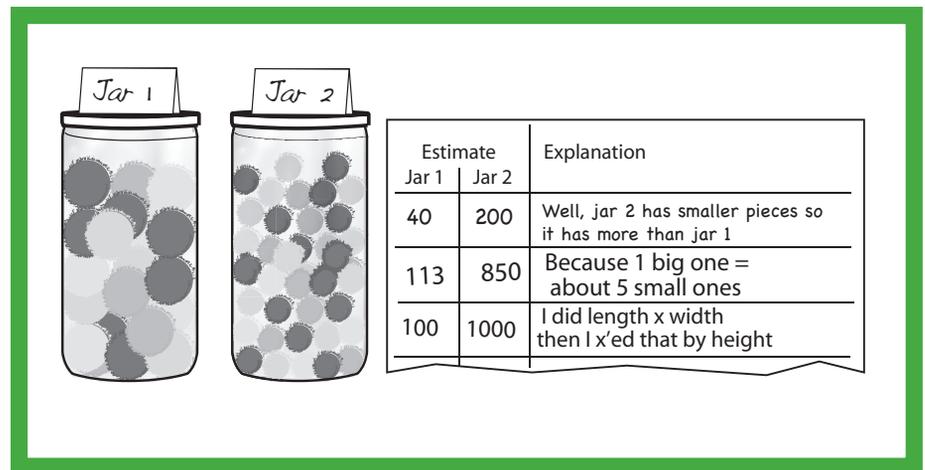


Figure 2. Estimation Strategies Recorded at a Public Library

### Children’s Books as Mathematical Springboards

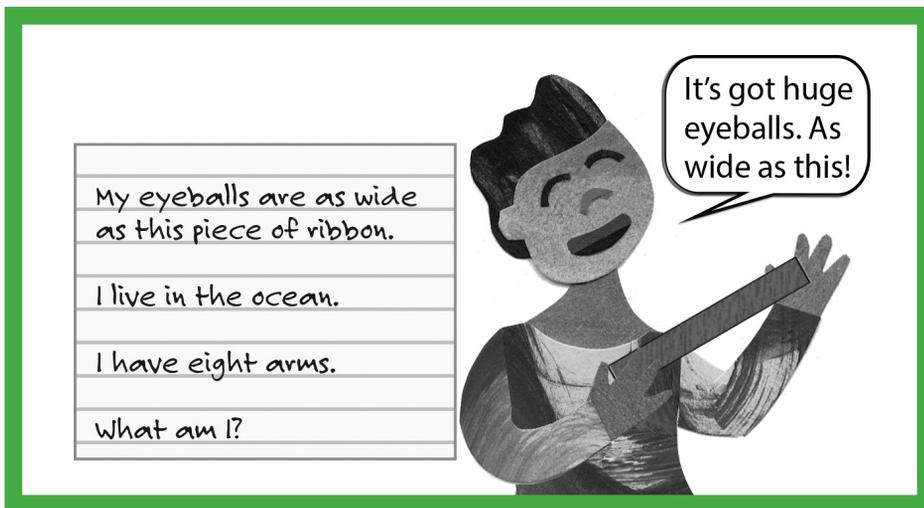
Mathematics is inherent in many aspects of children’s books: shapes and sizes in picture book illustrations, dimensions of fairy tale giants of phenomenal proportions, and quantities and measurements in record books. In one activity, Size Riddles (<http://mixinginmath.terc.edu/activities/sizeriddles.php>), children make sense of measurements while exploring nonfiction books about animals, plants, people, or anything that comes in different sizes. For instance, one LBIE focused the activity on sea creatures in order to align with her summer-long ocean theme. Children perused non-fiction books to find intriguing facts about the size of sea creatures; then they used the facts in riddles, accompanied by string or ribbon that they measured and cut to represent the size (Figure 3).

### What Changed When the Resources Were Distributed Widely?

Once we finalized the resources, we made them available for free access on a public website: <http://mixinginmath.terc.edu>. For evaluation purposes, we selected eight primarily low-income cities and regions across the U.S. In each, a library administrator sent out an e-mail encouraging LBIEs to review the website and use any activities they wished. Use was voluntary; in most cases, administrators had no supervisory role over LBIEs and did not track or follow up on use.

### Survey Process

In each of the next three years, an external evaluator who had not been involved in the resource development sent an annual electronic survey to LBIEs in the eight regions with the help of their library administrators. LBIEs were asked to fill out the complete survey if they had learned of MotS resources at least four months previously. Survey items addressed incorporation of mathematics into work with children, math-related attitudes and beliefs, reasons for including mathematics in



**Figure 3. A Size Riddle**

programs, and perceptions of benefits to children. The evaluator had already gathered baseline data on a subset of these issues through an electronic survey near the start of the project.

Each year, respondents noted how much time had passed since they were initially exposed to MotS resources. Other survey questions asked about respondents' professional roles—children's librarian, library-based afterschool educator, and others—and about the extent of their use of the resources, where we found a range from those who used them daily to those who never used them. Survey questions varied to some extent from year to year, so annual comparisons are not always possible. Below we cite the year in which the data were reported. All data are drawn from corresponding evaluation reports (Char & Foote, 2009; Char & Berube, 2010; Char & Clark, 2011). The response rate each year was just over 50 percent, with 67 respondents at baseline, 28 in 2009, 83 in 2010, and 148 in 2011.

### Survey Findings

#### **Frequency and Nature of LBIE Mathematics Offerings**

At baseline, approximately 10 percent of LBIEs surveyed had *ever* used mathematics with children in *any* context (Char & Foote, 2009). As one LBIE said in response to an open-ended survey question, "Prior to MotS I didn't think about the role of mathematics in the library, as my personal experience using mathematics wasn't strong or positive" (quoted in Char & Clark, 2011).

In annual surveys, the vast majority of LBIEs reported that, because of MotS resources, they were now using mathematics regularly in a wide range of contexts, with the total amount of mathematics integration skyrocketing. For

instance, in 2010, 74 percent reported integrating mathematics into crafts programs at least monthly, 28 percent doing so at least weekly, and 3 percent daily; 40 percent incorporated mathematics into story times and book clubs at least monthly and 21 percent at least weekly (Char & Berube, 2010).

#### **Talk about Mathematics**

At baseline, talk about mathematics apart from homework was minimal: Only 11 percent of

LBIEs surveyed in 2009 reported *ever* discussing mathematics in everyday life with children; 5 percent said they felt able to explain how mathematics for the elementary grades aligned with the library's mission (Char & Foote, 2009).

After exposure to MotS resources, LBIEs noted a variety of ways in which they wove mathematics into their daily conversations with children: 61 percent reported infusing mathematics into the questions they asked children as they chatted with them; 32 percent now used mathematical language in their library orientations; and 59 percent found occasion to discuss the role of mathematics in everyday life with children at least monthly—with 31 percent doing so weekly and 9 percent daily (Char & Berube, 2010; Char & Clark, 2011). Fifty percent felt confident in their ability to explain how mathematics for the elementary grades aligned with the library mission, a tenfold increase compared to baseline (Char & Clark, 2011; Char & Foote, 2009). These mathematics interactions built on

LBIEs' everyday knowledge of, for example, taking a measurement, reading a simple graph, and estimating a quantity. The MotS resources helped LBIEs to see the relevance of their knowledge to their work with children.

#### **Why LBIEs Incorporated Mathematics**

When asked to rank factors that contributed to these changes in practice, each year the LBIEs' top two reasons were their own commitment to offer mathematics to children and children's interest and demand (Char & Berube, 2010; Char & Clark, 2011). The LBIEs made their choices autonomously: Only 8 percent noted that pressure from a supervisor or

As one LBIE said in response to an open-ended survey question, "Prior to MotS I didn't think about the role of mathematics in the library, as my personal experience using mathematics wasn't strong or positive."

library director was a factor in decisions to begin and sustain use of mathematics in their offerings (Char & Clark, 2011).

LBIes attributed their newfound mathematics commitment to MotS resources, with 90 percent maintaining that they developed a much more positive attitude toward mathematics, 88 percent coming to believe that all librarians should learn more about integrating mathematics into programming for children, and 60 percent noting that including more mathematics is now a strong priority for their libraries (Char & Clark, 2011). As one respondent put it, “I now consider mathematics to be a part of the offerings a library can have” (quoted in Char & Clark, 2011).

The MotS resources not only offered a new vision of mathematics for the library but also gave LBIes a way to realize this vision. No matter their setting, programming themes, and circumstances, they reported that they found activities in the resource bank that enabled them to integrate mathematics into their existing practices. Furthermore, each year, about 50 percent went beyond MOTS resources and, for the first time, created their own mathematics activities (Char & Berube, 2010; Char & Clark, 2011; Char & Foote, 2009).

### **Lasting Changes**

These results were sustained over the three years of surveys, with mathematics becoming integral to LBIes’ programs. For instance, each year, about 90 percent stated that continuing to include mathematics in offerings for the elementary grades was a strong priority, and just over 50 percent reported regularly discussing the role of mathematics in everyday life with children (Char & Berube, 2010; Char & Clark, 2011; Char & Foote, 2009). These results are particularly striking given that the evaluation took place during and immediately following the recession of 2008, with libraries undergoing budget cuts and consequently reducing staff time and programs. Nevertheless, the changes continued over time, lasting well beyond the initial flurry of excitement that can accompany a new educational method or set of resources.

The perception of lasting change is echoed by state and regional library leaders interviewed by the MotS evaluators. One said, “I saw libraries that may have started a bit hesitant at mathematics really open up because the activities made them confident that they could do them with their children” (quoted in Char & Clark, 2011). Another added:

What the project did was make that connection that “I can do what I’m doing regularly, select intentionally books that have a good foundation to talk about math, and have activities that are related.” That was a

change in their behavior and they’re [now] making a conscious effort (quoted in Char & Clark, 2011).

### **Effect on Children**

To assess the effect on children, evaluators surveyed 34 LBIes expressly tasked with homework help and with academic enrichment when homework help is not needed. These LBIes had the option of using MotS resources as a component of their academic enrichment. Unlike children’s librarians, for whom interactions with children comprise only a portion of their daily jobs (with cataloging, reference, collection management, and other tasks consuming much of their time), these LBIes spend their working hours with children and are thus poised to observe the mathematical growth of individual children over time. Their perceptions of changes in children’s attitudes toward mathematics are summarized in Table 3 (next page).

### **Why Choose Mathematics?**

Each out-of-school environment—afterschool program, summer camp, childcare center, or library—has unique affordances and constraints; each is staffed by informal educators with their own traditions, professional practices, and values.

LBIes enjoy a wealth of books, opportunities to offer public programs, and a great deal of autonomy. They must contend with limitations in the degree of mess, movement, and noise they can accommodate and in the extent to which they are available to supervise children. When offered mathematics resources expressly tailored to these realities, LBIes made substantial and long-term changes: They began to weave mathematics into many areas of their practice, regularly shared their everyday mathematics knowledge with children, and came to view mathematics as integral to their work and to children’s engagement and learning. They particularly valued the fact that they could integrate mathematics into their existing areas of strength and expertise, drawing on the themes, projects, and ways of interacting with children they had developed over time to address local interests and needs.

Perhaps, like many informal educators, the LBIes in our study felt strongly all along that children should succeed at mathematics. However, it was not until they encountered resources that honored and built on features of the library setting and on their own unique talents as informal educators that they saw themselves as capable of helping to realize that success.

The MotS resources not only offered a new vision of mathematics for the library but also gave LBIes a way to realize this vision.

**Table 3. Perceptions of Changes in Children Due to Experience with MotS Resources, 2011**

BECAUSE OF MY USE OF MotS RESOURCES, CHILDREN IN MY LIBRARY...	PERCENT (N = 34)
Have gained confidence in mathematics	78%
See mathematics as relevant to everyday life	70%
Have developed mathematics skills	69%
Have gained enthusiasm for mathematics	67%
Can better explain their mathematics ideas	59%

Source: Char & Clark, 2011

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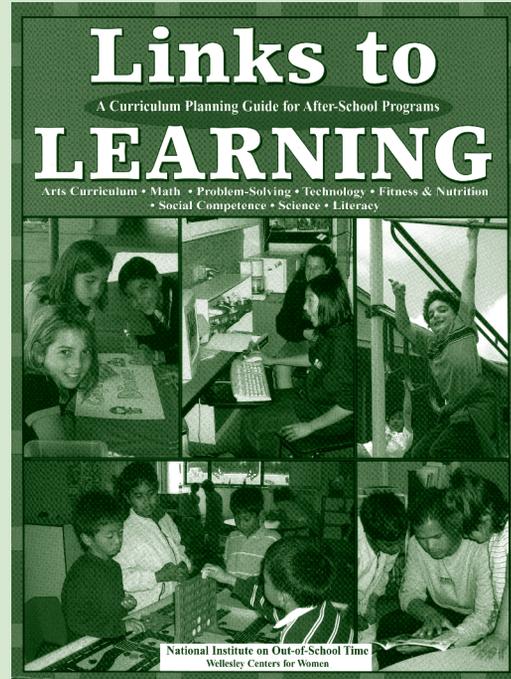
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# effective STEM programs for adolescent girls

## Three Approaches and Many Lessons Learned

by Harriet S. Mosatche, Susan Matloff-Nieves, Linda Kekelis, and Elizabeth K. Lawner

"I learned to create surveys and understand statistics."

"I know how to do research and how researchers work."

"Sometimes it's better to work as a group than individually." "I now see the value of subjects like earth science." These were some of the responses teen girls gave when asked about the most important thing they had learned from their experience in Access for Young Women, a girls' leadership program infused with science, technology, engineering, and math (STEM) content run by Queens Community House in New York City.

Similarly, the comments below come from girls who participated in engineering-focused Techbridge and Girls Go Techbridge programs, which are based in Oakland, California, and have program sites around the country.

"Circuits are really freaking fun."

"I learned that scientists can have hobbies, too."

"Everyone likes the soldering best because no one

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had ever done it before, and you felt responsible because you were using a power tool.”

“It was through Techbridge that I discovered my love for engineering.”

While women’s participation in math and physical science continues to lag to some degree behind that of men, the disparity is much greater in engineering and computer science (National Science Foundation, 2011). A review of over 400 studies related to the possible causes of women’s underrepresentation in STEM (Ceci, Williams, & Barnett, 2009) identified several reasons, including the following:

- More boys than girls perform at the very highest levels in spatial reasoning and math ability, including on so-called “gatekeeper” tests such as the SAT-M and GRE-Q.
- Girls who have high math abilities are more likely than boys who have high math abilities to also have high verbal abilities, giving them more choices of careers to pursue.
- Women who have high math abilities are more likely than men with high math abilities to choose careers in non-math intensive areas. This preference shows up as early as adolescence.

Though boys may outperform girls at the highest levels on math and science standardized tests, girls tend to get better course grades in math and science than boys do (Halpern et al., 2007). Furthermore, SAT-M scores tend to under-predict girls’ success in college math courses. Girls also show less interest in math and science than boys do and have lower confidence in their math abilities, beginning to underestimate their math abilities as they enter middle and high school.

In order to address these barriers, Halpern and colleagues (2007) recommended teaching girls that their academic abilities are malleable, giving them prescriptive and informational feedback, providing high-achieving female role models who overcame initial difficulties, creating an environment that inspires curiosity in order to generate long-term interest in math and science, and making spatial skills training available to girls (Halpern et al., 2007). The first two of these recommendations aim to improve girls’ *confidence* in their abilities in math and science, while the next three focus on increasing their *interest* in math and science. These are important areas for intervention, since perceptions of ability and performance expectations have been found to predict performance and career choices in math (Eccles & Wigfield, 2002).

The results of a study by Brown and Leaper (2010) suggest that academic sexism affects large numbers of girls, although the strength of the effect varies by race, ethnicity, and age. Specifically, European-American girls between 16

and 18 and Latina girls between 13 and 18 who experienced repeated sexist comments about girls’ abilities in math and science had lower perceived competence in those fields than did those who experienced fewer instances of academic sexism. In addition, 16–18-year-old girls, regardless of race or ethnicity, who had experienced several instances of academic sexism valued math and science less than those who experienced fewer such instances.

Research has found that interventions can be useful in increasing girls’ perception of competence in science. Weisgram and Bigler (2007) reported that girls who learned about gender discrimination, including learning about famous female scientists who faced discrimination, increased their confidence in doing science and their belief in the value of science. A synthesis of evaluations of six STEM out-of-school time (OST) programs for girls (Chun & Harris, 2011) suggested that successful programs make STEM activities appealing to all girls, not just those who are already interested in the field, and build personal connections to foster continued interest.

This article focuses on three approaches to STEM in OST that would be instructive for any organization seeking to develop STEM opportunities for teen girls. While Techbridge and Queens Community House focused on reaching populations most underrepresented in STEM—girls of color and those from immigrant and low-income families—the strategies they used could be applied to any population of adolescent girls.

## Techbridge Strategy and Results

Launched by the Chabot Space and Science Center in 2000 with a grant from the National Science Foundation, Techbridge has provided STEM opportunities to more than 3,000 girls, mostly middle school girls in underserved communities. Techbridge offers afterschool and summer programs that include hands-on projects, career exploration, and academic and career guidance in science and engineering to girls in grades 5–12. Techbridge also helps families to encourage their daughters’ pursuits and collaborates with role models and teachers to guide and support girls on their paths to academic and professional fulfillment.

Techbridge projects include Electrical Engineering, in which girls build solar night lights and learn to solder; CleanTech, in which girls build solar cells and learn about renewable energy; and AppInventor, which teaches girls to create their own Android applications. Role models and field trips enhance the girls’ experience by providing real-life examples of STEM careers and helping to dispel stereotypes.

An evaluation of the Techbridge program during the 2010–2011 school year (Ancheta, 2011) gathered pre- and

post-participation surveys for 237 girls. Statistically significant positive changes were registered for these survey statements:

- I know what scientists and people who work in technology do.
- I know what it means to be an engineer.
- I do science-related activities that are not for schoolwork.
- Adults have told me I should think about a career in science, technology, or engineering.
- I have talked to a scientist, engineer, or technology worker about his/her job.

For each of these statements, girls in a comparison group who had not participated in Techbridge showed no statistically significant change from the beginning to the end of the school year (Ancheta, 2011).

The 30 trained teachers who delivered the Techbridge afterschool program all agreed that the program increased their ability to engage girls in technology-, engineering-, and science-related projects as well as their knowledge of other science and technology resources (Ancheta, 2011).

An adaptation of the program, Girls Go Techbridge, began in 2008 with Girl Scout staff and volunteers as facilitators. Now in 15 Girl Scout councils around the country, Girls Go Techbridge provides user-friendly “programs-in-a-box” that allow facilitators to spend their time implementing the programs rather than researching activities and preparing supplies. Each of the five program boxes includes a detailed leader guide with tips for facilitators, ideas for parents, and ways to involve role models, along with all the materials needed for the activities. Power It Up focuses on circuitry and electronics; Make It Green helps girls learn about green building design and energy conservation; Design Time encourages girls to be creative problem-solvers while building toy prototypes; ThrillBuilders asks girls to create a model of an amusement park to introduce them to simple machines; and Engineers to the Rescue allows girls to make a water filter and to build a car prototype that can travel over rough terrain. A camp manager said of the program, “It is refreshing to see that girls are as thrilled doing the Techbridge activities as they are riding horses.”

In 2010–2011, the Girls Go Techbridge program was implemented with Girl Scout councils in four states. Matched pre- and post-participation surveys were available for a diverse group of 1,234 girls, with the largest

number in sixth grade. All statements on the surveys yielded statistically significant positive changes (Mosatche, 2011):

- It is fun to learn about science, technology, and engineering.
- I am good at science.
- I know how circuits work.
- I know about green building materials and design.
- I know about the design process that engineers use to create a product.
- I want to be a scientist or engineer or work in technology when I grow up.
- I know what scientists and engineers do.

One of the most impressive findings was in response to the open-ended question, “What kind of job do you want to have when you are older?” In both program years studied, twice as many participants aspired to be engineers at the end of the program as at the beginning. The percentages of other career choices did not change over time. The comparison group data support the validity of this finding, since few respondents chose engineering (Mosatche, 2010, 2011).

### Access for Young Women Strategy and Results

The Queens Community House (QCH), formerly Forest Hills Community House, was founded in 1974 in Queens, New York City, as a multiservice organization serving all ages. In 1993, QCH initiated Access for Young Women (AFYW) to promote gender equity. The program’s initial goal was to address barriers in the organization’s teen recreation programs, which were serving twice as many teen boys as girls. After several years of using a gender-specific approach to youth development and risk prevention, QCH began to focus on gender equity in education by engaging girls in research and analysis of their own conditions. In 1998,

the organization developed a comprehensive 20-session leadership and advocacy curriculum for girls ages 12–18. Participants learned about gender equity, Title IX, sexual harassment, body image, and women’s rights. Other elements of the program were counseling, college advising, SAT preparation courses, career panels, and summer video and photography classes. The following year, AFYW participants led an annual conference, researching topics of interest and creating presentations. Additional innovative curricula were created in future years to engage returning

Techbridge projects include Electrical Engineering, in which girls build solar night lights and learn to solder; CleanTech, in which girls build solar cells and learn about renewable energy; and ApplInventor, which teaches girls to create their own Android applications.

participants. The program expanded to new sites at public high schools and community centers around Queens.

In 2005, with growing public attention to the importance of STEM and new funding for STEM education, AFYW added an emphasis on science and math to its leadership focus. New topics included discovering math and science in everyday life and using research to advocate for oneself and others. Participants conducted a social experiment to learn about the scientific method and the language of research (Mosatche & Lawner, 2010a). Later, tutoring sessions in math and science were added. The STEM focus in AFYW has consistently been on using the scientific method in the social and natural sciences and on using technology for research and presentations.

Unique to the success of AFYW is that it has been promoted as a leadership program, which appeals to girls who are not already interested in STEM. Through the leadership curriculum, girls learn how societal ideas about gender roles influence their choices. STEM engagement occurs through projects that apply STEM skills and concepts in ways with which the girls are already comfortable, such as using computers or planning their weekend activities. In this way, girls who do not initially think they are interested become engaged in STEM. The explicit focus on recognizing and analyzing gender inequity may assist girls in overcoming hurdles if they later enter STEM fields.

From 2005 to 2009, AFYW participants completed pre- and post-participation surveys each year. In total, 121 matched pre- and post-participation survey pairs were identified, with some girls completing multiple surveys from multiple years in the program. Participants' perceptions of their knowledge of gender equity topics increased significantly over time; in some instances, more than one year was needed before significant change occurred. Statistically higher ratings occurred on post-participation surveys for the following (Mosatche & Lawner, 2010b):

- How much do you know about Title IX?
- I am comfortable speaking in front of a group, for example, at an assembly or in a class presentation.
- Women can succeed in careers in science, math, and technology.
- I am a leader at school.

Observations of the culminating conferences have consistently demonstrated participants' mastery of the tools of scientific inquiry, use of data in research, and

presentation skills. An end-of-year survey conducted by QCH staff in 2011 showed that 51 percent of girls were enrolling in advanced coursework in STEM, including Advanced Placement and honors-level courses in subjects such as chemistry, calculus, and physics. The survey also found that 45 percent of participants who had regularly attended the program for at least one year improved their technology skills, such as using the Internet for research, creating online presentations, and editing videos.

Since survey data pick up only some of the program impact, the evaluation of AFYW also included case histories developed over a period of at least three years. Ann (a pseudonym) was one of the teens profiled throughout her four years of participation in AFYW. During her first three years in

the program, Ann was adamant that she wanted to be a prosecutor, a career aspiration she had maintained since elementary school when she became concerned about the high rate of crime in her neighborhood. In addition to regularly attending weekly program sessions, Ann was always present whenever AFYW held a special workshop or outside event. In

her senior year of high school, Ann won the second prize in the science fair at her school, at which 4,000 students were enrolled—an achievement for which her years of experience doing research and conducting workshops at the annual AFYW conference prepared her. Ann has just completed her first year of college with a major in math, a choice she attributes to her experience in AFYW.

### Similarities and Differences

Table 1 summarizes the similarities and differences among Techbridge, Girls Go Techbridge, and AFYW.

### Challenges and Lessons Learned

While the Techbridge and AFYW programs have in many ways been successful in supporting girls' interest in STEM, both organizations have learned critical lessons they have used to revise the programs to better meet the needs of the girls they serve.

### Training Facilitators

Techbridge and QCH program results demonstrate the importance of having facilitators who are comfortable with both STEM and adolescent girls. Teacher participation is key to the success of Techbridge's afterschool programs. Teachers help recruit a diverse group of girls, including many who might not think they are "smart enough" to do science or

Unique to the success of AFYW is that it has been promoted as a leadership program, which appeals to girls who are not already interested in STEM.

**Table 1. Comparison of Three STEM Programs for Girls**

	<b>TECHBRIDGE</b>	<b>GIRLS GO TECHBRIDGE</b>	<b>ACCESS FOR YOUNG WOMEN</b>
<b>AGE LEVEL</b>	Grades 5–12	Middle school	Grades 7–12
<b>LOCATION</b>	California	13 states	Queens, New York City
<b>FACILITATORS</b>	Teachers and Techbridge program coordinators	Girl Scout council volunteers and staff	Social workers and youth workers
<b>PROGRAM DURATION</b>	One to six years	One day to one year	One to six years
<b>SUBJECT EMPHASIS</b>	Engineering, science, technology	Engineering, science	Leadership skills, science, math, technology
<b>SETTINGS</b>	Afterschool program in schools	Resident and day camp, afterschool program in schools, Girl Scout troop meeting, large-scale council event	Afterschool program in schools or community centers with a community-based summer component
<b>SPECIAL FEATURES</b>	Hands-on activities, interactions with role models, career exploration, field trips	Hands-on activities, interactions with role models, career exploration	Leadership activities, including a girl-led research conference; science and math tutoring; college visits
<b>EVALUATION METHODS</b>	Pre- and post-surveys of participants, comparison students, parents, and teachers; focus groups and interviews of girls, parents, and teachers; program observations	Pre- and post-surveys of participants, comparison students, and Girl Scout adult facilitators; focus groups and interviews of girls, parents, and Girl Scout council staff and volunteers; program observations	Pre- and post-surveys of participants; interviews of parents and staff; focus groups with participants; structured observations of program sessions and annual conference; case histories

work with technology. Many teachers have STEM expertise; they reinforce content knowledge and make connections between school and OST learning. However, Techbridge has found that teachers must maintain the “fun factor.” Program coordinators and teachers debrief after each session to ensure that they strike the right balance between

holding girls to high expectations while giving them freedom to socialize and to enjoy STEM activities.

Training is a critical component of Girls Go Techbridge. Though some program sessions are led by engineers and scientists, many are facilitated by Girl Scout staff and volunteers who do not have STEM backgrounds. Training

gives them hands-on experience with the activities girls in their groups will do. Adults leave the training feeling confident that they can facilitate sessions on such topics as electricity and simple machines. After being trained, one volunteer said, “I look forward to helping girls become stronger and smart and confident in themselves.”

When Queens Community House hired social workers who also had some academic STEM background to facilitate the program, these staff members were able to integrate science and math concepts into the leadership curriculum, thereby fostering girls’ confidence in their mastery of those subjects. A master teacher with decades of teen outreach experience assumed supervision of the program; though he did not have a STEM background, he was able to develop the instructional and engagement skills of program staff. AFYW facilitators were also expected to attend professional development events throughout the year. One participant, Tammy (a pseudonym), was observed at the beginning of the year to be totally disengaged from the group. She did not converse with her peers or participate in group discussions. Gradually, with the constant support of the experienced facilitator, Tammy began to open up. Several months into the program, Tammy was engaged in research with two other participants, preparing for the annual conference. At the conference, Tammy enthusiastically shared findings with the audience and answered questions with great confidence.

### ***Working Effectively with Teen Girls***

Techbridge teachers, Girl Scout staff and volunteers in Girls Go Techbridge, and AFYW facilitators are trained not only to deliver content but also to interact effectively with teen girls. Both organizations recognize that facilitators play a critical role in participants’ engagement, achievement, and retention in their programs. An AFYW participant explained this concept succinctly: “Whether I like math or science depends on who’s teaching it.”

Girls in focus groups said they would like facilitators to be “cool,” meaning that they understand the issues adolescents face and are knowledgeable about contemporary adolescent culture, without pretending to be teens. Girls also want adults to be comfortable with STEM subject matter but willing to admit when they don’t know an answer. In those situations, good facilitators demonstrate problem-

solving strategies. Many of the girls in these three programs are being exposed to complex ideas that are new to them. They need facilitators who do not judge them, but rather help them to feel comfortable trying out new ways of looking at problems or testing innovative strategies. A key strategy is asking questions: “How would you change that to make it go faster?” or “Where could you find information about that topic?” The facilitators’ questions and their encouragement inspire girls to explore and experiment.

Many girls talked about the importance of a sense of humor. Teen girls are not required to attend OST STEM programs, so, if they’re being led by adults who lack a sense of humor or a compassionate attitude, they will find something else to do. Warmth, commitment, and willingness to stand by teens even when confronted with challenging behavior are essential qualities. As in the example of Tammy’s growing engagement, staff members need gentle persistence, a caring attitude, and skill in handling overt challenges and passive avoidance.

### ***Developing Collaborations***

Collaboration in many forms is a key feature of the Techbridge and QCH programs. Outside partners have included museums, foundations, and companies that provided funding, STEM role models, or both. Local colleges and universities have been a source of program volunteers—both faculty and students—and have enabled girls to envision themselves in higher education and in STEM careers. Such partners provide girls with experiences beyond their local neighborhoods.

Girls Go Techbridge helps Girl Scout councils expand their outreach programs while building their capacity to deliver STEM programming. The program-in-a-box idea works well for partner groups, such as the Society of Women Engineers (SWE). At a Texas Girls Go Techbridge event, a SWE volunteer said, “We don’t have to develop programs any longer. This organization has done it for us.”

Another form of collaboration that was essential for all three programs was the opportunity for girls to work together. While many STEM programs, such as science fairs, are competitive, girls generally prefer more collaborative relationships (Kirk & Zander, 2002). In focus groups, program participants have consistently indicated that they prefer working with others to working on their own. Pairs of girls typically work together on Techbridge activities, each learning from the other’s questions and

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strategies. Girls who finish activities early internalize and demonstrate the Techbridge philosophy of offering support to those who are struggling with a step. While working together, the girls jointly discover that mistakes are part of the scientific process and that errors can lead to more effective problem solving. Participants in Techbridge programs recounted that some of their most memorable moments were during difficult projects, when they were challenged by failures but didn't feel alone in the process.

In AFYW, pairs or small teams of girls worked together for months to prepare for their conference workshops. By receiving ongoing feedback and encouragement from their partners, girls learned to persist at a task and improve their communication skills. The opportunity to explore and learn together is an important aspect of the program. Answers are not given to participants—they learn as much or more by what they do when things do not go as planned as when answers come to them readily. DeHaan (2011) noted that the most effective science teaching involves creative thinking and peer-to-peer interaction.

### ***Creating an Engaging and Relevant Curriculum***

“You need to connect science and math to real-life situations,” said one AFYW participant. The most successful activities in the Techbridge and AFYW programs are those that are hands on and relevant to girls' lives. For instance, participants in the Make It Green project in the two Techbridge programs learn conservation and recycling strategies they can use immediately at home, at school, and in the community. Participants who learned to solder as part of a project on circuitry realized they could use this skill to fix broken objects at home. One Girls Go Techbridge participant explained, “You learn concepts in science and math in school, but you never really apply them until you do something like this.” AFYW participants choose conference workshop topics that are important to them and their community. In 2011, one group decided to focus on teen dating violence. When they checked out statistics, they understood these findings in the context of their own lives and saw vital connections between research and real-world problems.

### ***Exploring STEM in Depth and Long Term***

Techbridge and QCH have developed curricula that provide girls with intensive STEM experiences. Participants who attend AFYW regularly develop relationships with

facilitators and peers; they also build on what they have already learned to reach a higher level of understanding. Evaluation data collected from AFYW participants found that those who attended the program for two years showed greater change in such areas as recognition that women can succeed in STEM careers than did girls who completed one year (Mosatche & Lawner, 2010b).

Techbridge requires a year-long commitment, and many girls return for multiple years across transitions from elementary to middle to high school. The longer girls participated in Techbridge, the more likely they were to report that they were good at technology and that they wanted to work in science, engineering, or technology (Ancheta, 2011). Though Girls Go Techbridge may be implemented in intensive short-term sessions, such as one-day special events, the program has also been offered over the course of a year in afterschool sessions. Moreover, when a topic like the engineering design process is included in several projects, girls who participate in more than one venue—perhaps a series of Girl Scout troop meetings as well as a one-week camp session—experience repeated exposure to that subject, a process that fosters learning and better retention.

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### ***Inspiring Career Exploration***

Both Techbridge and AFYW programs emphasize career exploration. Continuous integration of career information—particularly about engineering—with hands-on activities sets Techbridge apart from other STEM programs. Techbridge discovered through early focus groups that, though the girls enjoyed the projects, many regarded them as hobby activities rather than career prospects (Kekelis, Ancheta, & Heber, 2005). During the first year of Girls Go Techbridge, career activities were the least used. Focus groups and interviews with girls and facilitators pinpointed the reasons that these activities were not very popular, such as being too “school-like” or not interactive enough (Mosatche, 2010), so Techbridge staff developed new strategies to integrate career information in a more engaging way. For example, girls might take on roles as environmental engineers to filter polluted water, using a real environmental engineer's description of the process she would use.

College visits and career exploration were integrated into AFYW. For example, one curriculum session included a game that helped girls recognize the many contributions made by women in STEM throughout history. College

preparation activities, including free SAT classes as well as college application and financial aid assistance, were available to program participants.

### **Exposing Participants to Role Models**

Though hands-on activities can spark an interest in STEM, role models are instrumental in getting girls interested in technical careers. Since many Techbridge and AFYW girls are the first in their families to pursue higher education and professional careers, they do not have role models at home who work in STEM fields and can encourage them to follow in their footsteps. Furthermore, for most middle school and high school girls, science teachers are the only STEM role models they see. However, those teachers are not necessarily teaching in the fields in which they majored in college. Even if they are STEM experts, teachers with large classes and limited time are not likely to share information about their backgrounds, hobbies, and challenges.

Techbridge, Girls Go Techbridge, and AFYW expose adolescent girls to a variety of role models. Female STEM experts help to facilitate program sessions, serve on career panels, and even meet informally with girls during lunch and question-and-answer sessions. Having discovered that role models need guidance to be effective, Techbridge developed a training module to ensure that STEM experts understand program content and ways of working with adolescent girls (Countryman, Kekelis, & Wei, 2009; Kekelis & Wei, 2010). When role models show that they have interesting lives outside their labs or other work environments, they begin to dispel girls' negative stereotypes about scientists and engineers. The most effective role models are likely to be those who come from backgrounds similar to those of the participants; the similarity can encourage girls to imagine that they could be in those positions one day (Zirkel, 2002). The current demographics of the STEM workforce make recruiting such role models a challenge. Techbridge has been very explicit in its requests to partners for role models from ethnic and socioeconomic groups that are underrepresented in STEM fields.

Exposure to STEM role models who reflect the participants' communities is an area that AFYW staff members have identified as needing improvement. As a community-based organization, QCH has had limited access to professional organizations of women in STEM or women in university

STEM research centers, but that is the kind of support the program needs.

### **Enhancing the Program through Field Trips**

Because adolescent girls are interested in exploring new venues, both Techbridge and QCH set up field trips so girls can see STEM work environments and interact with women in these workplaces. Trips to colleges include tours of laboratories, technology centers, and research facilities. Girls meet female college students who are majoring in and excited about working in STEM. Effective field trips should offer more than just a tour of a facility. Personal connections with role models and hands-on activities during field trips help girls gain interest in STEM careers. Techbridge has developed and disseminated training and resources to support field trips for STEM programs.

Field trips also give participants a chance to bond with one another, fostering a sense of community as STEM explorers and building a supportive peer group within and outside the program. In addition to field trips, AFYW participants can attend six-week summer programs focused on developing technology skills in video and photography. These programs include visits to college campuses, which give girls a chance to recognize that becoming a college student can be a realistic part of their future.

### **Learning from Mistakes**

Having been in existence for more than 10 years, the Techbridge and AFYW programs have had many

opportunities to learn from their successes and their mistakes. Both organizations were consistently interested in girls' ideas for improvement. In focus groups and interviews, girls were asked such questions as:

- What suggestions do you have for improving this program?
- What would you like the adults to do differently?
- What grade would you give this program? Why?
- Would you recommend this program to your friends? Why or why not?

Participant comments during activities—"This is boring" or "There's too much to read"—led to changes in implementation. Adolescents constantly remind OST program developers and evaluators that activities must hold their interest, be fun, and not "feel like school." The

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lessons discussed in this article can help the field learn how better to support girls' engagement in OST STEM.

Successful STEM programs also encourage participants to learn from their mistakes. Girls learn that persevering in the face of unclear results, mistakes in procedures, and dead ends is vital in making progress. One Techbridge participant explained, "You learn a lot probably because a lot of the times, the experiments don't work. So you have to figure it out—what I did wrong and what I need to do to fix it." That's a lesson all of us working in OST STEM programs need to remember.

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# implementing out-of-school time STEM resources

## Best Practices from Public Television

by Christine Andrews Paulsen

Business leaders, educators, and government leaders agree that, in order for the United States to retain its standing as a world leader, public and private institutions need to work together to develop a well-qualified workforce in science, technology, engineering, and mathematics (STEM). However, the number of graduates with STEM degrees has not been equal to the need, partly because many students arrive at college unprepared to handle math and science (U.S. Department of Commerce, 2012).

In response to this crisis, billions of dollars have been invested in the public and private sectors to bolster children's academic achievement in STEM, to fuel their interest in STEM activities, and to foster their desire to pursue STEM in college and as a career (U.S. Government Accountability Office, 2012). Though many of these investments are going into formal

classroom programs, others target children in out-of-school time (OST) settings including afterschool programs, scout troops, museums, science centers, parks, zoos, aquaria, and homes.

In 2009, the National Research Council (NRC) argued, "Programs, especially during out-of-school time, afford a special opportunity to expand science learning experiences for millions of children" (NRC, 2009, p. 5). The report also says:

Science media, in the form of radio, television, the Internet, and hand-held devices, are pervasive and make science information increasingly available to people across venues for science learning. Science

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media are qualitatively shaping people's relationship with science and are new means of supporting science learning. (NRC, 2009, p. 3)

The National Science Foundation (NSF) has funded many programs to enable public media producers, including public television (TV) stations, to provide children's STEM programming in OST settings. These projects typically include a children's TV series (animated or not) aired on the Public Broadcasting Service (PBS), plus resources,

such as hands-on activity guides and educator toolkits, to support STEM learning in OST settings. Evaluation studies have demonstrated the positive impact of educational TV on children's STEM learning outcomes (Fisch, Lesh, & Crespo, 2010). This conclusion is echoed in a recent NRC report, which states that "the evidence is strong for the impact of educational television on science learning" (NRC, 2009, p. 3). Studies have also demonstrated the positive effect of the TV programs' STEM-related OST resources on children and OST practitioners. Educational

**Table 1. PBS Programs Reviewed**

PROGRAM	DATES PRODUCED	TARGET AUDIENCES	STEM CONCEPTS COVERED	PAPERS REVIEWED
<i>DragonflyTV</i>	2002–2009	9–12-year-olds	Science	Apley, 2006; Apley, 2008; Flagg, 2009; Robles, Helms, & Phillips, 2009
<i>SciGirls</i> ( <i>DragonflyTV</i> spinoff)	2010–present	8–12-year-old girls	Science	Flagg, 2012; Knight-Williams & Williams, 2008
<i>Cyberchase</i>	2002–2012	8–12-year-olds	Math	Apley, Graham, & Goldman, 2010; Fisch, 2006; Flagg, 2003a, 2003b
<i>ZOOM</i>	1999–2005	5–11-year-olds	Science, math, engineering	Goodman, 2005
<i>FETCH!</i>	2006–2010	6–10-year-olds	Science, math, engineering	Londhe, Kochman, & Goodman, 2007; Londhe, Pylvainen, & Goodman, 2009; Paulsen & Bransfield, 2009; Paulsen & Carroll, 2011; Paulsen & Goff, 2006
<i>Design Squad</i>	2007–2011	9–12-year-olds	Engineering	Vaughan, Pressman, & Goodman, 2007
<i>Design Squad Nation</i> ( <i>Design Squad</i> spinoff)	Since 2011	9–12-year-olds	Engineering	Paulsen, Green, & Carroll, 2011

TV programs offer children the opportunity to experience the same content across multiple contexts—home, camp, school—increasing the likelihood that they will experience a transfer of learning from one situation to the next (Fisch et al., 2010; Knight-Williams & Williams, 2008; Londhe, Pylvainen, & Goodman, 2009).

This paper explores the lessons learned from seven such programs and their NSF-funded outreach initiatives: *DragonflyTV* and *SciGirls*, produced by Twin Cities Public Television (TPT) in Minnesota; *Cyberchase*, produced by Thirteen in association with WNET in New York; and *FETCH! with Ruff Ruffman*, *ZOOM*, *Design Squad*, and *Design Squad Nation*, all produced by WGBH in Boston.<sup>1</sup> Evaluations of these programs and their supporting materials yield recommendations both on the content and format of OST STEM resources for elementary and middle school children and on outreach to engage target audiences. The promising practices outlined here can guide resource developers and practitioners as they create STEM resources or implement them in OST programming.

## Methodology and Resources Reviewed

As shown in Table 1, all seven programs reviewed in this article aired on PBS stations in the early 2000s; all were targeted to children at the elementary or early middle school level. To compile promising practices from these programs and their associated resources, I reviewed published and unpublished evaluations and then followed up with the programs' producers to verify program details and confirm my interpretation of the lessons learned.

The programs offered a wide variety of elementary- and middle school-level STEM resources to OST organizations and at-home audiences. All of the resources were available at no charge; however, some activities did require the purchase of materials or supplies, an issue discussed below. Generally, the programs offered the following types of resources for informal STEM learning:

- **Television episodes** offered online or on physical media
- **Educator guides** to leading hands-on STEM activities with children
- **Activity sheets** instructing children to do hands-on STEM activities
- **Activity kits** containing activity sheets, educator guides, and, in some cases, materials such as seed packets
- **Club guides** for 6–12 weeks' worth of structured or semi-structured STEM programming, including detailed instructions on how to lead STEM activities; activity sheets with instructions for children; and additional materials such as certificates, membership cards, and posters

- **Activity cards** providing families with quick ideas for doing STEM activities at home
- **Websites** featuring additional materials and, in some cases, opportunities to share work with others
- **Promotional materials**, such as advertising content, posters, flyers, costumes for characters in the TV programs, stickers, and tattoos
- **Online or in-person training** for OST practitioners

In addition to these tangible resources, public TV stations also offered grants or in-kind support to community partners for STEM events and activities. The stations' outreach teams supported partners with workshops or technical assistance on STEM concepts and national standards, setting up a STEM program or integrating STEM resources into existing programs, and managing groups of children. Exhibits in museums or science centers and overnight events in museum or camp settings rounded out the offerings.

## Promising Practices for Implementing STEM Resources in OST

The promising practices suggested by the seven public TV programs and their associated materials are generalizable across many kinds of programs and resources. The recommendations fall into two main categories:

- Content and format of OST STEM resources
- Outreach to and collaboration with OST communities

### Content and Format of OST STEM Resources

Whether they are media producers, curriculum developers, or practitioners introducing STEM activities in their own programs, people who develop and use OST STEM resources should consider these recommendations:

- Understand the audiences' needs.
- Evaluate STEM resources before and after implementation.
- Require only inexpensive, easy-to-find supplies for STEM activities, and provide options or alternatives.
- Require minimal preparation time.
- Ensure that paper-based resources, such as children's activity sheets, are available and are easy to reproduce.
- Provide opportunities for adapting or modifying activities based on the young people's skill level or other factors.
- Include support for OST practitioners.
- Promote effective use of video.
- Make STEM activities fun, creative, and as game-like as possible.
- Consider safety when designing and delivering STEM activities.

## Audience Needs

Review of the PBS programs suggests that, during the planning phase, developers of OST STEM resources must gather data—even anecdotal data—about the needs of the target audiences, including both the OST practitioners who will facilitate the activities and the children who will participate in them. Different communities have different priorities, demographic compositions, and available resources. During the needs assessment, developers must learn what audience members know and want to know about STEM. Also important are whether practitioners and children are comfortable engaging in STEM activities and whether programs have access to necessary resources including funding, in-kind donations, staff, volunteers—even storage space. Undertaking a needs assessment early in the development process can ensure that the materials are on target and appropriate for various audiences, including children of different ages and practitioners with varying amounts of experience with leading STEM activities. The needs assessment keeps developers from wasting time and financial resources by having to go back to the drawing board if the resources are not well received (Apley et al., 2010; Fisch, 2006; Goodman, 2005; Paulsen et al., 2011).

Understanding audience needs can also help OST practitioners as they deliver STEM programs to elementary and middle school children. Practitioners who have identified their children's literacy levels, prior experiences with STEM, and motivation to learn about STEM may save valuable time because they can tailor the program to children's needs *before* delivering the program and discovering too late that the program was not appropriate for their group.

## Evaluation Before and After Implementation

STEM resources should be evaluated both before and after implementation. Pilot testing before implementation offers an opportunity to try out STEM resources to ensure that they are usable and accessible (Goodman, 2005; Paulsen et al., 2011). It also enables OST STEM resource developers to ensure that the messages and content are on target and have a good chance of meeting audience needs. Data from an evaluation conducted

after the resources are used can drive informed decisions about program impacts and improvements (Apley et al., 2010; Knight-Williams & Williams, 2008). As the needs of elementary and middle school children change over time, the OST resources need to evolve to meet those changing needs.

OST practitioners should also review STEM resources before implementing them to ensure that they understand how to use them and to get clarification if necessary. Practitioners should consider sharing feedback on the OST STEM resources with the developers in order to inform improvements to future materials.

Undertaking a needs assessment early in the development process can ensure that the materials are on target and appropriate for various audiences, including children of different ages and practitioners with varying amounts of experience with leading STEM activities.

## Accessible Supplies

Many OST settings, including low-income households, have limited budgets for purchasing supplies for STEM activities. In addition, OST practitioners typically have little time to hunt for special supplies that are not readily available (Goodman, 2005; Knight-Williams & Williams, 2008). The *FETCH!* camp guide evaluation found that camp counselors preferred that the suggested list of materials have a

list of optional items or alternative materials for supplies that were harder to come by, such as pH strips (Paulsen & Carroll, 2011). In another example, *ZOOM* activities require materials that cost only \$25 for a group of 20 children (Goodman, 2005). OST practitioners should allow sufficient time to search the Web for the least expensive sources of materials, especially if local sources are scarce.

## Minimal Preparation Time

OST practitioners in the programs I reviewed reported they had little preparation time for STEM activities. Many worked only part-time and were not paid for preparation time, so they had little motivation to spend significant time preparing for a single activity. For example, activity leaders did not want to cut toothpicks in half for *Cyberchase* Workshops-in-a-Box (Flagg, 2003a; Goodman, 2005). To ease the burden on OST practitioners, elementary and middle school OST STEM resource developers should ensure that materials for each activity are easy to find and prepare. Pilot testing should provide some idea of the preparation time required for each activity. In one example, the *FETCH!* camp guide evaluation found that a single shopping list, rather than lists of materials with

each activity, would have made the process of collecting supplies more efficient for camp counselors (Paulsen & Carroll, 2011).

### Ease of Reproduction

Few OST settings have access to large color printers capable of reproducing oversized or colorful materials. STEM resources, such as children's activity sheets, should be provided as simple, two-color documents. For example, the ZOOM activities were designed in black and white specifically so that they were easy to photocopy (Goodman, 2005). The *SciGirls* activity guide evaluation found that, though 70 percent of practitioners who used the guides used both digital and hard copies, the remaining 30 percent relied solely on hard copies (Flagg, 2012).

### Adaptable Activities

OST STEM resource developers should ensure that activities can be modified or adapted to match the children's skill levels or other factors (Apley et al., 2010; Flagg, 2003a, 2009; Goodman, 2005; Knight-Williams & Williams, 2008; Londhe et al., 2007; Paulsen et al., 2011). OST programs often mix age groups, whether by design or out of necessity because of space and time limitations. STEM resources developed for fifth-graders may be used in a setting that also includes third-graders. Other factors include group sizes and the skill level of activity leaders. For example, one OST program may have a trained engineer leading STEM activities, while another relies on parents or volunteers.

To ensure that all elementary and middle school programs can benefit, STEM resources should include recommendations for use in different settings and with different sizes of groups. For example, ZOOM developed two formats for its hands-on activities: "'Workshop' activities are for small groups [fewer than 20 participants] and last 30–45 minutes each. 'Event' activities are for larger groups and last 15–20 minutes each" (Goodman, 2005, p. 8). Also, because attrition in OST settings is so common, it's important to design activities that don't rely on participation over an extended time.

Resources should also include recommendations for use with children of different ages or skill levels. For instance, OST practitioners may want to separate children into age groups for the purposes of completing STEM

activities. Alternatively, they may pair children who are close in age or assign older children to act as mentors to younger children.

### Practitioner Support

Whenever possible, OST practitioners leading STEM activities should be trained, whether online or in person, to prepare for activities ahead of time and to help children work in a self-directed manner (Flagg, 2003a, 2009; Knight-Williams & Williams, 2008). At a minimum, they should receive written or electronic information to help them learn about STEM content, national STEM standards, and other information. Evaluations of the *FETCH!* online training and the *Design Squad* educator's guide both found that practitioners were more comfortable leading STEM activities after receiving training (Paulsen & Bransfield, 2009; Vaughan, et al., 2007). In the *SciGirls* outreach evaluation (using investigations from *DragonflyTV*), one participant requested that activity guides be "a little more content-oriented so that if an OST practitioner wanted to use the materials and didn't have the background...you could reference other [content] areas" (Knight-Williams & Williams, 2008, p. 50).

Each of the ZOOM facilitator guides gives adult facilitators information about how to model and facilitate inquiry-based science activities, background about science content along with child-friendly explanations, suggested questions

to ask children to help guide investigation and draw out science concepts and process, group management tips, connections to related ZOOM science activities, and ideas for extending an activity (Goodman, 2005).

### Use of Video

The evaluations I reviewed show that combining media with outreach is a powerful way to deliver engaging STEM content in OST settings. Video is best used to introduce science concepts or to model the science inquiry process (Knight-Williams & Williams, 2008; Paulsen et al., 2011). In evaluating the use of *DragonflyTV* video in classrooms, Rockman and colleagues (2003) found that playing complete half-hour episodes was rarely effective. Rather, video was more effective when used to stimulate discussion and inspire engagement in related hands-on activities. When practitioners used video clips to pose a

To ensure that all elementary and middle school programs can benefit, STEM resources should include recommendations for use in different settings and with different sizes of groups.

question, allowed students to explore their own answers, and then played the rest of the video, they observed increased engagement and improved understanding of the process of inquiry (Rockman, 2003).

Despite the potential of video to engage children in STEM learning, its use may not be possible in some OST settings (Knight-Williams & Williams, 2008; Paulsen et al., 2011). In addition to technological problems, videos' depiction of resources or environments radically different from those of the OST program may prevent the use of videos (Knight-Williams & Williams, 2008). In the *Cyberchase Workshops-in-a-Box* evaluation, some leaders had trouble playing videotapes, so they couldn't access instructions that were included there (Flagg, 2003a).

### Fun, Creative Activities

In the *Workshops-in-a-Box* evaluation, children reported that they enjoyed the “academic” activities less than the game-like ones—even though all the activities taught math concepts (Flagg, 2003a). The *Cyberchase* at-home evaluation found that the math activities resonated with children because they were presented as magic tricks rather than as math problems (Flagg, 2003b). An evaluation of the *FETCH!* activity guide in camps found that the appeal of the activities lay in children's perception that they were fun (Paulsen & Goff, 2006). Children in the *Design Squad Nation* evaluation reported that they enjoyed the at-home activities because they required creativity and did not feel like schoolwork (Paulsen et al., 2011). Therefore, rather than positioning STEM activities as math, science, or engineering tasks, OST practitioners should try presenting them as games.

### Safety Considerations

The *ZOOM* evaluation recommended that activities *never* “include a heat source or any dangerous tools or substances, encourage items to be thrown in the air, or require large bodies of water” (Goodman, 2005, p. 8). The *FETCH!* camp guide evaluation further suggested that activities should not include dangerous substances like ammonia (Paulsen & Carroll, 2011).

When practitioners used video clips to pose a question, allowed students to explore their own answers, and then played the rest of the video, they observed increased engagement and improved understanding of the process of inquiry.

### Outreach to and Collaboration with OST Partners

In addition to the content and format of the resources themselves, evaluations of the seven programs suggest that the other key to success is to work closely with OST partners. My review uncovered the following promising practices:

- Focus on the shared mission to encourage OST partners to implement STEM activities.
- Consider local or national partner relationships as a leverage point to reach a wider audience.
- Look for ways to maintain long-term relationships with local OST organizations.
- Clarify expectations at the outset about participants' roles and responsibilities.
- Recognize that OST organizations may see publicity value in using STEM resources designed for a nationally broadcast program.
- Consider providing OST organizations with financial or in-kind support to implement STEM activities.

### Shared Mission

In order to encourage OST partners to implement STEM programs, resource developers can clearly align their activities with the OST organizations' missions (Apley, 2006; Robles et al., 2009). In the case of *DragonflyTV*, “recognizing that the two sets of partners [the show producer and an OST museum collaborator] shared a common mission was crucial in building trust and understanding, and in allowing these quickly established and intense partnerships to move ahead” (Apley, 2006, p. 10).

### Partnerships and Wider Audiences

One goal of all the programs reviewed was to reach out to the largest possible audiences. STEM resource developers can use established local partnerships as leverage to reach out to a wider community (Apley et al., 2010). For example, by partnering with a local Boys & Girls Club to develop resources, a STEM resource developer may be able to use the relationship to gain credibility and establish contact with other Boys & Girls Clubs and distribute the resources to clubs outside its local sphere. Partnerships with local or national STEM professionals may also be helpful. Some programs found that corporate partners offered volunteers who helped staff the STEM programs or provided mentoring. *ZOOM* reached out to engineers by establishing partnerships with national engineering soci-

eties. “National professional organizations are an effective way to begin creating relationships with non-traditional practitioners who might be interested in providing informal educational experiences to children” (Goodman, 2005, p. 10).

### Long-Term Relationships

The *ZOOM* evaluation highlights the importance of maintaining long-term relationships with OST partners:

Sustained partnerships are a key component to ensuring the use of outreach materials. Throughout its history, the *ZOOM* outreach team has maintained relationships with existing outreach partners even while adding new partners of interest....These partnerships were maintained because the *ZOOM* team actively communicated with individual sites to learn about their needs and to refresh their materials each season. (Goodman, 2005, p. 10)

Regular updates of materials also figured in the *FETCH!* Lab evaluation, which recommended refreshing content annually in order to sustain both visitor interest in the *FETCH!* Labs and the relationship between the TV station and its OST partners (Londhe et al., 2007). Other ways to sustain relationships included enlisting STEM professional partners to offer supplementary in-kind or financial support, tutors, or much-needed supplies.

### Clear Expectations

Partnerships with OST organizations go more smoothly when resource developers clarify expectations about participants’ roles and responsibilities at the outset (Apley et al., 2010). Being proactive about roles at the start of collaboration prevents communication problems later in the partnership. For example, the evaluation of the *DragonflyTV* museum collaboration notes that “partners on both sides of the collaboration often began with little understanding of the other institution’s organizational structure or the roles and relationships of different positions within the organizations” (Apley, 2006, p. 16). However, these relationships improved over time with better communication around roles and expectations (Apley et al., 2010).

### Publicity Value

Some OST practitioners may see collaboration with a nationally broadcast program as an “opportunity to boost their reputations within their own professional and local communities” (Apley, 2008, p. 13). One museum representative commented, “When you are a small museum, unless you are the only game in town, there is a lot of competition. I want people to think of us as often as they think of the Museum of Science in Boston. When you engage in projects like this, other museums take notice” (Apley, 2008, p. 14). Some museums looked to *DragonflyTV* as a means of driving viewers to their

Some OST practitioners may see collaboration with a nationally broadcast program as an “opportunity to boost their reputations within their own professional and local communities.”

doors. An OST practitioner noted, “[M]y hope is we get kids who might not otherwise visit a living museum [zoo or aquarium]” (Apley, 2006, p. 11).

### Financial or In-Kind Support

Offsetting costs for materials, resources, and staff time can be helpful to OST partners (Apley et al., 2010). In the *DragonflyTV SciGirls* outreach evaluation, one OST practitioner noted, “There were some financial constraints.... We definitely could have used more money for science equipment, supplies, etc.” (Knight-Williams & Williams, 2008, p. 19). The *FETCH!* Labs evaluation found that the most significant challenges faced by museum partners related to monetary issues. *FETCH!* Labs faced constant lack of adequate funding. Although this issue did not prevent implementation of the *FETCH!* program, it manifested in other ways, such as shortage of staff and inadequate promotional efforts (Londhe et al., 2007).

### Next Steps

This paper describes best practices gleaned from the experience of seven PBS TV programs and their distribution of STEM resources for use in OST settings. The STEM resources I reviewed varied from facilitator guides to on-line trainings, but one common element was the use of media, specifically TV programs. The evaluations of these programs reveal the power of media and its potential usefulness for teaching children about STEM in OST settings.

However, my review also uncovered gaps in our knowledge about the use of media, particularly videos. Thus, there is an opportunity for future research and evaluation to explore further the use of video in OST settings. Some potential research questions include:

- What are the differences between animated and live-action video with respect to STEM learning outcomes? Does the impact vary by children's age group, gender, or other factors?
- How feasible is the use of video in OST settings? What types of settings—for example, libraries vs. scout troops—are more likely to be able to use video in a meaningful way? What formats are most feasible? For example, are DVDs more or less likely to be used than downloadable videos?
- What is the optimal viewing time before the videos lose their ability to engage children? Does this time vary by children's age or other factors?
- What is the effect of empowering children to create their own STEM-related videos in OST settings? The popularity of websites like YouTube speaks to the ability of video to engage children. Future studies should explore the difference between limiting children to the role of passive observers vs. empowering them to create videos for STEM learning.

Researchers also have the opportunity to explore other whether other media can be used effectively in OST settings to deliver STEM content. They might look at whether technology-based media like websites and smartphone apps add value over more conventional technologies such as activity guides.

My review found that one of the major obstacles to providing STEM programming in OST settings, and the reason that public TV programs have included in-kind or financial support in their outreach efforts, has been lack of resources. Perhaps, with more research evidence to back them up, policymakers and funders will find ways to provide more significant funding for STEM programming in OST settings, supporting practitioners in engaging children in STEM learning, and, ultimately, increasing our chances of nurturing a generation of future STEM professionals.

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## Note

<sup>1</sup> ZOOM (NSF 9614743, 9814956, 0003651, 0125641, 0229796, 0337323, 0452485), *FETCH!* with Ruff Ruffman (NSF 0610406, 0714741, 0813513, 0840307), *Design Squad* (NSF 0515526, 0810996, 0917495), *Cyberchase* (NSF 9909404, 0206195, 0307763, 0407065, 0540279, 0638962, 0741683, 0840274, 1010981) and *DragonflyTV/SciGirls* (NSF 9909828, 0125738, 0741749).



# variations on a theme

## Characteristics of Out-of-School Time Science Programs Offered by Distinct Organization Types

by Sandra L. Laursen, Heather Thiry, Tim Archie, and Rebecca Crane

The out-of-school time (OST) domain offers a promising resource for enriching young people's experience of science, technology, and engineering (Afterschool Alliance, 2004). Belief is widespread that OST programs are ideal locations in which to learn science and that youth participation may increase access to science for underrepresented groups, such as girls or minorities, and enhance the science workforce (Afterschool Alliance, 2004; Afterschool Alliance & Coalition for Science After School, 2008; Chi, Freeman, & Lee, 2008; Congressional Commission, 2000; Friedman & James, 2007).

Indeed, many afterschool programs do offer science activities.<sup>1</sup> For example, an evaluation of the 21st Century Community Learning Centers program reported that 70 percent offered some science (Learning Point Associates, 2006); perhaps 10–15 percent were exclusively science-focused (N. Naftzger, personal communication).

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The Coalition for Science After School found that 88 percent of programs in its network offered science activities, yet most offered 40 or fewer hours of science programming per year (Chi et al., 2008).

Despite this broad interest, we know rather little about the scope or nature of OST youth programming focused on science (Chi et al., 2008). Friedman (2008) identifies several reasons for the inadequate state of knowledge. Variety poses a challenge for researchers, with OST sites in schools, museums, zoos, science and nature centers, aquariums, planetariums, and community centers; formats include afterschool clubs, camps, workshops, festivals, research apprenticeships, and more. Moreover, there is no single national network through which researchers might recruit nationally representative samples of programs. Diversity of activities and content in programs, as well as in the frequency, timing, and duration of programming, also make it difficult to study OST science. Thus, to date there have been no large-scale, national studies of characteristics or formats of science-focused OST programs.

These issues also complicate study of the youth outcomes of OST science. Most research and evaluation studies have documented youth outcomes at a single site. These studies have broadened our understanding of how youth engage with science in the afterschool space by documenting positive outcomes such as:

- Science learning: scientific concepts; technical, data-gathering, and analysis skills (e. g., Bell, Blair, Crawford, & Lederman, 2003; Bleicher, 1996; Etkina, Matilsky, & Lawrence, 2003; Ritchie & Rigano, 1996)
- Gains in teamwork and communication (Diamond, St. John, Cleary, & Librero, 1987; Ritchie & Rigano, 1996)
- Affective outcomes: positive emotions; growth of confidence, curiosity, or interest (Barab & Hay, 2001; Bouillion & Gomez, 2001; Diamond et al., 1987; Stake & Mares, 2001, 2005)
- Changes in identity: seeing oneself as a scientist; seeing science as relevant to everyday life; clarifying career ideas (Bouillion & Gomez, 2001; Diamond et al., 1987; Fadigan & Hammrich, 2004; Richmond & Kurth, 1999)
- Changes to life paths, such as greater likelihood of pursuing STEM undergraduate degrees and careers (Afterschool Alliance, 2011; Chi, Snow, Lee, & Lyon, 2011)

These science-specific outcomes augment more general benefits documented in the youth development literature (Catalano, Berglund, Ryan, Lonczak, & Hawkins, 2004),

such as reduction of risky behaviors and promotion of academic performance (Eccles, Barber, Stone, & Hunt, 2003). Variations by student characteristics—such as gender, age, and socioeconomic status—as well as by program design and implementation are important but less fully studied (Dubois, Doolittle, Yates, Silverthorn, & Tebes, 2006; Halpern, 2005; Rahm, Martel-Reny, & Moore, 2005).

Such findings suggest that engaging in well-designed science OST programs benefits participants. Early development of interest and competence in science, as well as exposure to professional role models and authentic experiences, may be important precursors that lead participants to take more, and more rigorous, science and mathematics courses in school, graduate from high school, and pursue degrees or jobs in science and technical fields. These fields offer well-paid, secure employment (Langdon, McKittrick, Beede, Khan, & Doms, 2011) and collectively generate innovation that fuels the nation's economy, improves human health, solves environmental challenges, and strengthens national security (Members of the 2005 “Rising Above the Gathering Storm” Committee, 2010).

Given these potential personal and societal benefits, it is essential to understand the design, structure, content, and goals of such programs. Only then can we hope to elucidate the conditions under which OST science programs may or may not achieve good outcomes for participants, thus identifying evidence-based “best practices” for the field. Such information also helps to determine the extent of youths’ access to these experiences and to identify local and national opportunities to deepen and broaden access. Guided by similar thinking, recent efforts to “map” the OST landscape have explored youth exposure to science in general afterschool programs (Chi et al., 2008; Means, House, & Llorente, 2011; Noam et al., 2010). These studies have found that typical afterschool programs struggle to provide science programming because of a lack of resources and knowledge and limited access to professional development. They don't establish whether or how the same issues arise in OST programs that are specifically focused on science.

Several recent studies have mapped particular segments of the OST science community, taking the first steps to increase understanding of this domain and generating some insight into common program characteristics and concerns. For example, a recent survey of OST science programs serving older youth suggested that the majority target underserved students (Porro, 2010). Typical program elements include teamwork, inquiry-based learning, career awareness, and mentoring. An effort to map the diverse portfolio of projects funded by the National Sci-

ence Foundation's Innovative Technology Experiences for Students and Teachers (ITEST) program documented that many of these projects rely on partner organizations and a mix of volunteers and paid staff to serve varied audiences including educators, researchers, youth, and policymakers (Parker, Na'im, & Schamberg, 2010). Like the programs for older youth, many ITEST projects serve underrepresented minority youth. The projects encompass a variety of program designs and formats, including summer, afterschool, and weekend programming; online or social networking components; and youth employment or internships. Finally, a study of youth science programs in museums and science centers (Sneider, 2010) found that these organizations provide a "wide range of learning experiences" for youth. Many science center programs serve older youth, provide adult mentors, and encourage youth, in turn, to teach the general public or to mentor younger students (Sneider, 2010).

Each of these recent mapping efforts focuses on a single segment of the OST science landscape; together they begin to reveal important characteristics and common threads that run across programs. However, to date there has been no systematic study of the broader landscape of OST science programming. Our national study, Mapping Out-of-School Time Science (MOST-Science), begins to fill this lacuna by examining a national sample of OST programs focused on science, engineering, or technology. Our research questions are:

- What features describe the landscape of U.S. science-focused OST programming?
- How do programs vary by activities, populations served, duration and frequency, desired outcomes, and other key factors?
- What patterns in these variables help to characterize current program offerings and define areas of future opportunity?

In this paper, we describe initial findings about the characteristics of these programs and their home organizations, including aspects of program design, structure, funding, staffing, and youth audience. We then discuss how organization types differ in these program aspects and draw out implications for practice.

However, to date there has been no systematic study of the broader landscape of OST science programming. Our national study, Mapping Out-of-School Time Science (MOST-Science), begins to fill this lacuna by examining a national sample of OST programs focused on science, engineering, or technology.

## Study Methods

To collect data for this study, we invited OST science program directors to fill out an online questionnaire.

## Questionnaire Development

Questionnaire items were developed based on our research questions and on data from more than 40 interviews conducted with OST science program directors and with well-placed leaders and observers in the field. The items were reviewed by several experts and then piloted by several program directors. After refining the questionnaire based on this feedback, we launched it online using FileMaker's Instant Web Publishing feature.

The questionnaire distinguished between the host organization and the one or more programs it runs. Respondents could enter multiple programs offered by their organization. The survey included sections addressing:

- The organization's location and type and the respondent's position in it
- The organization's connections: partnering organizations, funding sources, national networks
- Engagement in program evaluation
- Program title and history
- Program audience
- Program structure and fees
- Program content and staffing
- Any arrangement of programs into "ladders" or sequences for youth progressing in age and ability

Altogether, the survey included 126 items in 10 main sections. Because many questions depended on prior answers, respondents moved through the questionnaire in a non-linear fashion and did not answer all questions about each of their programs. Contact us for copies of the questionnaire items.

## Sampling

We established six criteria to bound our study sample, including programs that:

- Focus on science, engineering, or technology, as defined by the respondent
- Include youth in or entering grade 6 or higher

- Engage youth with their peers or the public
- Involve youth for multiple sessions
- Have existed for one year or longer
- Take place outside of school time

We selected these sampling criteria based on our research questions. We focused on the middle and high school years as the time when students' science interests may decline or strengthen and when students begin to make decisions about future careers (Tai, Liu, Maltese, & Fan, 2006). In naming our study MOST-Science, we used the term *science* broadly, including technology and engineering as well as life, physical, Earth, and space sciences. Disciplinary distinctions are often not firm at the lower levels of this grade range; they may matter more to adults than to young people. We excluded mathematics-focused programs based on our interest in engaging youth in hands-on investigation and design experiences, because these features are less often found in math programs. Finally, our choice to focus on group-oriented programs reflects our interest in the role of collaborative learning in youth outcomes.

The questionnaire was launched in November 2011 and closed in June 2012. We distributed the questionnaire through multiple mechanisms, trying to reach the widest possible sample. Invitations were issued through e-mail distribution lists and newsletters, direct e-mail invitations, our professional and personal networks, "MOSTcards" distributed at meetings and conferences, and social media.

In all, we sent nearly 2,300 e-mail invitations, more than 1,900 of which went to specific OST science programs. More than 300 additional invitations reached well-connected individuals in informal, K–12, after-school, and higher education and in diversity initiatives across engineering and science disciplines. We know that some of these individuals shared our invitation with their own networks and that some programs received multiple invitations. However, we have no way to assess how many people representing how many programs received an invitation, so we cannot compute a response rate for the questionnaire. Our final data set includes 712 programs from 45 states, of which 417 programs (59 percent) met all six sampling criteria and answered one or more questions pertinent to this analysis. The sample size for any particular result varies, as not all respondents answered every question.

We cleaned these data, removing write-in responses for future analysis before importing the quantitative data into the SPSS 20 statistical package, which we used to calculate means, frequencies, and percentages for the organization- and program-level data.

## How Do Program Features Vary by Organization Type?

We first describe the types of organizations contributing programs to our sample. We then examine how typical program characteristics vary across organization types, including aspects of the programs' youth audience, structure, and financial support.

### Types of Organizations Hosting OST Science Programs

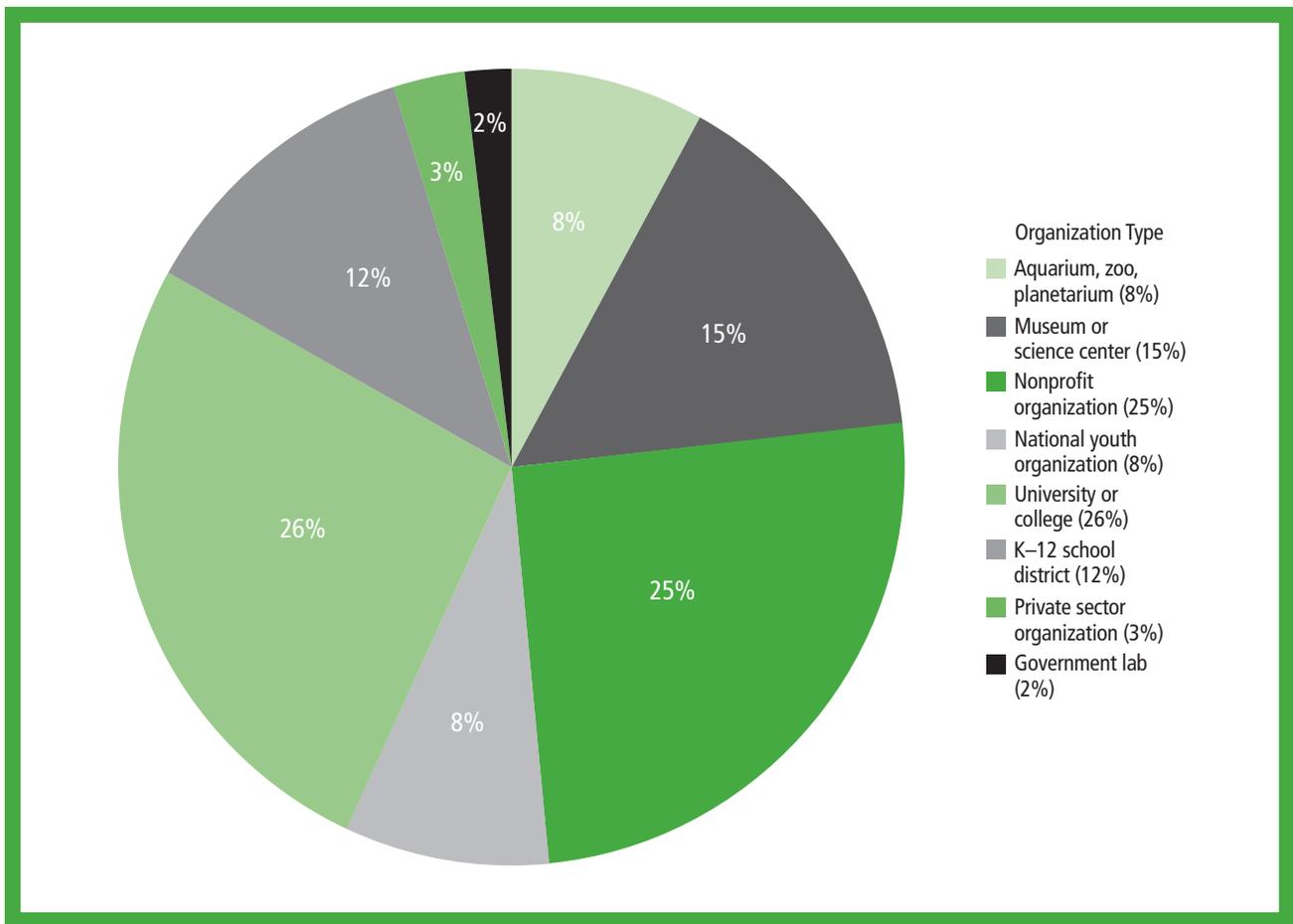
We collected data from 417 programs and classified their host institutions into eight organization types, as shown in Figure 1 (page 40). Respondents were asked to report on all of their organization's OST program offerings; some reported on a single program while others supplied data for up to six program offerings.

Roughly half of all programs in our sample were represented by just two organization types: nonprofit organizations and universities and colleges. Programs least represented in the sample were those hosted by private sector organizations and by government laboratories such as those run by the Departments of Energy, Commerce, and Defense. The majority of programs offered by private sector organizations were private summer camps, a fact that provides context for other results for this organization type.<sup>2</sup> We do not argue that this sample represents the distribution of OST science programs nationally. However, the breadth of the sample does enable us to examine differences in programs by their organization type.

### Contact Time for Youth Participants

We asked about the annual contact hours for an "average participant" in each program. Some programs likely reported based on actual records, while other programs reported best guesses that included variation in a typical participant's choices. Approximately half of all programs reported that their youth participants averaged 80 hours or fewer in a year, while half reported 80 hours or more. Approximately 25 percent of programs reported average annual contact hours over 200. Responses ranged as low as four hours and as high as 740 hours.

The average number of program contact hours differed widely by organization type, as shown in Figure 2 (page 41). Nonprofit organizations provided programs with more contact hours than did any other organization type. Programs in two categories, K–12 school districts and government labs, averaged 100 or fewer contact hours per year, with programs provided by government labs reporting the lowest average. Overall, contact time was high, in-



**Figure 1. Percentage of Programs by Organization Type (N = 417)**

dicating that many programs offered youth an experience of substantial depth; this finding also reflects our choice to exclude single-day programs.

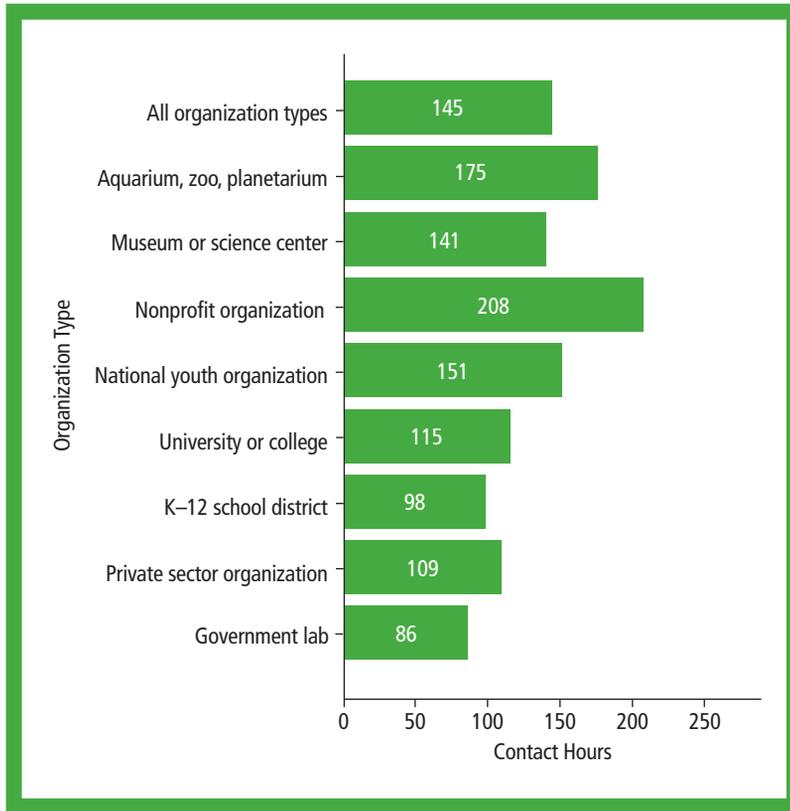
### **Characteristics of Program Populations**

We asked organizations to report the annual youth population for each program they described. The average population for each organization type is shown in Figure 3 (page 41). Private sector organizations showed a dramatically higher average annual population than all other organization types, at nearly 800. Approximately 90 percent of private sector programs were summer camps, which typically offer multiple sessions to large numbers of participants. Nonprofit organizations reported the next largest population, while programs offered by K-12 school districts served the fewest participants. These programs are likely limited to students in a particular district, whereas other organizations may recruit from a larger pool of participants. Programs by all other organization types served similar numbers of participants per year, at 100–200 youth.

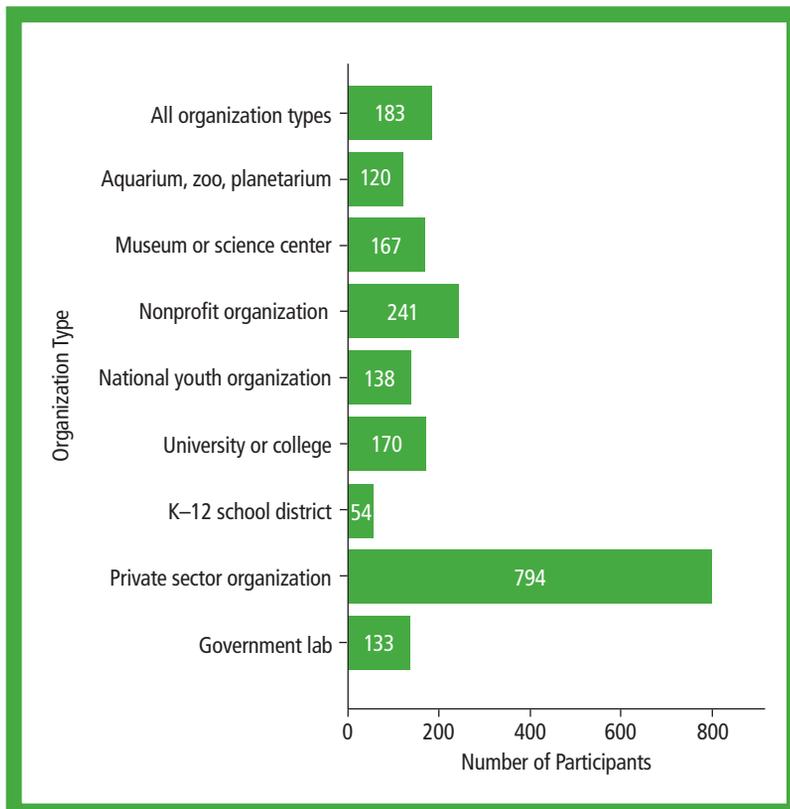
### **Demographics of Youth Participants**

We asked respondents to report the average demographics of their program participants by gender and ethnicity, as shown in Table 1 (page 42). On average, most programs across organization types served a high proportion of girls, 56 percent. National youth organizations reported the highest proportion of girls, at 82 percent, while private organizations, school districts, and government labs reported the lowest proportions, near 40 percent. All other organization types reported significant proportions of girl participants, perhaps indicating that many programs focus on engaging girls in science.

Overall, programs by nonprofit organizations served the most ethnically diverse populations, while programs by K-12 school districts and by aquariums, zoos, and planetariums served the least ethnically diverse populations. Private sector organizations and government labs reported programs with the highest average proportion of Asian students, while national youth organizations served the smallest proportion of Asian students. Programs by nonprofit organizations served the highest proportion of



**Figure 2. Average Annual Program Participant Contact Hours by Organization Type (N = 350)**



**Figure 3. Average Annual Program Population by Organization Type (N = 341)**

Black and Latino participants, while government labs served the lowest proportion. These results do not take into account program locations and variations in local populations.

### Target Youth Audience

We sought to understand whether and how organizations targeted specific youth audiences or included all types of youth (Figure 4, page 43). Respondents reported on whether their program targeted girls, underrepresented minorities, youth with disabilities, and gifted and talented youth. The targeted audience may differ from a program's actual audience, depending on the local population, the success of its outreach and recruiting, and whether it includes non-targeted groups.

In general, girls were most commonly targeted, followed by underrepresented minorities, gifted and talented youth, and youth with disabilities. National youth organizations most frequently targeted girls, with 67 percent of programs thus directed. This finding reflects the gender-specific nature of some national youth organizations, such as Girl Scouts and Girls Inc.

Underrepresented minorities were targeted by programs across all organization types, with nonprofit organizations targeting minority youth at the highest rate (49 percent) and national youth organizations at the lowest rate (10 percent). Gifted and talented youth were targeted by programs of all organization types except national youth organizations and government labs. Youth with disabilities were targeted less frequently than any other group. No government lab reported targeting these youth; they were most often targeted by private sector organizations (27 percent) and K-12 school districts (23 percent).

Overall, national youth organizations appeared to more often identify girls as a target audience than did other organizations. Government labs and aquariums, zoos, and planetariums less often defined any target audience than did other organization types, with no group targeted by more than 20 percent of organizations. In future work, we plan to look at these characteristics in relation to the organization's scope and mission, considering is-

**Table 1. Average Percentage of Program Participants by Gender and by Ethnicity, by Organization Type (N = 327)**

ORGANIZATION TYPE	GIRLS	ASIAN	BLACK	LATINO	MULTI-RACIAL	NATIVE AMERICAN	OTHER	WHITE
Aquarium, zoo, planetarium	60.6%	12.5%	14.8%	11.8%	4.6%	0.9%	1.5%	58.4%
Museum or science center	57.9%	9.6%	25.6%	16.9%	6.0%	2.2%	4.4%	49.0%
Nonprofit organization	56.2%	8.3%	35.6%	33.7%	8.2%	3.0%	6.6%	26.6%
National youth organization	82.3%	3.3%	19.6%	28.3%	6.6%	3.7%	3.3%	48.4%
University or college	57.8%	11.6%	19.9%	17.5%	4.9%	3.2%	2.6%	49.3%
K–12 school district	40.2%	18.6%	10.2%	13.6%	5.7%	0.5%	2.8%	61.5%
Private sector organization	40.0%	23.7%	9.7%	10.4%	11.8%	2.6%	7.0%	49.8%
Government lab	42.6%	23.3%	7.0%	10.0%	6.0%	0.3%	0.5%	45.4%
All organization types	56.1%	12.0%	22.5%	20.8%	6.2%	2.4%	3.8%	46.9%

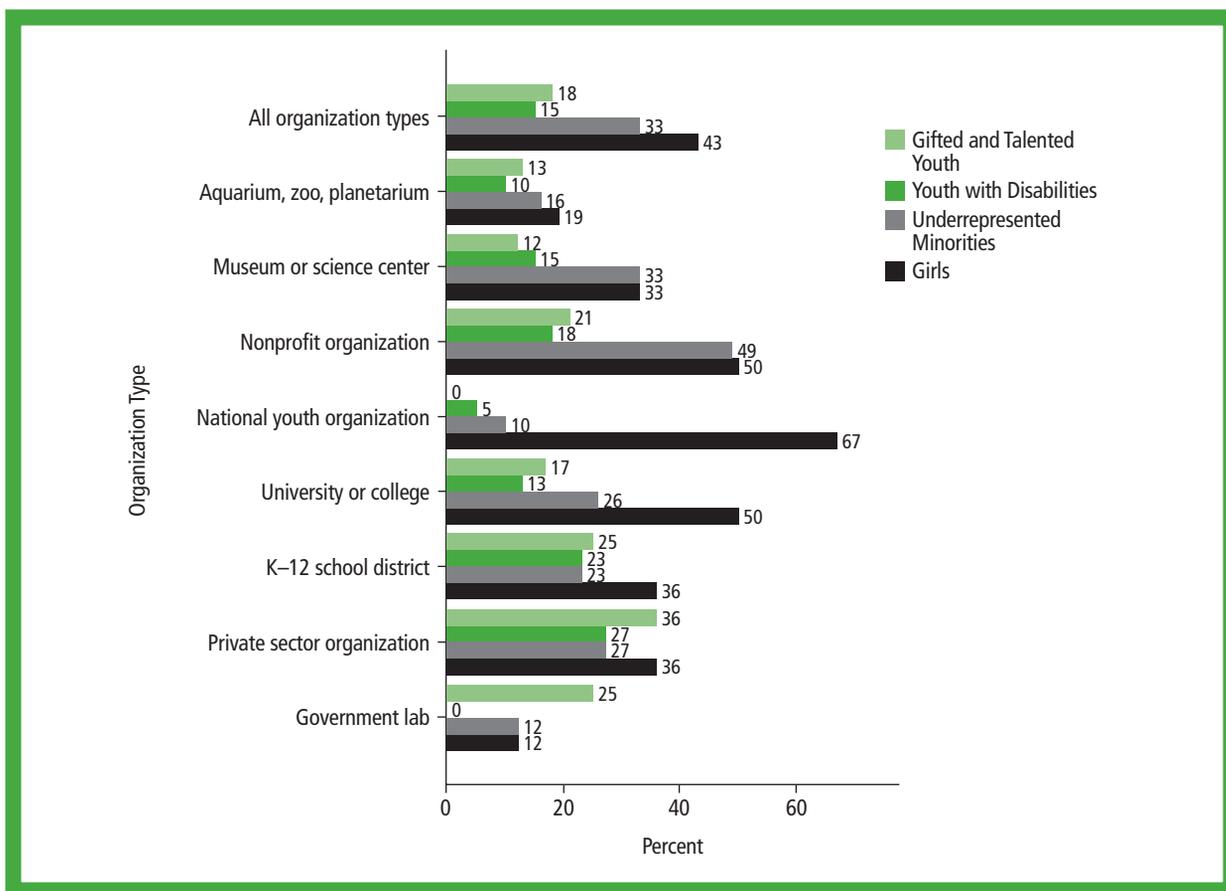
Note: Average percentages, as reported by respondents, do not total 100%.

sues such as expectations of publicly funded institutions, differences between scientific and educationally focused organizations, and the ability of local organizations to target specific local needs.

### **Financial Support of Youth Participants**

To understand the range of program practices intended to support youth financially, we asked organizations about fee structures and scholarship opportunities (Table 2, page 44). Respondents were asked both whether participants pay, do not pay, or are paid a stipend to participate

in their programs and whether scholarships are offered. Overall, the most common practice was to neither charge nor pay youth. National youth organization programs were most likely to require participants to pay (67 percent), but 85 percent of these also offered scholarships, a high proportion relative to other organization types. Our findings show that private sector programs were the least accessible for low-income participants. These programs often required participants to pay (38 percent) and were least likely to provide scholarships (33 percent).



**Figure 4. Average Percentage of Programs Identifying Specific Target Audiences, by Organization Type (N = 350)**

### ***Institutional Support: Funding and Networks***

In addition to the financial support of youth, we asked organizations to report on support for their programs at the institutional level by public and private funders (Figure 5). Overall, respondents reported that their programs were supported by zero to seven outside funding sources. On average, about half of the organization types were supported by more than two public and two private funders. The rest were supported by one or two public and private funders. In general, larger organizations had more funding sources than did smaller organizations.

One interesting exception to this general rule is shown in the programs offered by national youth organizations, which averaged just over one public and one private funder each. This finding suggests a reason that these programs often charge youth to participate, as reported in the previous section. It may also mean that external funding is sought by the national organization rather than by the local chapters that responded to our questionnaire.

We also asked respondents to report on professional affiliations related to their organization and programs (Figure 6). On average, all organization types reported at least one professional affiliation, with a maximum of seven. Museums, science centers, aquariums, zoos, planetariums, and

nonprofit organizations typically reported two to three professional affiliations, while all other organization types reported one to two professional affiliations. K-12 school districts, national youth organizations, and government labs appeared less well networked than were other organization types.

### ***Staffing and Professional Development***

We asked several questions about staffing and professional development in organizations. When asked if they had at least one full-time staff member, 90 percent of organizations that answered this question reported that they did. Private sector organizations reported the lowest levels of full-time staff, at 43 percent, reflecting a reliance of summer camps on seasonal staff.

Almost all (99 percent) organizations that responded reported that they had at least one staff member with an education background, and 99 percent also reported at least one staff member with a background in a scientific or technical field. National youth organizations reported the lowest rate of staff with science backgrounds (90 percent). We did not gather data on the percentage of staff who had education or science backgrounds, only on their presence.

All organizations reported providing initial training for employees; however, the opportunities for ongoing

	FEE STRUCTURE			SCHOLARSHIP	
	YOUTH PAY	YOUTH ARE PAID A STIPEND	YOUTH DO NOT PAY	NO SCHOLARSHIP OFFERED	SCHOLARSHIP OFFERED
AQUARIUM, ZOO, PLANETARIUM	9%	18%	73%	35%	65%
MUSEUM OR SCIENCE CENTER	26%	22%	52%	11%	89%
NONPROFIT ORGANIZATION	23%	13%	64%	40%	60%
NATIONAL YOUTH ORGANIZATION	67%	5%	29%	15%	85%
UNIVERSITY OR COLLEGE	21%	32%	46%	11%	89%
K-12 SCHOOL DISTRICT	18%	3%	79%	47%	53%
PRIVATE SECTOR ORGANIZATION	38%	0%	62%	57%	33%
GOVERNMENT LAB	0%	29%	71%	50%	50%
ALL ORGANIZATION TYPES	26%	17%	58%	26%	74%

**Table 2. Program Fees and Scholarships by Organization Type (N = 260)**

training varied across organization types. Roughly 50 percent of K-12 school districts provided ongoing training for program staff, while the average for all other organization types was better than 75 percent. The lower rate of staff training in K-12-based programs may reflect the use of teachers, who are assumed to have pedagogical or science content background, as staff.

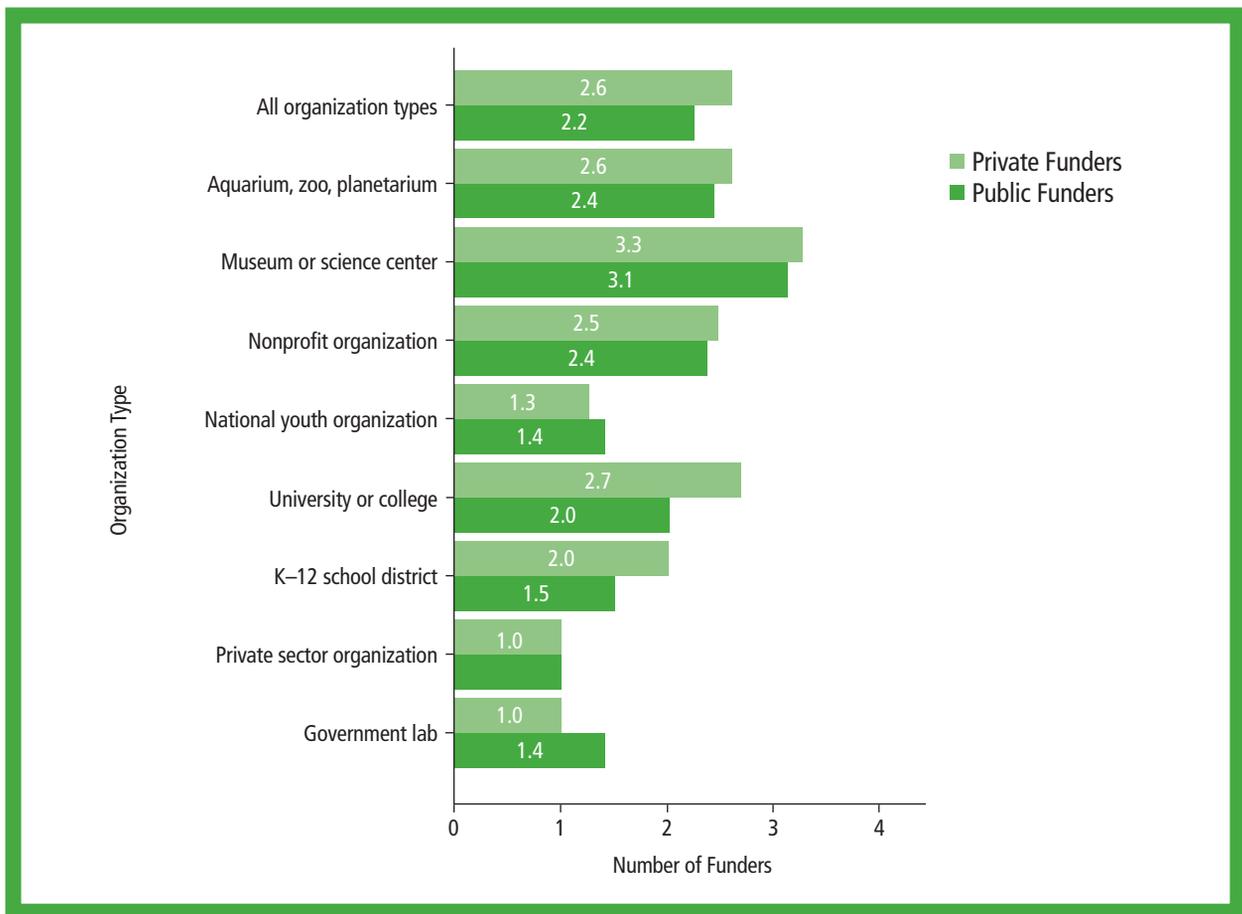
### What Features Distinguish Programs Offered by Specific Types of Organizations?

In the previous section, we discussed results for each questionnaire domain by organization type. When considering the cumulative results for each organization type, certain features stand out as distinguishing.

Several organization types showed features that relate to their dual expertise in science and education. For example, museums and science centers offered programs with

above-average contact hours and average annual program populations to a fairly diverse and often specifically targeted audience. Programs from these organizations were commonly quite accessible in terms of their fee structure and scholarship availability. They drew upon a large number of public and private funders and were well networked. Staff were more often full time, educated in relevant areas, and trained for their program duties, reflecting the dual scientific and educational missions of these institutions. Though often operating at more modest scales, programs from aquariums, zoos, and planetariums showed similar features. Programs from colleges and universities likewise reflect the scientific, educational, and logistical expertise typically available in higher education institutions.

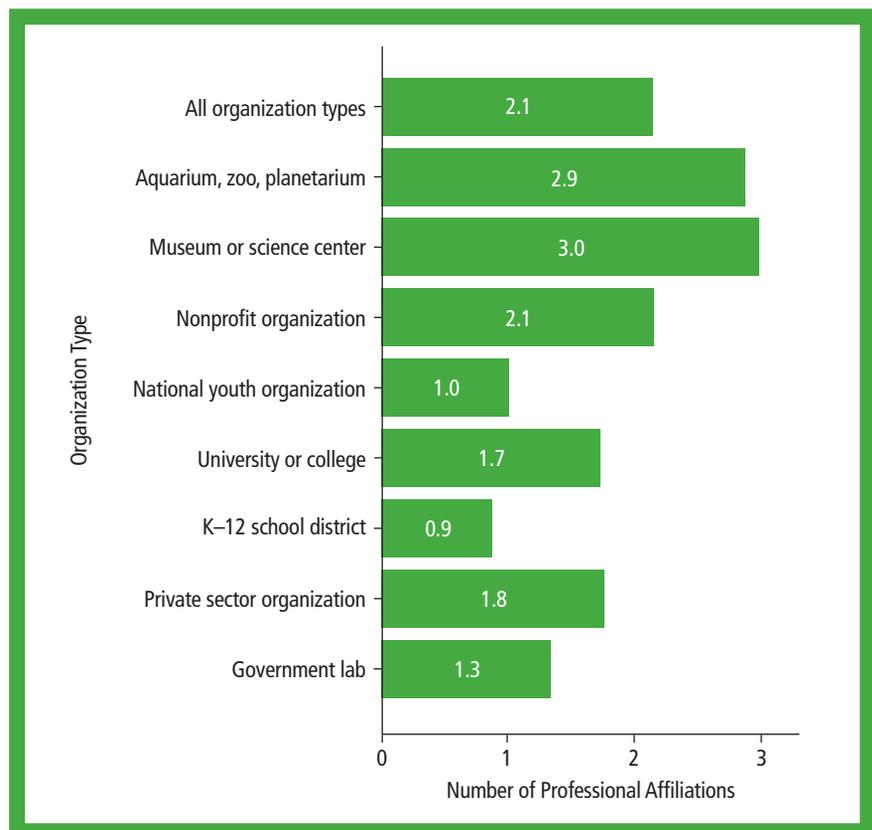
A different set of strengths was exhibited by programs that were most effective in reaching large and diverse youth audiences. For example, nonprofit organizations offered the



**Figure 5. Average Number of Program Funders by Organization Type (N = 208)**

highest number of contact hours to a high number of participants per year, suggesting the high local impact of their programs. They often targeted minority youth or girls and accordingly served the most diverse audiences. Programs offered by nonprofit organizations were generally accessible in terms of fee structure and scholarship opportunities as compared to those offered by other organization types. They generally had an above-average number of funders, were well networked, and were staffed with educated and trained personnel.

Similarly, national youth organizations also provided an above-average number of contact hours to a smaller yet diverse audience. Many of the organizations we surveyed were



**Figure 6. Average Number of Professional Affiliations (N = 207)**

gender-specific and thus targeted girls at a much higher rate than did other organization types. Though these organizations required youth to pay for programs more often than did other types, this requirement was ameliorated by the high rate at which they offered scholarships. Among national youth organizations, personnel less often included individuals with STEM backgrounds than did personnel from any other organization type. These features of nonprofits and national youth organizations may be typical of organizations that emphasize positive youth development.

Programs hosted by K–12 school districts provided below-average contact hours to the smallest number of annual participants. They also had the least ethnically diverse participants, despite often targeting all underrepresented groups. Such targeting may not translate into program participation if these groups are not well represented in the school district. School-district-based programs provided fewer opportunities for ongoing training compared to other organization types. These characteristics may reflect variation in the designs and missions of school-based programs, ranging, for example, from academically focused programs focused on closing an achievement gap in the district to small science clubs spearheaded by a single teacher.

Comparing these features highlights the potential for mutually beneficial partnerships between organizations of different types—for example, to meld the scientific resources of a museum with the ability of a local nonprofit to reach underserved students of color or to draw on university outreach to provide programming for local and regional chapters of a national youth organization. The data also suggest potential for science-focused organizations to partner with K–12 school districts on OST programming.

### Implications for Practice

This study is the first to distinguish characteristics of youth OST science programs by organization type. Leaders of science-focused OST programs might use the characteristics of these programs to benchmark their own activities. Differences among programs sponsored by other types of organizations may not be evident to those working in a particular sector. Moreover, because

organizations may be networked primarily with others of a similar type, characteristics held in common across organization types may go unrecognized, meaning that useful lessons and expertise may go unshared across these informal boundaries.

A striking finding is the high variability in some characteristics by organization type. Programs vary notably in the size and demographics of the youth populations they serve and in their desire or ability to target particular groups. The relative strength of programs for girls in the data set may suggest that policy and programming efforts to encourage girls in science are finally bearing fruit. Other results suggest opportunities and unfilled niches for practitioners to pursue—for example, programs for gifted and talented youth are relatively common across organization types, but there is a distinct lack of programs targeting youth with disabilities. To meet this need, organizations with scientific and educational resources might seek out partners or service providers

who work with specific disability communities to identify ways to serve youth with disabilities. Creative partnerships of these types may in turn be able to access a greater variety of funding sources; funders may develop new initiatives to encourage new, cross-cutting forms of partnership.

This variability, while interesting, also points to the difficulty of conducting studies like this one: The variation inherent in programs' home institutions, designs, and audiences means that there are no single points of contact by which researchers can reach or

engage program leaders. The onus is on researchers to communicate the value of answering research questions that may seem merely academic to hardworking youth program leaders who are immersed in mentoring young people and running and sustaining their programs.

Out-of-classroom experiences are an ideal venue for building “personal connections with the ideas and excitement of STEM fields” (President’s Council, 2010, p. xi) and can “play a key role in supporting the future of the country’s STEM workforce” (Afterschool Alliance, 2012). Our findings offer encouragement about the range, variety, and strengths of organizations sponsoring OST science programs—yet they also show that some youth subgroups are underserved. Our results do not speak to

Moreover, because organizations may be networked primarily with others of a similar type, characteristics held in common across organization types may go unrecognized, meaning that useful lessons and expertise may go unshared across these informal boundaries.

the sheer magnitude of need for high-quality science-rich OST programming.

### Future Work

Overall, the results ring true to descriptions and explanations offered by practitioners, indicating that our study has high content validity and suggesting the promise of the more detailed analyses now underway. We plan to explore our questionnaire data with a focus on program-specific issues, independent of organization type, and to examine possible relationships between these two ways of slicing the data. For example, we will look more closely at differences in programs by intensity, duration, and structure of contact hours, comparing, for example, intensive forms such as camps with extended forms such as afterschool programs. We will also explore linkages between youth populations served and program design choices. Finally, we will combine these and other questionnaire data with a rich body of data from in-depth interviews with more than 50 program leaders and other well-placed observers so that we can better understand the circumstances, constraints, and opportunities that give rise to these patterns in program design and characteristics.

### Acknowledgments

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## Notes

<sup>1</sup>In this paper, we use *science* to mean science, engineering, and/or technology.

<sup>2</sup>Several other types of organizations also offered camps. Comparison of the camp format with other formats is a program-level analysis that will be discussed in future reports.



# shifting expectations

## Bringing STEM to Scale through Expanded Learning Systems

by Jessica Donner and Yvonne Wang

There is widespread consensus that improving our nation's competitiveness in science fields urgently demands improved science, technology, engineering and math (STEM) education, particularly for underserved youth. As a result, policymakers, funders, and educators have led a call to stimulate the U.S. STEM pipeline. Recognizing that schools can't do it alone, they have called for "all hands on deck" to boost STEM achievement, ignite passions in science, and expose students—particularly female and minority students—to STEM career possibilities.

Expanded learning opportunities, such as afterschool and summer programs, are particularly well positioned to help address the STEM education crisis (Afterschool Alliance, 2011). A large percentage of youth participating in afterschool programs are members of groups traditionally underrepresented in STEM fields. Additionally, the nature of these programs—featuring

low student-to-staff ratios and opportunities for hands-on and project-based learning—makes them an ideal environment for inquiry-based informal science education (Friedman & Quinn, 2006). Nevertheless, high-quality STEM education does not seem to be happening

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at scale. Science education is not typically expected of programs in the way that art, music, and physical activity are. As noted in a 2008 study from the Coalition for Science After School (Chi, Freeman, & Lee, 2008) surveys of frontline staff have revealed significant obstacles for informal science education in afterschool, including lack of staff buy-in, comfort, or experience in science; insufficient staff training; and a lack of materials. To address the STEM gap in expanded learning programs, expectations of programs must change and frontline staff must be supported with professional development in STEM.

### **A National Strategy to Build STEM Education Systems**

In an effort to prepare all children for post-secondary success and a lifetime of science-based learning, the Collaborative for Building After-School Systems (CBASS) and TASC, with generous support from the Noyce Foundation, have developed a national initiative to institutionalize engaging, inquiry-based STEM experiences in afterschool. In 2007, TASC set out to stimulate a culture shift among afterschool leaders and staff in order to increase the demand for and delivery of high-quality informal science education in New York City afterschool programs. This strategy, *Frontiers in Urban Science Exploration (FUSE)*, employs a twofold systemic approach to bring about this culture shift and shape practice. First, a “grassstops” strategy, led by local out-of-school time (OST) intermediary organizations, engages leaders and staff of schools and afterschool programs, along with government officials, science organization leaders, policymakers, and funders, in building enthusiasm and capacity for inquiry-based STEM learning after school. Second, a “grassroots” strategy gives frontline afterschool staff and supervisors who do not have STEM backgrounds the content knowledge, instructional skills, and confidence to facilitate STEM activities effectively. CBASS is expanding the New York City work of FUSE in six locations—Baltimore, Boston, Chicago, Oakland (CA), Palm Beach County, and Providence—to demonstrate the feasibility of a systemic strategy to advance STEM education and to identify promising practices to inform policy and practice nationally. As of the submission of this article, evaluations of the initiative had been conducted in New York City, Providence, and Oakland; therefore, we focus on those cities’ promising practices and grassroots outcomes. Evaluations for the remaining four cities are forthcoming.

The FUSE strategy is designed to be both flexible enough to be effective across jurisdictions and focused

enough to result in similar shared effects. The strategy builds on local assets while maintaining broad core elements to support program success. Core elements of afterschool STEM programs fall into two categories: program and system (Table 1). Program-level elements describe characteristics of high-quality afterschool science education, while system-level elements describe characteristics of well-coordinated systems that lead to improved quality, scale, and sustainability.

### **Promising Approaches**

Intermediary OST organizations in the cities where FUSE has been implemented have tested approaches at the grassroots and grassstops levels to foster the mindset that frontline staff members, though not necessarily trained in STEM disciplines, can effectively facilitate informal science education. Though FUSE embraces a holistic system approach targeted to frontline staff and city leadership, 2010–2011 evaluation findings pointed to a correlation among strong gains in staff and youth outcomes and grassroots activities directed toward frontline staff. These findings are preliminary; our future evaluations will look more closely at the effect of the grassstops strategy on sustainability and on culture shifts at the program and city leadership levels.

Here we focus on promising practices from the 2010–2011 school year in New York, Providence, and Oakland that have helped contribute to positive staff and youth outcomes. The practices fall into three categories:

- Providing experiential, sequential training opportunities
- Assessing quality STEM programs
- Engaging staff in peer learning communities

#### ***Experiential, Sequential Training Opportunities***

When TASC set out to increase the amount of informal science education in New York City afterschool programs, it built on existing high-quality curricula rather than creating its own. TASC’s criteria for high-quality science curricula included that they:

- Be inquiry-based and hands-on
- Involve youth in higher-order thinking skills such as decision making, planning, problem solving, and reflecting
- Include opportunities for parental involvement
- Provide chances for youth to learn about role models
- Encourage youth to see themselves as learners
- Use techniques appropriate for a variety of learning styles, with attention to the needs of underrepresented populations
- Use affordable materials that are easy to find

SYSTEM LEVEL	DEVELOP STAFF	<p>To ensure continuity of skills and expertise from year to year, training and technical assistance are:</p> <ul style="list-style-type: none"> <li>• Ongoing: conducted in multiple sessions across the year with repeated observation and coaching</li> <li>• Differentiated: incorporating advanced activities to ensure skill improvement for returning participants</li> <li>• Cohort-based: involving multiple sites trained as a group</li> <li>• Delivered to teams: attended by supervisors and frontline staff from the same site</li> </ul>
	UTILIZE COORDINATING ENTITY	<p>A coordinating agent, such as an intermediary, supports the development of the informal science education strategy by:</p> <ul style="list-style-type: none"> <li>• Leveraging resources</li> <li>• Vetting curricula</li> <li>• Organizing training</li> <li>• Disseminating promising practices</li> <li>• Fostering partnerships and collaborations</li> <li>• Evaluating quality and impact</li> </ul>
	ENGAGE CROSS-SECTOR LEADERS	<p>To stimulate a culture shift about the importance of STEM in afterschool, leaders from community, school, informal science, and business sectors are engaged through convenings, alliances, and strategic planning.</p>
PROGRAM LEVEL	INTEGRATE HIGH-QUALITY CURRICULA	<p>High-quality curricula:</p> <ul style="list-style-type: none"> <li>• Are designed for afterschool</li> <li>• Are inquiry-based and grounded in fun</li> <li>• Involve familiar materials to make the case that science is part of our everyday lives</li> <li>• Promote equity among boys and girls and among students of varying abilities and ethnicities</li> <li>• Are evidence-based</li> <li>• Are affordable</li> </ul>
	PROMOTE CO-INQUIRY	<p>Staff and students work side by side to explore and test assumptions.</p>

**Table 1. FUSE Core Elements**

- Be easy to implement for staff with no science background
- Address national STEM standards
- Include a staff training component
- Provide appropriate content for a diverse urban audience

TASC created a menu of STEM curriculum options each year, ensuring that the offerings included a range of age levels and a variety of STEM subjects. The menu included descriptions of each program, the appropriate age range, the dates of trainings, and any costs associated with implementing the curriculum. TASC required sites to fill out an application form and sign a memorandum of understanding that detailed their commitment. TASC worked with sites to identify appropriate curricula and support the delivery of the activities based on each site's STEM readiness and goals.

TASC then designed a series of experiential, sequential training sessions for staff to attend throughout the year. At each training, the TASC STEM team facilitated and modeled the curricula through hands-on activities so that staff had the opportunity to engage in the activities themselves before implementing them with youth. Experiential training in specific informal science curricula gives site coordinators and frontline staff the curriculum, hands-on materials, and coaching they need to implement science education. Site staff generally attended in teams of at least two to ensure consistency of STEM programming from year to year. Ongoing trainings throughout the year allowed staff to reflect with peers on what worked and what didn't and to refine the co-inquiry pedagogical approach.

**Peer Learning Communities**

In an effort to increase the capacity of afterschool providers to provide accessible, high-quality informal science education as well as to develop staff members' confidence in facilitating STEM activities, partners in

Oakland, California, developed an intensive peer learning community. Staff from 25 sites across the Oakland Unified School District attended monthly meetings

convened by staff from the district and from Techbridge, a nonprofit organization that provides STEM experiences for underserved youth. Topics included teaching inquiry-based science, promoting science career exploration, engaging families and the community, supporting equity in science programming, integrating role models, and scaffolding science material so that students build on their knowledge and skills over the course of the year.

Over the past two years of experimenting with the learning community, Techbridge found that a session works best if it includes the following components: peer-to-peer sharing on challenges and best practices, hands-on modeling of an activity where participants can observe best practices being implemented, reflection about the rationale behind the practice, and time to adapt the strategy to participants' afterschool programs.

As an essential complement to the learning community, each participant is paired with a trainer for the entire year to receive ongoing support. Participants receive two coaching sessions during the school year, in the fall and spring. Each session includes an observation of the participant leading a science lesson followed by a debrief to identify areas for improvement and develop action plans.

The learning community contributed to staff motivation and confidence in facilitating STEM activities. One participant reported, "I used to have a hard time putting my lessons together, but now, because of the Science Learning Community, I can transform a regular lesson into a science lesson." Another added, "I used to be afraid of teaching science. Now I feel more comfortable because of the Science Learning Community."

## STEM Quality Assessment

Observational tools to support quality improvement of STEM programs are emerging. For example, Dr. Gil Noam of the Program in Education, Afterschool, and Resiliency (PEAR) led the development of the DOS tool. The Educational Equity Center at FHI 360 developed a quality assessment tool that adds dimensions of gender equity through the Great Science for Girls project.

As part of the FUSE initiative, the Providence After School Alliance (PASA) worked with the David P. Weikart Center for Youth Program Quality to develop and conduct a preliminary validation of a new observational assessment for STEM-focused OST programming. Based on the Weikart Center's Youth Program Quality Assessment (YPQA), the STEM PQA consists of both observational and interview forms. PASA is now using the STEM PQA to observe STEM-focused programs and to coach instructors on how to improve quality.

## The Effects of FUSE Afterschool STEM Systems

New York City, Providence, and Oakland each developed strategies and systems to support and train their frontline staff to deliver high-quality STEM activities. The evaluations focused on outcomes of these grassroots strategies during the 2010–2011 school year.

Using self-reported data from staff and youth, we explored the effect of the FUSE program on staff members' instructional confidence and on youths' STEM-related knowledge, confidence, motivation, and interest. The evaluation sought to answer the following research questions:

- Does training have an impact on staff outcomes?
- Does program dosage have an impact on youth outcomes?
- Does training staff have an impact on youth outcomes?

### Methodology

Staff members were surveyed at the beginning and at the end of the school year using an adapted version of the Science Teaching Efficacy Belief Instrument, developed by Riggs and Enochs (1990) for the National Association for Research in Science Teaching. Surveys were administered to determine how effectively staff members felt that they could teach science in afterschool and how much of an effect they thought they could have on youths' science learning. The instrument consists of two subscales: the instructional confidence score, which indicates how confident the staff member is in his or her ability to effectively teach science, and the personal impact score, which measures how much the staff member believes that his or her teaching can

influence youths' science learning (Bursal, 2008). Tests showed strong reliability for the instructional confidence subscale and moderately strong reliability for the personal impact scale while validity tests revealed all items were significantly and positively correlated (Riggs & Enochs, 1990). Additionally, data on staff training dosage were collected for New York City, but not for Providence and Oakland.

Twice during the year, youth participants were asked about their STEM-related knowledge, confidence, motivation, and interest. Two measures were used to assess these domains. At the first measurement, participants completed

the Excited, Engaged and Interested Learner Survey (Common Instrument), which is being validated during the 2012–2013 school year by PEAR. The tool asks youth about their STEM habits, engagement, and career plans and about their feelings toward both in-school and out-of-school STEM. At the second measurement, youth again completed this survey as well as an adapted version of the Student Science Attitude Change tool (originally called Student Subjective Attitude Change Measures) developed by Stake and Mares (2001) of the University of Missouri-St. Louis. This scale captures participants' assessment of the degree to which the program brought about positive change in their science motivation, confidence, and knowledge. The adapted version used a four-point scale, from "not at all" to "definitely," on which students rated statements in the form "My experiences in the afterschool science program [led to an outcome]." Tests of reliability resulted in strong reliability for motivation and confidence and moderately strong reliability for the knowledge scale (Stake & Mares, 2001). Youth program participation data was also collected for Providence and Oakland, but not for New York City.

### Findings

Findings center on staff members' beliefs about their confidence and efficacy and on youth participants' assessments of changes in their STEM knowledge and attitudes.

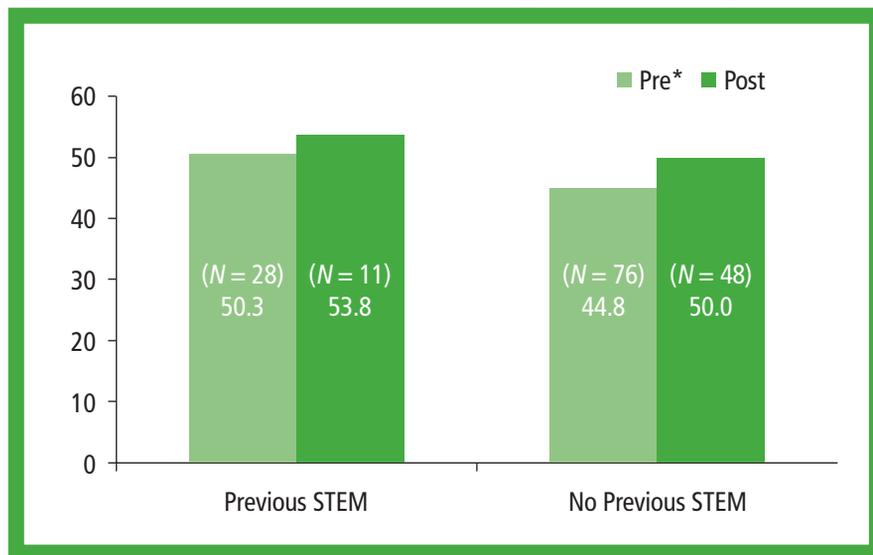
### Staff Members

One key finding was that FUSE participation built confidence among inexperienced STEM instructors. Before FUSE training, staff who had previous STEM experience scored significantly higher on the instructional confidence scale than did those with no previous STEM experience. This difference is consistent with research suggesting that experienced teachers have higher self-efficacy beliefs than do

novice teachers (Angle & Moseley, 2009). After training and a year of experience, the difference disappeared. This finding suggests that, after participating in FUSE, inexperienced staff caught up with their more experienced peers. Figure 1 shows instructional confidence scores for New York City and Figure 2 for Oakland. None of Providence's staff members had previous STEM experience, so there was no comparison group.

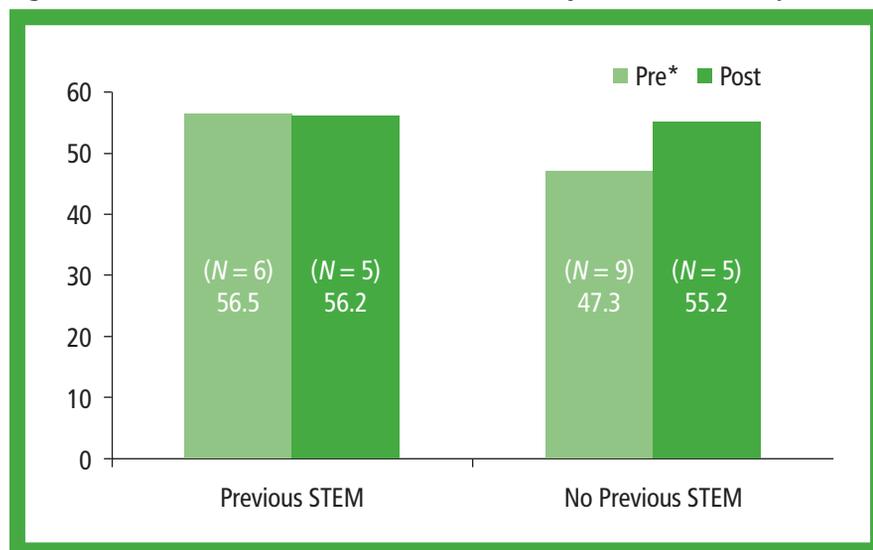
One city's evaluation found that training attendance and dosage were associated with increased instructional confidence or personal impact scores. In New York City, two groups of staff took the end-of-year survey: a program group of staff who attended training and a comparison group of staff who did not. New York City was the

**Figure 1. NYC Instructional Confidence Scores by Previous STEM Experience**



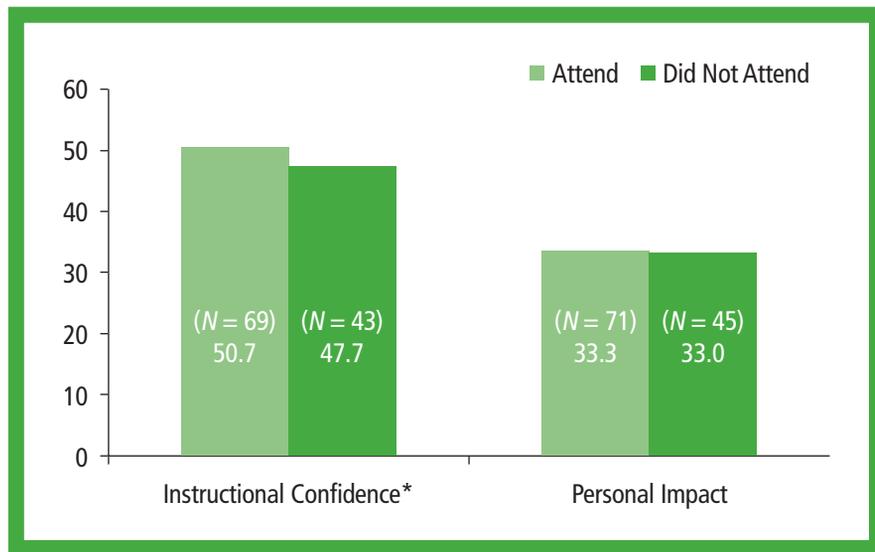
Note: Pre- and post-program survey scores are not matched to individual staff members.  
\*  $p < 0.05$

**Figure 2. Oakland Instructional Confidence Scores by Previous STEM Experience**



Note: Pre- and post-program survey scores are not matched by individual staff members.  
\*  $p < 0.05$

**Figure 3. NYC Instructional Confidence and Personal Impact Scores by Training Attendance**



\*  $p < 0.05$

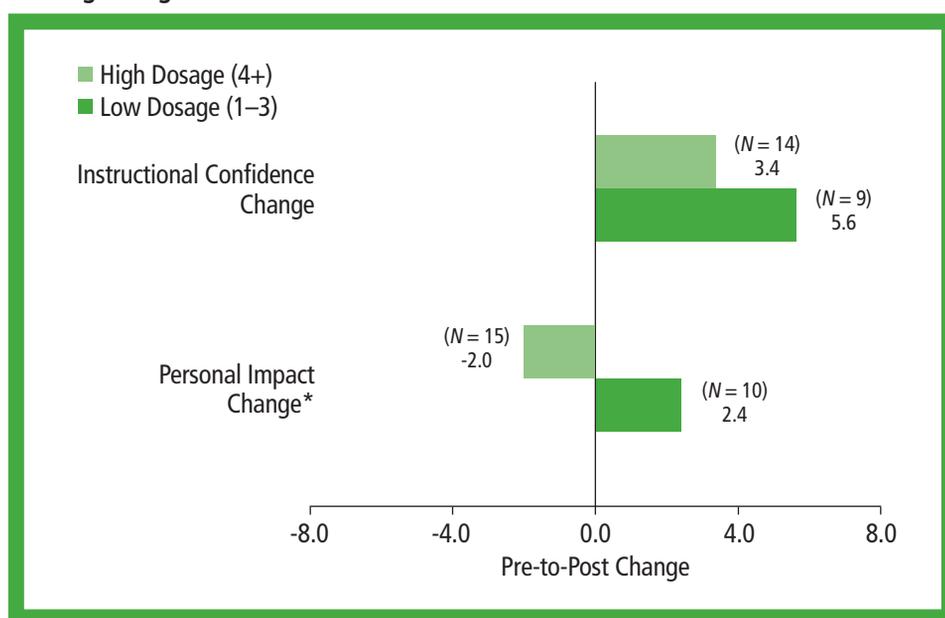
only city to distribute surveys to staff members who did not participate in training. The program group had significantly higher post-program instructional confidence scores than did the comparison group, as shown in Figure 3. Personal impact scores were similar for both groups.

New York outcomes also showed that the dosage of training affected personal impact scores. Figure 4 shows that staff who attended one to three training sessions had a mean decline of 2.0 points in personal impact, while staff who attended four or more sessions had a mean increase

of 2.4 points. This between-group difference in personal impact scores is statistically significant; it suggests that greater depth of training helps staff to see themselves as having an important effect on youths' STEM learning. Furthermore, youth science motivation and science confidence were both positively correlated with staff training in New York City, the only site that collected data on training dosage. Having staff members attend more training was correlated with greater student motivation and confidence in science, as found in the Attitude Change survey. In afterschool programs that had staff members attend more FUSE trainings, youth reported more positive feelings about engaging in science as a result of their program experiences. The Excited, Engaged, and Interested Learning Survey also showed a relationship between staff training dosage and youth attitudes about science. The number of training sessions staff attended was significantly and positively correlated with youths' agreement with such statements as, "I like to take things apart and learn more about them," "I would like to have a science or computer job in the future," "I get excited to find out I will be doing a science activity," and "Science is one of my favorite subjects after school." These findings

support those from the Attitude Change survey, where staff training was found to be significantly correlated with student motivation and confidence.

**Figure 4. NYC Instructional Confidence and Personal Impact Score Change by Training Dosage**



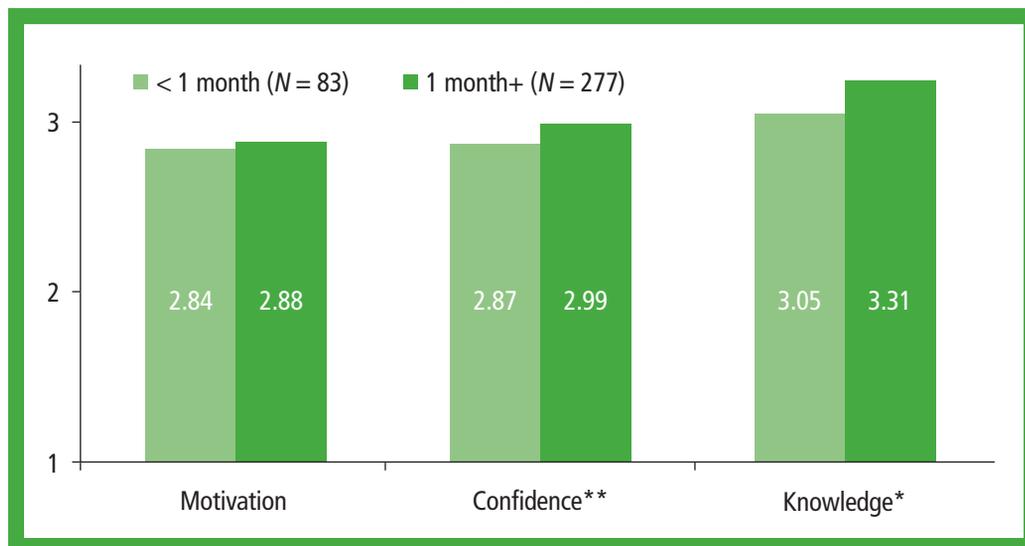
Note: Change score is calculated based on staff who had complete scores on both pre- and post-program surveys.

\*  $p < 0.05$

### Youth Participants

The post-participation surveys found a relationship between level of student exposure to STEM and self-reported science knowledge. In both Oakland (Figure 5) and Providence (Figure 6), science knowledge was significantly higher for youth who were exposed to STEM curricula for more than one month than for those who had less than one month's worth of STEM activities. Changes in science confidence scores were also higher in both cities for

**Figure 5. Oakland Student Attitude Change by Dosage**



\*  $p < 0.05$       \*\* Not significant at the 0.05 level, but a trend exists.

**Figure 6. Providence Student Attitude Change by Dosage**



\*  $p < 0.05$       \*\* Not significant at the 0.05 level, but a trend exists.

students with more than one month of participation, though the differences were not significant at the 0.05 level. Student participation data were not available for New York City.

Furthermore, Oakland's survey results showed significantly higher science motivation and science confidence scores for youth who were exposed to STEM curricula for three or more hours per week than for those who had fewer than three hours per week of STEM activities, as shown in Figure 7. The trends in Providence were in the opposite direction, though the findings there were not statistically significant. New York, again, did not provide student participation data.

alongside students. Broadening the understanding of who can deliver afterschool science education helps to build the case that afterschool is a natural place to engage young people in science.

**Curriculum matters.** Selecting appropriate and high-quality curriculum materials is essential to providing youth with hands-on STEM experiences that engage and excite them. Activities should be relevant to the participants, inquiry-based, and hands-on. Curricula that use easy-to-access, culturally familiar materials send a powerful message to the participants that science is everywhere, giving them an opportunity to continue the learning beyond the afterschool setting.

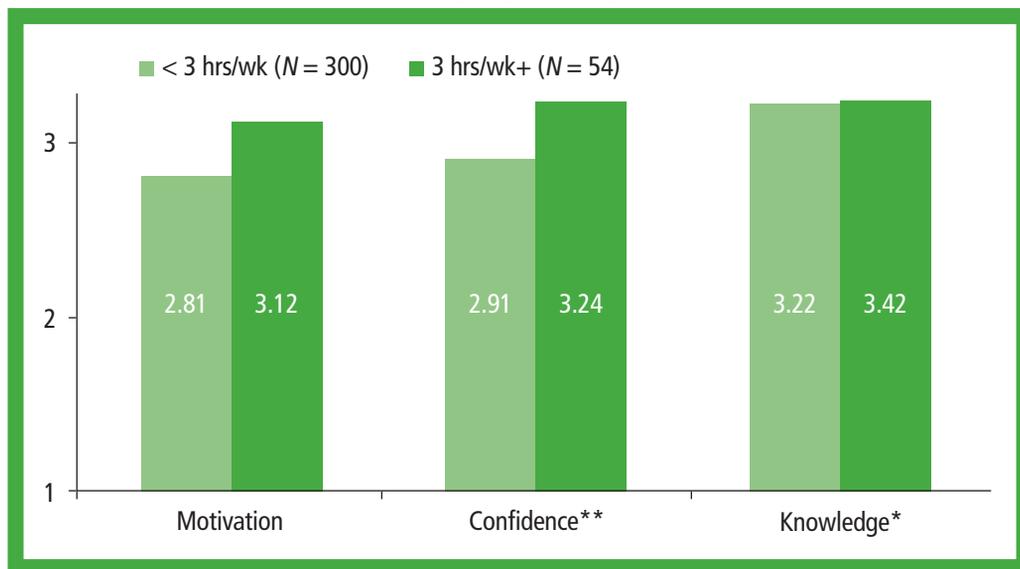
## Recommendations

Drawing from evaluation findings and the programmatic experiences of the New York, Providence, and Oakland initiatives, we suggest the following recommendations to support community-wide efforts to integrate STEM experiences into OST programming.

### Outreach should emphasize that youth development experts can facilitate STEM co-inquiry.

Outreach to afterschool programs and schools should aim to build public understanding that anyone with appropriate training and support—not just science experts—can implement STEM in afterschool programs. Successful informal science programs draw on the youth development expertise of afterschool leaders to adopt a co-inquiry approach, in which leaders learn

Figure 7. Oakland Student Attitude Change by Intensity



\*  $p < 0.05$

\*\* Not significant at the 0.05 level, but a trend exists.

**Provide training to staff members in order to boost staff and youth outcomes.**

Attending training may help staff without STEM background or experience rise to the same levels of confidence as STEM-proficient staff members. Training sessions are particularly helpful when they are hands-on and ongoing, allowing staff members to “be the youth.” Staff members learn to anticipate youth questions and comments and, as a result of learning by doing, increase their confidence in their teaching. Training not only benefits staff members but also supports youth outcomes. Having more trained staff members at a site is correlated with higher student STEM confidence and motivation. In addition, continuous onsite coaching, in which quality advisors observe STEM activities and work with staff to identify areas for improvement and to develop action plans, supports program improvement.

**Ensure consistent and sustained STEM participation for youth.**

Young people enjoy inquiry-based STEM activities after school; they report that participation increases their knowledge about science. STEM activities should not be a special event in afterschool programs. Rather, students should have opportunities to engage in STEM activities regularly in order to build on what they’ve learned in previous sessions. FUSE evaluations found that sustained involvement correlated with youth reports that activities increased their science knowledge. Additionally, more intense exposure, such as three or more hours per week, correlated with youth reports that activities increased how much they cared about science and how confident they felt about their science abilities. These relationships demonstrate the important role that afterschool science education can play in transforming STEM learning for kids.

**Coordinating entities are important change agents in building quality informal science education systems.**

A lead coordinating agency, such as an intermediary, helps to broker partnerships and has a bird’s-eye view of a community’s resources for supporting STEM education. In line with their core functions, intermediaries can provide professional development,

leverage resources, convene stakeholders, and conduct research to expand and sustain afterschool systems that promote informal science education. Coordinating entities are well positioned to bring high-quality STEM to scale.

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# getting intentional about STEM learning

by Michael MacEwan

*In an afterschool space, desks are grouped in fours. In the center of each group is a seemingly random assortment of materials, including uncooked spaghetti, spiced gumdrops, and a small cardboard square. After a brief introduction to the activity, a staff member posts the challenge on the wall: Using only these materials and working together as a team, each group must build the tallest possible tower that can support a 20-ounce water bottle independently for 10 seconds.*

Teams look at the materials, discuss the challenge, and brainstorm possible solutions. Then they begin to manipulate the materials. Through trial and error, they refine a solution until they feel confident it is ready to be tested.

I am describing a typical scene in the 21st Century Community Learning Center (21st CCLC) I used to direct. The team members are the fourth-graders my program served—but they could equally well be the staff leader

and his counterparts, whose professional development included participating in this same activity before they led it.

As a program director, I worked to create a “culture of STEM” for both program participants and staff. Science, technology, engineering, and math (STEM) served as the central topic across all of our enrichment clubs. Almost every activity involved some aspect of STEM; everything we did was hands-on and inquiry based. We equipped staff to lead STEM activities using the same hands-on, inquiry-based approach. Most of the time, we integrated STEM with other content areas such as language arts. We thus had taken the first steps toward making STEM learning an intentional component of our program. The next step we might have taken was to use theme-based learning across the entire program.

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## What Children Experienced

The community our program served was an urban New Jersey school district whose population was more than 90 percent Latino. We served only fourth-graders in all five of the district's elementary schools. As a direct result of the staff's hard work and commitment, program participants outscored their non-program peers on standardized tests in math, language arts, and science.

Clear, definitive results showed that our methods were working.

Our young participants knew they were in a STEM-focused afterschool program. In retrospect, I don't know that they understood what that meant. At the time, I subscribed to the idea of "disguised learning"—hiding the educational value of program activities. I thought that participants would have fun while learning skills that would translate to other areas. Our goal was for participants to use critical-thinking and problem-solving skills to understand broad STEM concepts, rather than focusing on vocabulary and terminology.

We therefore masked the content of activities. Though activities were STEM focused, we tended not to tell participants that they were learning engineering or physics or math.

I now think we were doing a disservice to those youth. Even though my staff and I highlighted *that* the kids were learning, we didn't tell them *what* they were learning or how it fit into a larger picture. We could have drawn the connection for them, telling them that this fun activity in which they were engaged was actually helping them learn math, science, and language arts. This connection would demonstrate not only that they could "do science" or "do math," but also that they could have fun doing it.

Every enrichment club had its own STEM theme, though that theme did not carry over to other clubs. For example, in the Sports and Math club, youth participated in physical activities and solved related math problems. They might shoot a basketball from various spots on the court and calculate the average number of shots made and missed and the probability that a shooter would make or miss a shot from each location. They might also learn to calculate baseball or softball statistics or explore the physics behind how soccer players can "bend it" like David Beckham. To integrate their STEM sports learning with other curriculum areas, we had participants keep detailed journals including written descriptions of each activity,

the math to support the activity, drawing and sketches to recreate each activity, and graphs of their data.

## How Staff Were Equipped

Professional development is the key to developing high-quality STEM programming. The biggest obstacle to implementing STEM learning is not cost, but staff members'

fear of leading STEM activities. Staffers do not need a STEM background to lead STEM activities; exposure to STEM through professional development will lead to comfort, making concepts less foreign and teaching the staff to reason through problems the same way we hope the kids will. Professional development for OST should strike a balance between teaching content and pedagogy skills while modeling best practices to engage youth.

Professional development thus looks almost exactly the same as the activities staff members will ultimately lead with kids. When I led STEM pro-

fessional development, staff members would come into the training space and wonder what we were up to that day. I'd give the materials and the challenge and ask them to come up with their solutions. I modeled my interactions with them as I expected them to interact with the youth. The only difference was that, with the staff, I would stop to interject teaching tips, for example, highlighting where children might struggle and offering suggestions to ease their frustration. When staff do activities in professional development before they attempt them with kids, they learn to anticipate possible problems. We talk about strategies to engage all children and ways to alter the challenge to ensure that everyone, regardless of abilities, can complete the task.

In the spaghetti tower challenge, groups encounter many obstacles before they start to show success. Teams figure out fairly quickly that they need to use the gumdrops as connectors for the spaghetti. The first obstacle is that the spaghetti breaks pretty easily when they try to push it into the gumdrops. Once groups understand the limitations of the spaghetti, they can build taller towers. With height come additional obstacles: Usually the towers start to twist or lean. Groups overcome this problem by adding cross-supports or a "kickstand." Then they find that the tower twists because of the weight of the gumdrops. Eventually someone figures out that the gumdrops do not have to remain whole; pieces can be torn off to bind the spaghetti, thus reducing the weight as the height increases.

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Groups will inevitably discover loopholes. For example, the last time I led this activity with adults, I had a particularly creative (and slightly theatrical) group call me over to their table, quickly pour the water from their bottle into a travel coffee mug, and then place the empty bottle on top of their tower with a flourish, pointing out that I had never specified that the bottle be full of water. They were absolutely correct, but in the spirit of the challenge, I had them try it with a full bottle—and they were successful anyway. A key teaching tip I always leave adults with is that kids are masterful at finding these loopholes.

At the conclusion of the spaghetti activity, we discuss the challenge, the obstacles, and ways leaders can help groups find solutions. We also discuss the content areas included in the activity, as well as other topics that can be linked to it. It is easy to see the connection to engineering and math, but links to architecture and language arts may not be as obvious. For architecture, staff could lead a discussion about how some structures have to look a certain way because of their function or the materials with which they are constructed. To incorporate language arts, I would have the young people write a tower-building instruction manual with step-by-step instructions, illustrations, and a troubleshooting guide.

Leading professional development in this way has many advantages. Staff members gain many of the same benefits the children gain from these experiences. Working in small groups allows staffers to bond with their peers. They learn that problems sometimes have multiple solutions. Having done the activity themselves, they are able to better assist children who are struggling and have a better idea of what the results can be. These exercises also reinforce staffers' confidence in their ability to lead activities, fostering the belief that they can "do STEM" with children.

Ultimately we want both staff and participants to see that STEM is not some group of isolated subjects but a common factor in many activities they already enjoy. STEM needn't be intimidating. We all do math and science every day without giving it any thought. While driving your car, you are continually doing math and physics while going from point A to point B.

### How It Could Be Better

As illustrated in the spaghetti tower challenge, staff in my program worked to show the connections between STEM

and other content areas. However, we could have done more to bridge all content areas by implementing a fully integrated program-wide theme encompassing all enrichment activities.

For example, the theme of "technology through the ages" could highlight how every generation invents or improves solutions to meet the challenges of its time. An OST program could allow participants to choose a technology used in an ancient civilization and then find modern equivalents, or participants could track the evolution of a single technology, like the telephone. Tracking a technology through the cultures that used it infuses social studies into the theme. Engineering can be included by having students determine how the technologies were created, how they worked, and how they were improved over time. Math questions could be interspersed throughout the activities; for instance, participants could research and graph the number of home telephones in the U.S. for each decade from invention through the present. Additional math problems could support what the students have discovered. Literacy and language arts skills should be

included in all activities relating to the theme. Participants could maintain data logs of their research or write newspaper articles announcing the technologies as they are introduced throughout history, outlining the context, the problem the technology solves, and how it was created.

This approach counteracts the current tendency to conduct education in silos, teaching content areas like science and language arts separately. Children are not trained to approach a problem as a whole, considering all of its parts. Instead, they have been taught to categorize activities by content area: "Oh, this is math." Depending on their perception of math, this categorization leads some children to embrace the activity, while others shut down. A child who struggles in math is likely to do better if numbers are presented in a context that has relevance to him or her. This kind of relevance is where theme-based curriculum excels. The theme-based approach can have a profound effect at any grade level.

Weaving STEM through all program activities is one step toward offering intentional, high-quality STEM learning after school. Taking the next step to create a program-wide theme-based curriculum would optimize the "culture of STEM" and, at the same time, foster a culture of holistic learning for the whole child. Such a program would help to produce well-rounded, thoughtful youth; the effects would carry over to participants' school and home lives.

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## Collaborating to Build Capacity

Though afterschool programs have the potential to introduce much-needed STEM learning in innovative ways, they are often hindered by a lack of capacity, resources, and sustainability strategies.

The National Girls Collaborative Project (NGCP), a national initiative partially funded by the National Science Foundation, works to help youth-serving organizations infuse STEM content in their programming.

NGCP brings together organizations such as afterschool and summer programs, museums and science centers, K–12 schools, colleges and universities, professional organizations, and industry. The premise is that collaboration can strengthen the capacity of existing organizations to deliver high-quality STEM programming, especially for youth underrepresented in STEM.

NGCP focuses on four capacity-building strategies:

- **Structured in-person collaboration and professional development.** NGCP Collaboratives bring together professionals committed to encouraging girls in STEM for learning, collaboration, and resource sharing. A total of 5,607 professionals have participated in NGCP in-person events across the U.S. since 2006.
- **Incentives for collaboration and sustainability.** NGCP Collaboratives provide mini-grants of up to \$1,000 to two or more individuals or organizations collaborating on a STEM project for youth in their region.
- **Facilitating collaboration through online connections.** NGCP's online program directory allows projects and organizations to enter basic program data and contact information along with brief descriptions of organizational goals, population served, and geographic location. Program directory entries also include "resources needed" and "resources available" as catalysts for collaboration.
- **Online professional development and dissemination.** NGCP provides free webinars to make current research accessible. A monthly e-newsletter disseminates exemplary practices and effective program models for engaging youth in STEM, highlights mini-grant projects, and publicizes efforts and events related to informal education and STEM.

For more information on these strategies, visit [www.ngcproject.org](http://www.ngcproject.org).



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# Afterschool Matters

## Call for Papers

Spring 2014 Issue

*Afterschool Matters*, a national, peer-reviewed journal dedicated to promoting professionalism, scholarship, and consciousness in the field of afterschool education, is seeking material for the Spring 2014 issue. Published by the National Institute on Out-of-School Time with support from the Robert Bowne Foundation, the journal serves those involved in developing and running programs for youth during the out-of-school time hours, in addition to those engaged in research and in shaping youth development policy.

*Afterschool Matters* seeks scholarly work, from a variety of disciplines, which can be applied to or is based on the afterschool arena. The journal also welcomes submissions that explore practical ideas for working with young people during the out-of-school hours. Articles should connect to current theory and practice in the field by relating to previously published research; a range of academic perspectives will be considered. We also welcome personal or inspirational narratives and essays for our section "Voices from the Field."

Any topic related to the theory and practice of out-of-school time programming will be considered for the Spring 2014 issue. We invite you to discuss possible topics in advance with us. Suggested topics include:

- Physical activity and healthy eating
- STEM (science, technology, engineering, and math) program delivery or STEM staff professional development
- Expanded or extended learning time and the OST hours
- School-community partnerships that support OST programming
- Innovative program approaches
- OST programs and civic engagement, social and emotional development, arts development, or academic improvement
- Research or best-practice syntheses
- OST program environments and spaces
- Key aspects of program leadership and administration
- OST system-building such as cross-city and statewide initiatives
- Special needs youth in OST
- Immigrant and refugee youth in OST
- Youth-centered participatory action research projects
- Gender-focused research and policy initiatives related to OST

### Submission Guidelines

- Deadline is July 19, 2013, for the Spring 2014 issue of *Afterschool Matters*.
- Submissions should be submitted electronically in Microsoft Word or Rich Text format.
- Submissions should not exceed 5,000 words.
- Include a separate cover sheet with the manuscript title, authors' names, addresses, phone numbers, and e-mail addresses.
- The names of the authors should not appear on the text, as submissions are reviewed anonymously by peers.
- Follow the *Publication Manual of the American Psychological Association, 6th Edition* (July 2009), for reference style guidelines. Present important information in the text and do not use extensive footnotes.

**Inquiries about possible articles or topics are welcome.**

**To inquire or to submit articles, contact:**

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