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 "grasstops" 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 grasstops 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 grasstops 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	To ensure continuity of skills and expertise from year to year, training and technical assistance are: • Ongoing: conducted in multiple sessions across the year with repeated observation and coaching • Differentiated: incorporating advanced activities to ensure skill improvement for returning participants • Cohort-based: involving multiple sites trained as a group • Delivered to teams: attended by supervisors and frontline staff from the same site
	UTILIZE COORDINATING ENTITY	A coordinating agent, such as an intermediary, supports the development of the informal science education strategy by: • Leveraging resources • Vetting curricula • Organizing training • Disseminating promising practices • Fostering partnerships and collaborations • Evaluating quality and impact
	ENGAGE CROSS-SECTOR LEADERS	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.
PROGRAM LEVEL	INTEGRATE HIGH-QUALITY CURRICULA	High-quality curricula: • Are designed for afterschool • Are inquiry-based and grounded in fun • Involve familiar materials to make the case that science is part of our everyday lives • Promote equity among boys and girls and among students of varying abilities and ethnicities • Are evidence-based • Are affordable
	PROMOTE CO-INQUIRY	Staff and students work side by side to explore and test assumptions.

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:

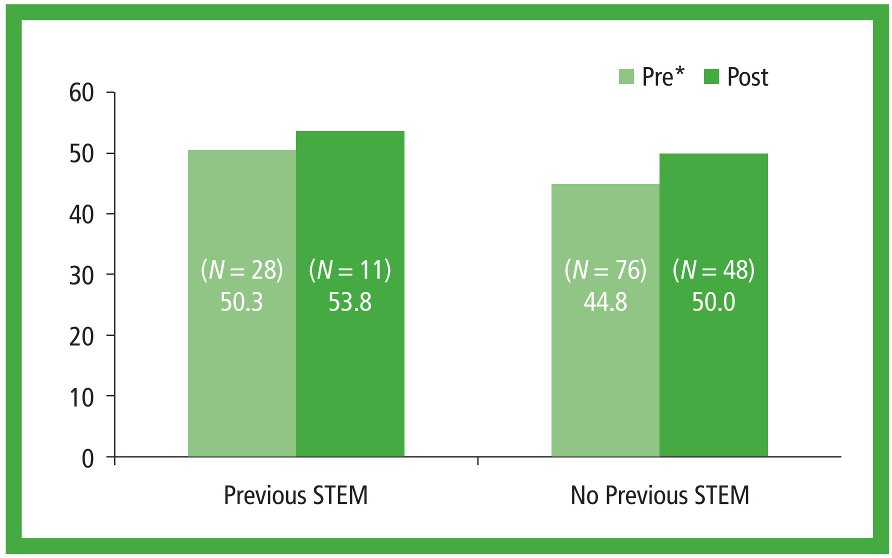
- Does training have an impact on staff outcomes?
- Does program dosage have an impact on youth outcomes?
- Does training staff have an impact on youth outcomes?

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

Figure 1. NYC Instructional Confidence Scores by Previous STEM Experience



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

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

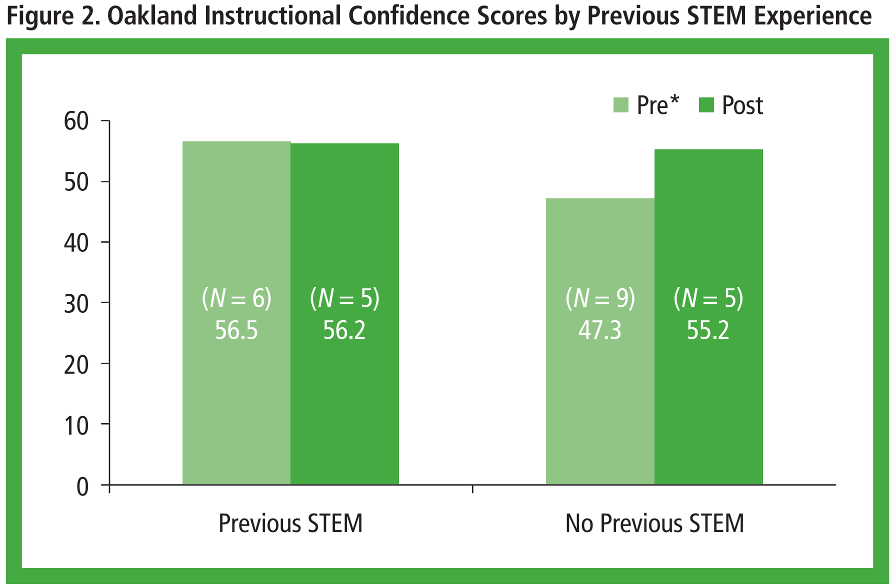
Findings center on staff members' beliefs about their confidence and efficacy and on youth participants' assessments of changes in their STEM knowledge and attitudes.

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.

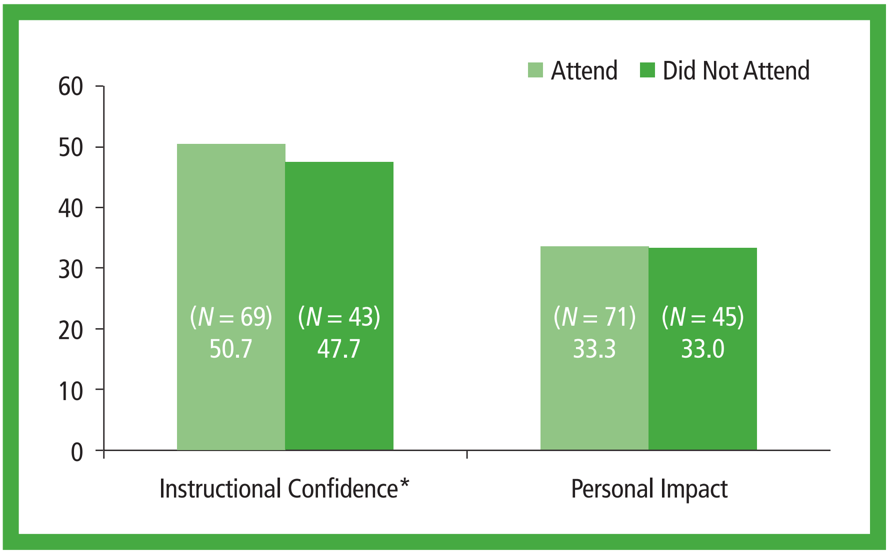
One city's evaluation found that training attendance and dosage were associated with increased instructional confidence or personal impact scores. In New York City, two groups of staff took the end-of-year survey: a program group of staff who attended training and a comparison group of staff who did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

Figure 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



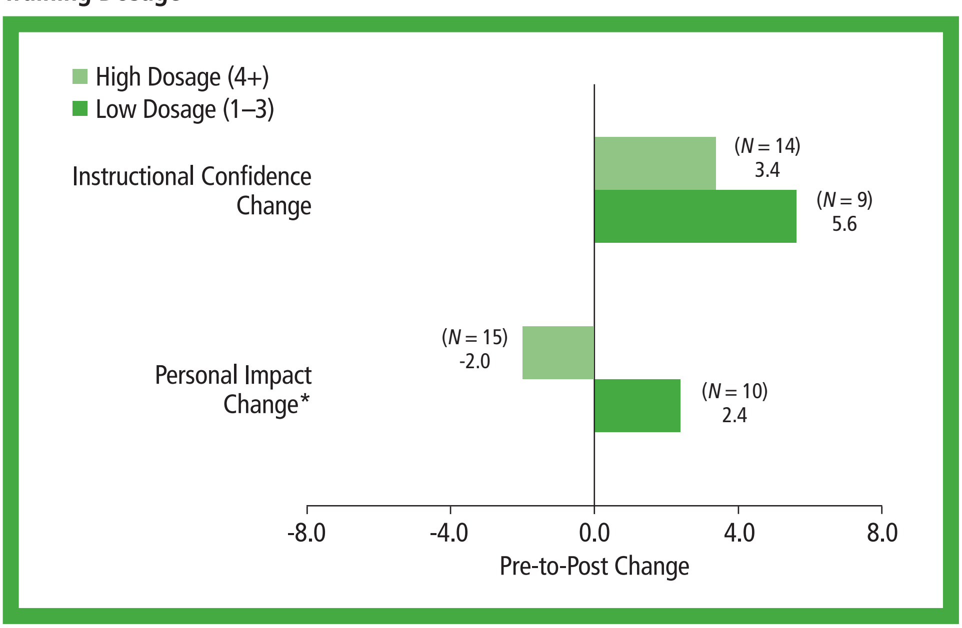
* $p < 0.05$

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

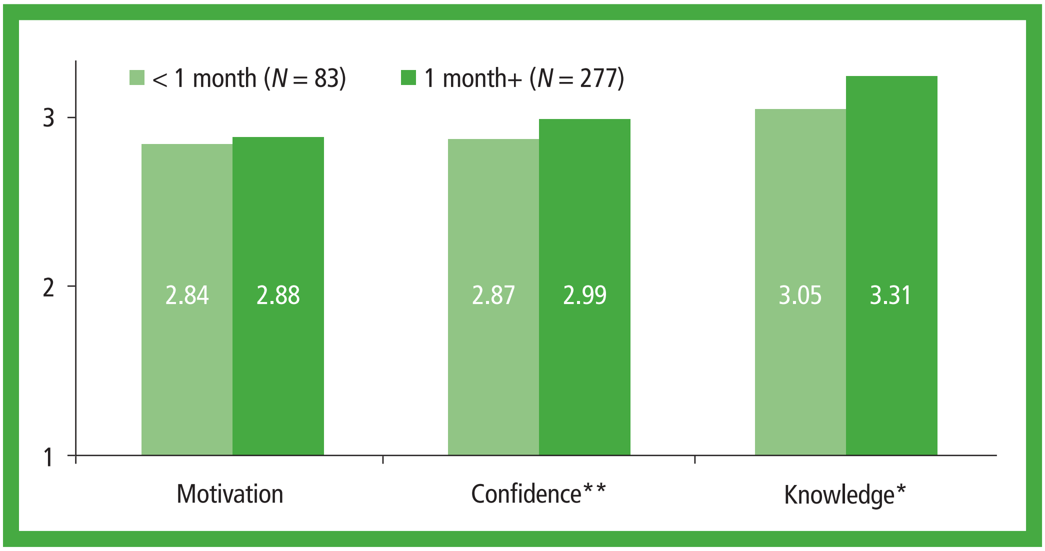


Note: Change score is calculated based on staff who had complete scores on both pre- and post-program surveys.
* $p < 0.05$

Youth Participants

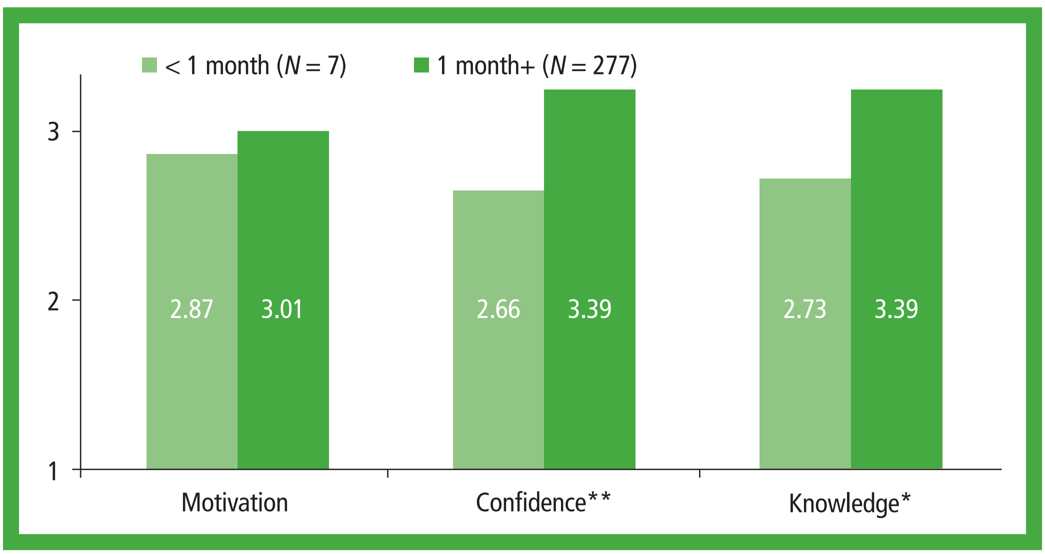
The post-participation surveys found a relationship between level of student exposure to STEM and self-reported science knowledge. In both Oakland (Figure 5) and Providence (Figure 6), science knowledge was significantly higher for youth who were exposed to STEM curricula for more than one month than 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.

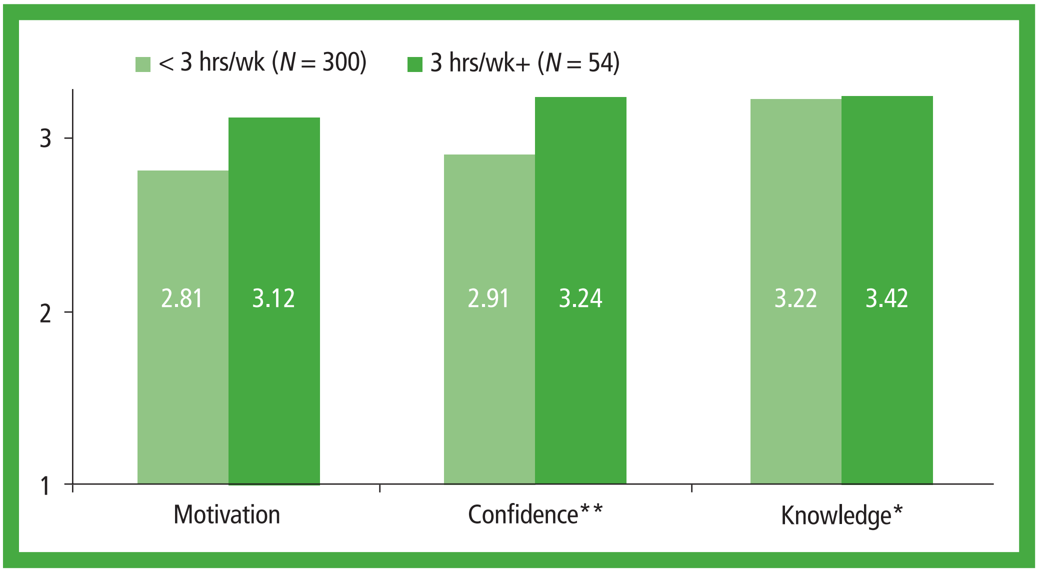
Recommendations

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 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.

Figure 7. Oakland Student Attitude Change by Intensity



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

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.

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.

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