How to Build a Robot

Collaborating to Strengthen STEM Programming in a Citywide System

by Meghan Groome and Linda M. Rodríguez

You have to stick with it. It takes time, patience, trial and error, failure, and persistence. It is almost never perfect or finished, but, with a good team, you can build something that works. These are the lessons youth learn when building a robot, as many do in the out-of-school time (OST) programs supported by the initiative described in this paper.

Similarly, implementing high-quality, sustainable programming in science, technology, engineering, and mathematics (STEM) across the largest publicly funded OST system in the country took time, teamwork, and persistence. The New York City Department of Youth and Community Development (DYCD) and the New York Academy of Sciences collaborated to develop a replicable program model for increasing the capacity of OST organizations to provide STEM learning opportunities. The process of developing this model and the lessons we learned provide a roadmap for other OST systems looking to enhance program capacity.

The importance of increasing the number of Americans entering STEM fields is well documented. The STEM workforce accounts for more than 50 percent of the nation's sustained economic growth (U.S. Department of Labor, 2007). Our nation's ability to develop this workforce is an issue of equity and economic vitality; workers and citizens with solid STEM skills are indispensable to our international competitiveness and ongoing innovation. In the next few years, 70 percent of all jobs created—not just those in technical fields—will require some STEM competency (Thomasian, 2011) and

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key 21st century skills such as critical thinking; active learning; and mathematical, inductive, and deductive reasoning. Individuals without these skills will effectively be shut out of many employment opportunities and, in many cases, relegated to low-wage, low-skill jobs (Thomasian, 2011).

OST programs are uniquely positioned to inspire and prepare youth to enter STEM fields by improving academic proficiency and building interest in STEM disciplines at an early age (New York State Afterschool Network & The After-School Corporation, 2012). Compared to traditional school structures, OST programs typically offer smaller class sizes, less focus on tests, and more fluid uses of time. OST programs can also play a significant role in increasing the staggeringly low numbers of students of color, women, and low-income youth in STEM disciplines (U.S. Department of Labor, 2007) because many programs are located in large urban school districts or community-based centers in low-income neighborhoods (Brisson et al., 2010). For example, most of the OST programs DYCD funds through contracts with community-based organizations (CBOs) across New York City are located in economically disadvantaged neighborhoods. Finally, OST programs can provide three elements that lead to persistence in a STEM career: engagement, continuity, and capacity (Jolly, Campbell, & Perlman, 2004).

Create a Frame

A solid foundation is required to ensure that a robot can maintain its structure over time. Selecting the right pieces—plates, beams, and gears—is an essential first step. Similarly, in its efforts to increase STEM learning across the OST system, DYCD needed to choose its area of focus and select the right partners. In 2006, DYCD embarked on a planning process to expand STEM programming in the OST system, which includes more than 530 programs located in public schools, Beacon Community Centers, CBOs, and public housing developments citywide.

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Focus on Youth in Middle School

In 2009, the percentage of New York State students scoring at or above proficiency on the National Assessment of Educational Progress (NAEP) in fourth and eighth grade math and science assessments hovered within two points of the national average, while the top three states in each category scored an average of 10–16 points higher than the national average (National Center for Education Statistics, 2009). More distressingly, the percentages of Hispanic and Black students scoring at or above proficiency in fourth and eighth grade math and science on the NAEP in 2009 lagged 25–38 points behind that of their white peers (National Center for Education Statistics, 2009).

According to a 2009 study by the Educational Testing Service, middle school is a key age when students form identities as STEM learners and commitments to STEM subjects. As content becomes increasingly complex, middle school students—particularly girls and English language learners—lose interest in STEM (Braun, Coley, Jia, & Trapani, 2009). Implementing STEM in OST programs for middle school youth bolsters their engagement and exposes them to science before they transition to high school. Research shows that students who are interested in STEM in eighth grade are more likely to choose STEM careers than are peers who have no interest in science, even those who perform better in school (Afterschool Alliance, National Afterschool Association, & National Summer Learning Association, 2011).

Early Pilots

From 2006 to 2009, DYCD explored several options for building STEM capacity in the OST system, such as OST staff training and pilots in hydroponics and nutrition. Though they were committed to offering STEM programming, most CBOs did not have the staff or resources to provide STEM learning opportunities regularly. One challenge was a lack of multi-year funding for sustained planning and implementation. Another was that OST staff had limited capacity to lead STEM activities effectively due to their own lack of exposure to math and science. Like many adults, OST staff charged with leading STEM activities often had no positive STEM experiences on which to draw. In an interview, one OST program director noted that, for staff who may not have had positive experiences in science or math, "their own anxieties from failure in school come into play." As has been highlighted in numerous studies about the importance of training OST workers, "staff development for youth workers is the missing link to promoting STEM topics" (Coalition for Science After School, 2008, p. 3). In fact, in a national survey of more than 1,000 afterschool programs, 67 percent said they needed staff professional development to strengthen STEM program-

ming (Afterschool Alliance, S.D. Betchel, Jr., Foundation, & Time Warner Cable, 2011).

Over the last decade, leaders from the science and youth development communities have worked together to identify ways to increase informal science learning opportunities for youth. Strategies have included bolstering the knowledge and skills of OST staff to lead STEM activities, aligning OST content with school STEM content, building partnerships between science organizations and OST programs, mentoring, forming STEM-focused youth clubs, and integrating science into other program areas (Bevan et al., 2010). DYCD explored a number of different strategies, creating a foundation for the expansion of STEM programming in NYC's OST system. However, other pieces were needed to increase system capacity.

Making It Work

Adding the mechanical aspects of a robot, such as the motor and sensor, transforms the object—creating movement and new possibilities. As part of DYCD's exploration of strategies to complement its existing investments in STEM education, DYCD staff approached the New York Academy of Sciences to discuss opportunities to access the wealth of resources available in New York City's scientific community. For nearly 200 years, the Academy has promoted links between science and society. It has more than 25,000 members, including 27 Nobel laureates as well as CEOs, philanthropists, and leaders of national science funding agencies. Unlike many other scientifically rich institutions such as universities and museums, the Academy's main resources are its members—including scientists in training who come to the Academy for career advancement programming. The Academy's Science Alliance supports 8,000 graduate students and postdoctoral scientists, many of whom are looking for opportunities to learn to teach and mentor.

As in most promising collaborations, both DYCD and the Academy had something to gain and something to give. For DYCD and the city's OST system, the Academy offered a single point of contact for dozens of scientific institutions, including major universities such as Columbia University and Cornell Weill Medical College. For the Academy, access to a single point of contact for hundreds of CBOs meant an efficient means of reaching youth. Although capacity building through collaboration at this scale was not a new concept, it would represent a major accomplishment and provide a possible national model for tapping local expertise to strengthen youth STEM learning. Such collaboration, as Project Exploration and the Coalition for Science After School (2009) put it, can enable "professionals across projects and communities to generate and carry out creative solutions and strategies that maximize benefit beyond that which each entity could accomplish" (p. 21).

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The New York Academy of Sciences Afterschool STEM Mentoring Program, a partnership between DYCD and the Academy, was launched in late 2010. Then and now, this initiative matches OST programs with young scientists of the Academy's Science Alliance, who serve as STEM mentors in the programs. In this model, OST staff do what they do best—provide a "non-threatening, non-academic environment for hands-on learning that is collaborative, informal, and personal" (Chun & Harris, 2011, p. 1). The Academy's mentors add their knowledge of and enthusiasm for STEM fields.

The STEM initiative uses strong curriculum partners—the mentors—to infuse STEM into community-based OST programs. Bypassing the constraints of the formal classroom structure, it provides relevant, hands-on curriculum; opportunities for youth to interact with young, diverse scientific role models; and content knowledge and resources—important characteristics of strong afterschool programs, according to the Coalition for Science After School (2007). It also gives mentors the invaluable opportunity to work outside university walls to impart their knowledge and enthusiasm to young people. They strengthen their communication skills, deepen their understanding of STEM content areas, and practice teaching in collaboration with CBO staff. Additionally, mentors benefit from opportunities to network with other scientists.

Roles

Early on, DYCD and the Academy established partner roles and responsibilities. The Academy agreed to lead the day-to-day operations of the initiative, including organizing an annual citywide family science day. The Academy:

- Recruits and trains mentors
- Selects STEM curricula that fit best practices in youth development and informal science education and are aligned with the New York State Scope and Sequence
- Assists mentors and OST programs with ongoing communication, builds successful site-level collaboration, and troubleshoots site-specific issues
- Collects data on the mentors' experience with the STEM initiative
- Organizes networking opportunities for mentors and OST staff
- Identifies and secures resources to support the initiative, including program supplies

Meanwhile, DYCD continues to encourage STEM programming and to support the OST programs it funds. Specifically, DYCD:

- Provides ongoing professional development to increase OST staff capacity to engage youth in STEM activities
- Identifies and selects programs that are a good fit for the initiative
- Continuously monitors OST programs, providing technical assistance and recommendations for improvement
- Promotes events like the citywide family science day
- Provides youth development training for mentors
- Facilitates appropriate NYC Department of Health volunteer screening

DYCD and the Academy assigned lead staff to coordinate partnership activities. These staff, who had access to the senior leaders of their organizations, played a pivotal role in promoting the STEM initiative, identifying opportunities to refine and enhance the model, and reaching out to new partners. While none of the lead DYCD staff were trained scientists, they shared a passion for STEM fields. Their personal interest was a major factor in the success of the partnership.

Program Elements

The concept of using local scientists as volunteers to build STEM content is simple and can be replicated in other settings. We found that four core elements were crucial:

1. Recruitment through partnerships with academic institutions
2. Training and curriculum
3. Site selection and mentor placement
4. Ongoing support

Recruitment Through Partnerships with Academic Institutions

The Academy has long-standing formal relationships with 40 universities and academic medical institutions in New York City. Young scientists from these institutions and their sponsoring faculty members are already engaged in Academy programming, so they are receptive when the Academy sends them recruitment materials advertising mentoring opportunities. In the universities, faculty, administrators, student activities leaders, and offices of career advancement also receive information to share with potential mentors. Prospective mentors complete an online application outlining their background, professional goals, experience with teaching and mentoring, and reasons for interest in mentoring. They must also provide a letter of support from their sponsoring faculty members.

Mentors are required to:

- Complete two full-day training sessions
- Work with OST staff to schedule the day and time of the weekly lessons
- Attend a kick-off mixer reception at the beginning of each semester
- Complete a fingerprinting and background check process

The Academy accepts about 100 mentors a semester, with about 30 percent returning from the previous semester. Most are drawn to the program to improve their teaching and mentoring skills, continue their involvement with community service, or serve as role models. Some need to fulfill an outreach requirement of their university. One doctoral student's application statement provides a typical reason for participation:

> Throughout grade school, I was blessed with phenomenal biology teachers. Their influence in my life has enabled me to enter a field that fascinates me every day. . . . I would like to become a mentor in the Academy's Education Program to help another young mind discover the wonder of science.

The Academy strives to identify STEM mentors from diverse backgrounds. Mentors are trained to facilitate an activity that addresses the issue of diversity in the STEM fields. This activity, Draw a Scientist, usually takes place on the first day of the mentoring program. The premise is simple: Ask youth to draw a picture of a scientist. When the youth compare their drawings, they usually discover that almost everyone has drawn an older

white man wearing a lab coat and glasses and carrying a beaker or another piece of equipment. The drawings are a great way to get youth talking about their assumptions about scientists. They also provide the mentors with a way to share their backgrounds. Programs that repeat this exercise after a few months often find that youth draw themselves or their mentors.

Training and Curriculum

Once chosen, mentors go through a two-part training process. First, they select a curriculum and attend a full-day workshop to learn to teach it. The curricula are all hands-on enrichment programs designed to be taught in OST settings. Mentors can choose one of seven 10–12-week modules, including robotics, human body systems, genetics, and others. The topics were selected because they fit the New York State Scope and Sequence and are of interest to middle school students. The curriculum providers, who include Cold Spring Harbor Laboratory, Cornell University, and New York University, lead the curriculum training. In addition, experienced mentors attending the workshops can describe how they implemented the curriculum. The Academy provides a deep library of lesson plans, all following the same basic structure. The lessons require supplies that can easily be purchased in local stores and provide enough variety to allow mentors to deepen their relationships with their students.

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The mentors attend a second workshop focused on youth development, offered through DYCD. This workshop provides an overview of middle school youth development, pedagogy, and classroom management; it also outlines roles and expectations for working with youth. Afterschool staff often attend the workshop to help the mentors understand that the OST staff are the experts in working with children and to counteract any misconceptions mentors may have teaching about middle school children.

Site Selection and Mentor Placement

Every year, DYCD and the Academy select afterschool sites from among the DYCD-funded CBOs that submit applications. For the first two years of the STEM initiative, the Academy worked with approximately 90 of the 123 programs that applied.

In order to participate in the STEM initiative, CBOs must agree to meet certain requirements:

- CBOs assign a staff member—ideally one who has an interest in STEM—to support the mentor in such areas as classroom management.
- Staff participate in the kick-off mixer and a youth development workshop with their assigned mentor.
- Sites provide basic school supplies such as paper, pencils, cups, and so on. Mentors are supplied with scientific materials and have a small budget to buy additional items.
- Sites dedicate a consistent classroom-like space for STEM activities.

OST programs complete a simple application for the STEM initiative. In their applications and in staff interviews, CBOs cited these primary reasons for applying:

- To increase access to high-quality STEM education
- To meet parents' demands that the CBOs provide additional academic programs
- To provide expert support for existing STEM programs such as robotics
- To forge closer relationships with volunteer organizations and academic institutions

In selecting afterschool programs, DYCD staff balance a desire to create maximum opportunities for youth, especially those in economically disadvantaged communities, with realistic expectations about programs' capacity to work with mentors. Specific considerations include how long the program has been in existence, its accessibility by public transportation, its size, the number of middle school youth it serves, and the experience level of its staff.

Once mentors complete training, they are matched with OST programs based on geography and curriculum choice. Whenever possible, more than one mentor is assigned to each site. Though the mentors may teach different curricula, this duplication helps when a mentor has to leave the program. The mentors assigned to a site usually find ways to work together.

Mentors are expected to teach one hour each week for nine weeks; many mentors teach more hours and continue beyond nine weeks. Once matched with a program, each mentor is paired with at least one OST staff member in a co-teaching model; the pair go through training together and then collaborate to plan and ex-

ecute the lessons. OST staff and mentors are encouraged to integrate thematic learning, project-based learning, and skill-building into STEM activities.

Ongoing Support

DYCD and the Academy maintain lines of communication with the mentors and OST program staff to identify and solve problems when they arise. Common problems include changes in schedules, adaptation of lesson plans to meet the background and interest of the students, and communication between mentors and OST staff. Mentors experience the problems typical of new teachers. In addition, matches occasionally need to be dissolved due to schedule changes, lack of resources, and changes in a mentor's status. In this case, the Academy and DYCD staff work with the CBO to find a new mentor or supply activities to fill the dedicated time.

Costs

The estimated cost per mentor is about $800, which covers curriculum training, supplies for both training sessions and STEM classes, travel, and printing. In-kind contributions from the Academy, DYCD, and the CBOs include fingerprinting, support for mentors and OST staff, the time of the OST staff who co-facilitate STEM activities, activity space, youth development training, and supplies.

Assess, Refine, Test Again

Usually a robot design is tweaked a few times before it is complete to ensure that the robot is balanced and stable, that its sensors work, and that it can change direction as needed. DYCD and the Academy regularly collect data on partner institutions, mentors, and OST programs to evaluate the initiative: mentor and CBO application data, regular surveys, program site monitoring, and interviews. The numbers show that, through mid-2012, the STEM initiative recruited 20 university partners and placed more than 380 mentors in 90 OST program sites. More than 5,000 middle school students received nearly 80,000 student-hours of learning. Findings from analysis of the data collected yield insights into the experience of the partner institutions, mentors, and OST programs.

Perceptions of Partner Institutions and Mentors

In its first year, the pilot provided proof of concept for the initiative's value to the scientific community. The Academy recruited and trained 120 graduate students and postdoctoral fellows and then placed them at more than 90 DYCD-funded OST programs. Of these 120 mentors, 78 percent earned an Academy teaching credential, which requires 24 hours of teaching and training; 30 percent taught for more than one semester. Several independently approached the Academy to explore offering their support to new mentors.

Evaluation data indicate that the mentors felt well prepared to teach their curricula, emerged with more confidence in their ability to teach, and would recommend the program to a colleague. Interviews with university and college faculty who participated in the pilot demonstrate their satisfaction with the program: They said they would continue to send young scientists to the Academy as potential mentors and would recommend the program to other faculty members.

In Fall 2010, project staff surveyed the first cohort of mentors before and after they completed the curriculum training about their sense of preparedness to teach and their implementation of the curriculum. Of the 35 mentors surveyed, 65 percent felt well prepared to teach their curriculum. All 35 offered suggestions for improving the training and lesson plans; these suggestions were used to improve both in the next semester. Most (80 percent) reported that teaching was a positive experience, and 60 percent indicated that they wanted to teach again the next semester.

Project staff also interviewed with ten mentors from the first cohort at the end of the fall semester. Of these ten, six reported problems of logistics, including inappropriate room assignments, lack of supplies, and inconsistent scheduling. All ten mentioned positive experiences with their students, with eight reporting on specific student conversations. Nine out of ten reported that teaching was different from what they expected, but that they found it to be rewarding and enjoyable. None of the interviewees reported difficulties with classroom management. This finding may be attributed to the presence of the OST staff co-teachers.

At the end of the first year, the Academy conducted a survey of the mentors. Of the 46 respondents, 90 percent indicated that they enjoyed the program, and 95 percent said they gained confidence in their teaching skills. All of them said they would recommend the program to their peers. The survey showed that 53 percent of mentors felt that their students had a wide range of abilities and backgrounds in science or math. In order to better understand the barriers to success, the Academy asked the mentors to rank the problems they encountered at their sites; 65 percent said they had problems communicating with their sites to schedule classes or finding planning time, while 26 percent reported having inappropriate facilities, such as lack of a blackboard or consistent classroom space.

Perceptions of CBOs and Their OST Programs

In 2011, DYCD conducted site visits to 24 participating CBOs. Site visitors reported that the children seemed to enjoy and value the program, were engaged in the hands-on lessons, and had come to expect science to be part of their OST experience. The researchers also reported that three sites previously considered to have low capacity to implement academic programs and maintain external partnerships greatly benefited from having a mentor. Leaders at these three sites reported that participation in the STEM initiative built their capacity to implement an academically focused curriculum, that their co-teaching staff gained confidence in teaching STEM, and that they could envision themselves implementing similar programs in the future.

In Summer 2012, DYCD surveyed program directors who had mentors at their sites. Of the 44 directors who received the survey, 12 responded. Program directors were generally satisfied with the mentors; in fact, 11 out of 12 requested to have a mentor again the following school year. The CBO that did not request a mentor had raised enough funding to hire STEM specialists of its own. The challenges directors cited related to the logistics of mentor coordination. A robotics team coach discussed the importance of the support of the OST staff member. He observed that, while mentors sometimes lacked experience with youth, they "will always evolve and learn from the process. They were hesitant at first but gradually interacted more, engaging and learning from the students."

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In the surveys and subsequent follow-up interviews, the 12 program directors discussed the value of this approach to increasing the capacity of OST programs to offer STEM programming. For example, one director said:

> The mentors are passionate about what they are teaching, knowledgeable, and willing to adapt their material for the specific population. The activities are engaging and hands on, so the learning is "disguised" for the participants.

Another noted:

> The mentors in our program did everything—they were very hands on, including organizing trips and even bringing in animals for activities. Having mentors involved in the OST program demonstrated to staff that youth actually like science, because the attendance rates were very high on the days when mentors joined the program.

Adaptation and Replication

DYCD and the Academy are experimenting with components of the model, using key lessons to adapt practices or test new theories. Both organizations understand that "there is a need to bring greater complexity to the notions of sustainability and scale-up; rather than expanded replication, there is a need to consider isolating features or elements that are transportable and scalable" (Bevan et al., 2010, p. 18).

The Academy has done two major adaptations to date. In 2011, the Academy and DYCD adapted the model into the Summer Matters Program, a six-week, full-day summer enrichment program for 2,000 middle school students. This program was part of a public-private partnership led by DYCD. Each 10–12-week school year curriculum was adapted into a three-week module that met twice a week for 2.5 hour blocks. The Academy provided stipends to the mentors, who were recruited from its pool of experienced mentors. Curriculum partners, experienced mentors, and Academy staff collaborated to make curriculum changes including creating longer lab activities, adding activities with more kinesthetic elements, and finding affordable field trips related to the content.

The second adaptation came when the Academy partnered with Citizen Schools to bring the initiative to Newark, New Jersey. Citizen Schools runs extended learning day programs, often funded by a school improvement grant that holds the organization responsible for student performance. Although the spirit and everyday activities of the STEM initiative remain the same, the additional accountability measures have led to an emphasis on more rigorous lesson planning and the addition of a capstone project

designed by the mentor. The curricula also shifted to reflect New Jersey standards rather than those of New York.

The Academy and the State University of New York (SUNY) have developed a plan to take the STEM initiative statewide. The ambitious plan includes mechanisms that will allow the Academy to conduct the program across a large geographic area. These include distance learning techniques and a hub-and-spoke model in which SUNY campuses support local CBOs. A formal outline of required staff supports and funding will establish a versatile blueprint for implementing the program in other regions.

DYCD has also engaged in replication of the model. In partnership with the Academy and the New York University (NYU) Center for Mathematical Talent, DYCD-funded OST programs participated in a summer math pilot in 2012. OST staff received training and support from DYCD and NYU to use the NYU *Finding Math* curriculum, which uses lessons with games and puzzles to give youth opportunities to consider how math factors into everyday life.

In 2012, DYCD expanded STEM programming across NYC's OST system by adding a new funding requirement that required grantees to provide at least two hours of STEM or literacy programming every week. Activities were to be, in the language of the RFP, "designed to build basic literacy and math skills as well as 21st century skills, such as teamwork, problem solving, and critical thinking." A technical assistance provider offers ongoing support to CBOs, focusing on increasing OST staff capacity to facilitate high-quality STEM and literacy activities. In addition, building on lessons from the mentor initiative, DYCD and the Academy work with CBOs to develop partnerships with academic and other STEM-related institutions in their neighborhoods. Investments in OST staff development improve staff capacity to facilitate STEM activities but cannot make up for a lack of expertise or access to resources, such as museums, parks, and universities, that can enrich STEM learning. Identifying local resources is thus a key strategy for OST programs that want to improve their STEM offerings.

As youth learn when building a robot, creating a strong foundation and making the key components work are the most important steps in the process. OST programs have positive youth development principles as their foundation; they are designed to promote inquiry-based, hands-on learning. The STEM initiative provided the key components; it allowed CBOs to leverage the tremendous resources available in NYC's scientific community to increase STEM learning opportunities for youth. Although this type of partnership builds CBOs' capacity by bringing in content experts, staff development is also needed to ensure that both OST staff and STEM mentors have a deep understanding of one another's fields and can fully capitalize on partners' experience and resources.

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References

Afterschool Alliance, National Afterschool Association, & National Summer Learning Association. (2011, May). *Afterschool and summer programs: Committed partners in STEM education.* Retrieved from http://www.afterschoolalliance.org/STEM_JointPositionPaper.pdf

Afterschool Alliance, S. D. Betchel, Jr., Foundation, & Time Warner Cable. (2011). *Afterschool: A vital partner in STEM education.* Retrieved from http://www.afterschoolalliance.org/Afterschool_as_STEMpartner.pdf

Bevan, B., Michalchik, V., Bhanot, R., Rauch, N., Remold, J., Semper, R., & Shields, P. (2010, June). *Out-of-school time STEM: Building experience, building bridges.* Retrieved from http://informalscience.org/images/evaluation/STEM_OST_Conf_Report.pdf

Braun, H. I., Coley, R. J., Jia, Y., & Trapani, C. S. (2009). *Exploring what works in science instruction: A look at the 8th grade science classroom.* Princeton, NJ: Educational Testing Service.

Brisson, L., Eisenkraft, A., Flatow, I., Friedman, A., Kirsch, J., Macdonald, M., . . . Witte, J. (2010). *Informal science education policy: Issues and opportunities.* Washington, DC: Center for Advancement of Informal Science Education.

Chun, K., & Harris, E. (2011). STEM out-of-school programs for girls. *Research Update: Highlights from the OST Database, 5,* 1–8. Retrieved from http://www.hfrp.

org/content/download/3847/105424/file/ResearchUpdate5-STEM-012611-FINAL.pdf

Coalition for Science After School. (2007, March). *Science in after-school: A blueprint for action.* Retrieved from http://www.greatscienceforgirls.org/files/Science-in-Afterschool.pdf

Coalition for Science After School. (2008). *Staff capacity and professional development for after-school STEM: A summary of key research.* Retrieved from http://afterschoolscience.org/pdf/coalition_publications/Staff%20Capacity%20and%20Professional%20Development.pdf

Jolly, E., Campbell, P., & Perlman, L. (2004). *Engagement, continuity, and capacity: A trilogy for success.* St. Paul, MN: Science Museum of Minnesota.

National Center for Education Statistics. (2009). *NAEP mathematics 2009 district snapshot reports* (NCES 2010455). Washington, DC: Institute of Education Sciences, U.S. Department of Education.

New York State Afterschool Network & The After-School Corporation. (2012). *Science beyond the classroom: Critical to New York's future.* Retrieved from http://www.expandinglearning.org/sites/default/files/Science%20Beyond%20the%20Classroom-%20Critical%20to%20New%20York%E2%80%99s%20Future.pdf

Project Exploration & the Coalition for Science After School. (2009, March). *A watershed moment: The first National Conference on Science and Technology in Out-of-School Time.* Retrieved from http://www.projectexploration.org/wp-content/uploads/2013/04/watershed-2009.pdf

Thomasian, J. (2011). *Building a science, technology, engineering, and math education agenda: An update of state actions.* Washington, DC: National Governors Association Center for Best Practices.

U.S. Department of Labor, Employment and Training Administration. (2007, April). *The STEM workforce challenge: The role of the public workforce system in a national solution for a competitive science, technology, engineering and mathematics (STEM) workforce.* Retrieved from http://www.doleta.gov/youth_services/pdf/STEM_Report_4%2007.pdf