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."

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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

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.

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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

Table 1. Comparison of Three STEM Programs for Girls

	TECHBRIDGE	GIRLS GO TECHBRIDGE	ACCESS FOR YOUNG WOMEN
AGE LEVEL	Grades 5–12	Middle school	Grades 7–12
LOCATION	California	13 states	Queens, New York City
FACILITATORS	Teachers and Techbridge program coordinators	Girl Scout council volunteers and staff	Social workers and youth workers
PROGRAM DURATION	One to six years	One day to one year	One to six years
SUBJECT EMPHASIS	Engineering, science, technology	Engineering, science	Leadership skills, science, math, technology
SETTINGS	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
SPECIAL FEATURES	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
EVALUATION METHODS	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.

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."

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

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.

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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.

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.

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.

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

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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