youth as community science experts in green energy technology

by Angela Calabrese Barton, Daniel Birmingham, Takumi Sato, Edna Tan, and Scott Calabrese Barton

"We know what we are doing. We know how to make a difference. We know how to save energy and how to convince other people of better ways to do things with electricity. That is one way that we are experts."

These words come from Janis, a 13-year-old African American and incoming ninth grader who has participated in Green Energy Technology in the City (GET City) for nearly four years, first as a student-participant and later as a youth leader. Janis went on to say:

> What I would like do in the future... is become an engineer specializing in computer and electrical engineering or reverse engineering. I would like to invent or create something that will save energy and be very useful to people, that will cost less. I would love to create an energy-efficient refrigerator that will use less and maybe tell you how and what items that are still in the refrigerator. I am aware of energy-efficient refrigerators that are currently in the market, and I am very interested in learning about how such refrigerators are actually designed and made.

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Consistent with these ideals, Janis refers to herself as a *community science expert,* or someone who can "make a difference" because of what she knows about science and about her community. These aspirations are new for Janis, who, in fifth grade when we first met her, openly expressed a dislike of science, was unfamiliar with engineering, and aspired to be a singer. Janis describes GET City as the place where she learned what an engineer is and where she realized she could use her love of art to do science and engineering. It was also where she learned that being smart in science was not only for "geeks."

Janis' story is, unfortunately, the exception and not the norm. In the U.S., African Americans make up only 5 percent of the engineering workforce, mostly as technicians rather than managers or leaders (National Action Council for Minorities in Engineering, 2011). This statistic has changed little in the past two decades despite efforts to reform science and mathematics in our nation's schools. In particular, interest and motivation in science, technology, engineering, and math (STEM) drops precipitously in the middle grades, when youth make critical course choices that can have lifelong consequences (Vedder-Weiss & Fortus, 2012).

In this paper, we examine what it means to become a community science expert (CSE) like Janis and why this goal is important for youth in afterschool environments. Using GET City as a case study, we describe how this afterschool program nurtures youth as CSEs. We draw on data gathered in 2007–2010 including student and teacher interviews; field notes on student participation; student artifacts; and pre- and post-participation measures of technology knowledge and skills, STEM practices, career aspirations, and community engagement. The guiding questions for the case study included "What does it mean to become a CSE?" and "Why should developing CSEs be an important outcome of afterschool programming?"

Becoming a Community Science Expert

Success in school science has been narrowly defined by achievement scores. However, as noted by others (for example, National Research Council [NRC], 2009), this narrow framing overlooks other crucial indicators of learning and development, such as changes in identity and in forms of participation. Learning science is a long-term process of becoming a legitimate participant; it involves learning the discourses and practices of science (Lave & Wenger, 1991; Rosebery & Warren, 2008). Especially for students for whom science represents ways of knowing, talking, or doing that are different from those they usually experience, figuring out how to negotiate the multiple discourses and knowledge of the science learning community can be challenging (Moje, et al., 2004; Rosebery, Ogonowski, DiSchino, & Warren, 2010).

A growing body of research demonstrates how informal science settings, both programmed and freely formatted, have been successful in reaching youth from underrepresented backgrounds (NRC, 2009). This work shows how informal science learning not only supports knowledge gains but also increases the desire to participate in science (Dierking, 2007; Falk, Storksdieck, & Dierking, 2007; Harvard Family Research Project, 2011). Informal science environments recognize and value a broad set of learning outcomes that are more consistent with how people learn in everyday life than are traditional school outcomes (NRC, 2009). Outcomes more recognized as important forms of learning and achievement in informal settings than in traditional settings include development of science identity—for example, "I am an oceanographer who loves to dance with the dolphins"—and novel forms of participation that merge cultural and scientific practices (Calabrese Barton & Tan, 2010; Nasir & Hand, 2008). The dolphin-dancing oceanographer, for example, might become the choreographer of an artistic and scientific documentary.

Drawing on this research base, we posit that one important outcome of community-based informal science programming is providing opportunities for youth to become CSEs. Becoming a CSE involves developing deep knowledge of science and applying that knowledge by taking action in meaningful ways in the local community. We define CSEs as youth who are knowledgeable in science, are deeply connected to place, and use their expertise and connections to engage community members and take action on local issues (Calabrese Barton & Tan, 2010). As Lee and Roth (2003) argue, "science is not a singular normative framework for rationality, but merely one of many resources that people draw on in everyday collective decision-making processes" (p. 2). CSEs combine scientific knowledge with community experience to inform action.

Community science expertise challenges traditional notions of scientific expertise because it values experiential knowledge, family concerns, and community history alongside scientific knowledge. Youth are positioned as experts—as individuals who are capable of leading and making a difference by using science in their communities. Authority is shared; community science expertise requires multiple perspectives and engagement with many people. From this perspective, scientific expertise can be leveraged to redistribute the power structure in a community.

The idea of being CSEs was initially developed by youth in GET City. They began to refer to themselves as people who, as Janis says, "make a difference" because of the science they know and the work they do with that knowledge in their community. When asked to describe, for a presentation to a sustainability scholar, what CSEs are and do, GET City youth created a slide that described CSEs as "committed... ready to learn... willing to take on big problems that will help your community... willing to make a difference." This concept of community science expertise highlights the need to learn relevant science, identify community issues, and take educated action to improve the community.

GET City supports youth in becoming CSEs by providing a platform where they can engage in scientific discourse while having the freedom to affect their community in ways that matter to them. Supporting youth in developing as CSEs positively affects their interests and aspirations in science and engineering. The next sections describe how GET City has helped youth to become CSEs. We first explain the structure of GET City and give an example of how it supports youth in developing identities as CSEs. Then we discuss implications for other programs interested in giving youth opportunities to gain knowledge and interest in science and to use that knowledge to take action in their local communities.

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Green Energy Technology in the City

Supported by the National Science Foundation, GET City serves 20–30 youth annually at the Boys and Girls Club in Great Lakes City, MI (a pseudonym). The authors of this paper designed the program and work as facilitators in it. The youth are local to the area; many come from low-income and minority backgrounds. Child poverty in Great Lakes City has increased more than 40 percent since 2000 (Michigan League for Human Services, 2009). More than a quarter of Great Lakes City children live below the poverty line, with the rate jumping to over 40 percent for African-American youth.

GET City is built on the premise that meaningful learning happens when youth engage in authentic investigations of local problems and have scaffolded opportunities to educate others about their findings. This year-round program helps youth to develop into science and engineering *experts* and *citizens* by supporting them to take on green energy issues and to communicate findings to their community. Supporting youths' development as CSEs are the three organizing components of GET City:

- Building STEM expertise
- Building STEM citizenship
- Educating others

The first component is *building STEM expertise*. GET City engages youth in authentic investigations of issues that have local relevance and global importance, fostering deep engagement with energy and environmental issues. Youth engage in authentic scientific practices: asking research questions; developing, testing, and revising scientific models; collecting and analyzing data; and reporting and defending findings. GET City investigations usually emerge from youth questions that are generated in collaborative discussions with adult staff about energy concerns in the city and state. For example, the youth investigated whether their city should build a hybrid power plant because their parents received letters from the local power company regarding potential rate hikes. GET City investigations are supported by field trips to related partner projects such as power plants, wind farms, solar arrays, and LEED-certified buildings.

The second component is *building STEM citizenship*. As part of their investigations, youth develop multimedia products to educate particular audiences on energy issues, addressing the question, "What's important for others to know about my investigation?" These products include digital public service announcements, podcasts, raps, and others. Developing these products encourages youth to discern the scientific messages that are most salient to other people. The process helps youth move from being STEM experts to being STEM citizens as well.

The third component is *educating others*. Youth use their knowledge and products to educate target audiences and enable them to adopt green practices. The GET City Education Network provides an audience for youths' scientifically rigorous ideas. In this network, youth work with GET City staff, local teachers, and community leaders to develop their multimedia products into educational activities that align with school and community needs. GET City youth typically host three community forums each year to teach their findings to peers, families, and community members, reaching 50–150 people per event. Youth also teach lessons in their school, where they educate peers about their findings in youth-centered ways.

The GET City website, where youth blog and post multimedia products, provides additional authentic audiences.

GET City's three components support youth in developing expertise and using it in powerful ways in their community. Case study and external evaluation data (Laorenza, Whitney, & Feger, 2010) indicate that GET City youth not only made a difference in their school and community, but also significantly increased their interest and career aspirations in science and engineering along with their knowledge and skills. Even more interesting, they also placed more value on science and information technology for solving community problems (Laorenza et al., 2010). These outcomes support the idea that developing youth as CSEs is important.

Like many science-related public policy initiatives, this one focused on action goals and behavioral changes but did little to help people understand the science behind the changes. Our goal in introducing this unit to GET City youth, therefore, was to help them get smarter about the science underlying Change a Light, Change Michigan.

So what does becoming a CSE look like in action? What strategies and planning practices are used in the three components of GET City to support youth in developing as CSEs?

Community Science Experts in Action

To address these questions, we studied a GET City investigation of the statewide initiative Change a Light, Change Michigan. We used this policy in our investigation because it enabled youth to engage with current local energy-related dialogue and to take action based on their understanding of the science and of community needs. The investigation is thus typical of GET City experiences.

Authentic Investigations

During the 2009–2010 school year, GET City youth investigated the newly introduced initiative Change a Light, Change Michigan, which encouraged residents to switch from incandescent light bulbs to compact fluorescent lights (CFLs). The investigation began with the questions, "What is this initiative asking residents of our state to do, and why? Why should we care?" Like many science-related public policy initiatives, this one focused on action goals and behavioral changes but did little to help people understand the science behind the changes. Our goal in introducing this unit to GET City youth, therefore, was to help them get smarter about the science underlying Change a Light, Change Michigan. The youth delved into several months of scientific investigation, including experiments designed to produce electricity from different sources, exploration of energy supply and consumption in their city, and study of the relationship between energy conservation and carbon emissions. The investigation was built around the idea that people and organizations have carbon footprints: Daily activities such as driving a car and turning on lights produce carbon dioxide. An additional premise was that people have some control over the size of their carbon footprints.

In the first part of the investigation, youth gathered data to determine their own carbon footprints and that of the community club that hosts GET City. Using online calculators, GET City youth surveyed their own and their families' energy practices to determine their carbon footprints. They compared footprints with one another and with youth around the globe. They asked their parents and other family members how they kept track of their energy usage, if at all. They interviewed grandparents and great-aunts and uncles to learn how appliance usage had changed over two generations. They determined the power needs of representative electrical items in homes and businesses and learned about the relationship between personal actions and energy usage. Embedded in these investigations were core concepts such as the law of conservation of energy and the fact that electrical energy is measured in kilowatt-hours. Students also audited the community club's energy practices: what appliances were used, how often, and for what purposes; whether appliances were left on when not in use. They then wrote a letter to the club president, recommending changes to conserve energy and reduce the club's carbon footprint.

In order to understand that energy consumption contributes to carbon emissions, youth have to understand how electricity is produced and delivered. For example, flicking on the light switch indirectly produces carbon through the harvesting and burning of coal. In the second part of the investigation, students built hand cranks using magnets, copper wire, and micro-amp bulbs to produce electricity using human power. They visited the local coal-fired power plant. They used these ideas to write and produce musical raps about the production of electricity.

In the third part of the unit, the youth delved more deeply into the public initiative Change a Light, Change Michigan. They came up with questions, such as, "Why

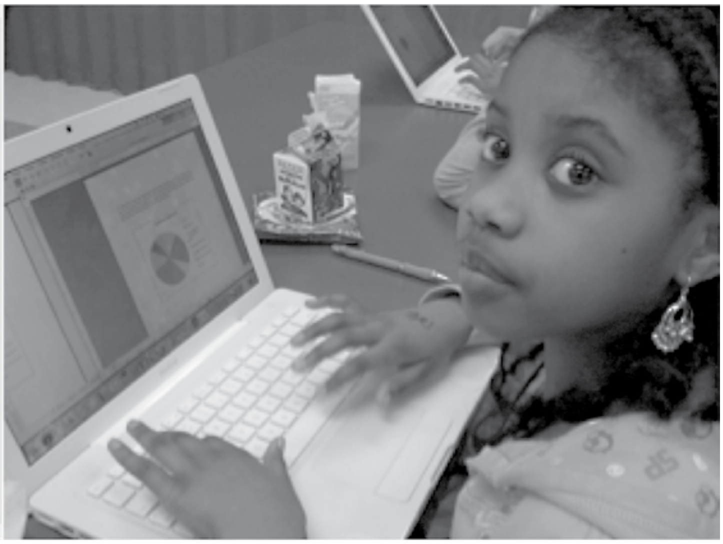

Figure 1. GET City Participant Analyzing Data

would changing the style of light bulb make a difference?" To satisfy their curiosity, the youth conducted several experiments, using digital probes to compare the power requirements and the heat and light outputs of CFLs and incandescent light bulbs. They then organized their data using spreadsheets (Figure 1). For example, they rode a bicycle connected to an electrical generator to power incandescent bulbs and CFLs so they could physically feel the increased effort needed to power the incandescent bulbs. They measured the heat emissions of the two types of bulbs after 1 minute, 5 minutes, and 10 minutes of usage. Embedded in these investigations were the core ideas of energy efficiency and energy transformation. Incandescent bulbs require more electricity because they convert electrical energy into both light and heat energy, whereas CFLs more efficiently convert electrical energy primarily into light energy. These experiences built the youths' expertise in energy-related science.

During this portion of the investigation, the local school district announced major budget cuts that would largely affect afterschool programming and special activities at the youths' school. Three GET City youth—we'll call them Etta, Chloe, and Chantelle—were particularly upset by these cuts. They decided to use their knowledge of Change a Light, Change Michigan to take action. They believed that, if they could figure out how much money the school could save by moving from incandescent bulbs to CFLs, they might be able to save afterschool programming while reducing their school's carbon footprint.

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Using Science and Community Knowledge to Take Action

With video recorder, surveys, and cameras in hand, Etta, Chloe, and Chantelle set out to perform an energy audit of their school. They counted the incandescent bulbs in the school building and documented their locations. They recorded the kilowatt-hour expenditure and the need for light in each location. Based on school routines, they conjectured how often and for how long each light would need to be on. Putting their data into spreadsheets, they calculated current energy expenditures and then performed the same calculation assuming that all bulbs were CFLs. Using the difference, they calculated how much money and how many pounds of carbon emissions would be saved if the school switched to CFLs. They also interviewed teachers and students on their energy practices in school.

Prior GET City investigations had shown these youth how to translate their findings into digital productions that were scientifically rigorous and relevant to their community. Using their own time as well as time in GET City, the three girls turned their findings into a four-minute public service announcement, "The Light Bulb Audit," targeted to school leaders and peers.

"The Light Bulb Audit" is serious yet humorous, scientifically complex yet accessible to the intended audience. It starts with a series of images backed by John Mayer's song, "Waiting on the World to Change." The first image shows youth playing and dancing in their school. The next images are of an incandescent light bulb and then a CFL accompanied by the text, "MAKE A CHANGE." The video then transitions to the three girls explaining their decision to conduct a light bulb audit and asking viewers if they think their school is green. Although their audit covered most school spaces, the girls focused their video on the bathrooms located in each classroom. The video shows its producers inspecting school bathrooms to count CFLs and incandescent bulbs, interspersing these shots with information about the number of watts used by each. The girls discover that all but one bathroom use incandescent bulbs, helping to set up their storyline about why their school must make a change.

The next segment of the video uses music, text, and vivid images to detail how and why energy efficiency reduces carbon emissions and is better for their environment. In the background is Michael Jackson's "Earth Song," whose lyrics question, "What have we done? Look what we've done." The video juxtaposes images of coal mines and coal harvesting with text declaring, "This coal mine used to be filled with trees and grass." As the music fades, Chloe asks viewers, "Have you ever seen those smoke stacks?" Next, we see a picture of the local power plant. Three stacks billow smoke of an ominous burnt-orange hue as the music asks, "What about flowering fields?" The mine image reappears, but now the text reads, "This land and our atmosphere may NEVER be the same."

The last segment of the video presents the girls' calculations of the money and carbon that would be saved if their school changed bulbs. The video closes with scrolling text reviewing how incandescent bulbs use more energy, while Michael Jackson's song says, "I'm asking you to make a change." The girls used their knowledge of energy-related science, of their school, and of IT applications to deliver an educational message to members of their community. The video, an instant hit among their GET City peers, spurred the group onto action.

Getting the Message Out There: Making Real Change

As a group, GET City youth decided that they needed to share their findings with their school. Using "The Light Bulb Audit" as the centerpiece, they prepared a 30-minute workshop for the school's student congress, focusing on why the school should switch the bathroom lights to CFLs. The youth prepared a presentation highlighting the energy consumption and emissions of incandescent bulbs and CFLs. They created a rap about the science of incandescent bulbs, carbon emissions, and climate change. In addition, they prepared a pledge committing to change the bulbs that they hoped all school leaders—student congress and adult leaders alike—would sign. The GET City presentation helped student representatives to deepen their scientific understanding of the environmental slogan Change a Light, Change Michigan, while pledging to make a difference in their school.

On hearing about the investigation and resulting school workshop, the local power company donated 1,000 CFLs for GET City youth to distribute to their schools, neighbors, and families. A group of 16 GET City youth took their workshop on the road to their churches and other community centers until all of the bulbs were distributed. The network of people who saw the "The Light Bulb Audit" expanded when it was shown on local television stations in Great Lakes City and Detroit. Its creators also submitted it to the Show Green! Student Film Challenge, a statewide competition organized by a Michigan nonprofit. The video won first prize for the under-12 category and was shown at Ann Arbor's historic theater to a packed audience.

Like all GET City youth, Etta, Chloe, and Chantelle worked as CSEs: In hopes of making a difference, they took action on an issue they saw facing their community. Table 1 highlights how the three organizing components of GET City were enacted in the Change a Light, Change Michigan investigation to support students' growth as CSEs. The goals, planning, and action were originated by the youth, either alone or in collaboration with adult leaders.

Implications

The GET City model can work in other informal learning contexts, even ones that may not have the same level of resources or support. Four core design principles are vital to supporting youth in developing as CSEs:

1. Ensuring community relevance
2. Valuing youth expertise
3. Distributed expertise and decision making involving local experts
4. Empowering youth to take action

The first principle, community relevance, supports youth engagement and inspires young people to learn more through scientific investigations. In the Change a Light example, the scientific investigations were based in the participants' school, community, and families. The investigation required a deep understanding of energy-related science. Situating the investigation in the community contextualized the science participants were learning and helped them form questions about what else they needed to know.

The principle of valuing youth expertise leads to authentic investigations. As the designers of the program, we realized that GET City youth brought rich and complex understandings of their community to their development as CSEs. Although we planned for youth to build deep understanding of energy-related science, their engagement would not have been the same if expertise had not been shared among members of the group. The youths' public service announcements were geared toward a local audience of peers, community members, and teachers. The youth used their knowledge of this audience, of

GET CITY COMPONENT	GOALS	PLANNING	ACTION EXAMPLES
Building STEM expertise	• Identify science-related concerns in the community • Identify science learning goals • Identify potential investigations • Identify community stakeholders and their potential role in supporting development of youth expertise	• Map out major activities of the unit • Develop lessons for authentic investigations and gather necessary materials • Make connections with local experts and resources • Select field trip sites and plan visits	• Light bulb audit • Experimenting with hand-cranked generators • Light bulb experiment comparing energy demands of incandescent and CFL bulbs • Visiting the local power plant
Building STEM citizenship	• Identify the message youth wish to communicate • Identify technology skills needed	• Develop lessons or tutorials for producing digital artifacts, such as videos, raps, websites • Allow time for supported use of technology	• Light bulb audit video • Coal rap
Educating others	• Identify the audience and its concerns	• Solicit youth input on the audience to whom they want to communicate the results of their scientific investigations • Support youth in planning appropriate format, events, and venues • Coordinate with selected audiences to create spaces for youth to share their work	• Workshop for the school student congress • Workshops at local churches and community centers

Table 1. Supporting the Development of Community Science Expertise

what its members cared about and what they responded to, when designing messages to share their findings.

Distributed expertise and decision making involves local experts in supporting meaningful STEM learning. Learning in informal environments is often described as a process of apprenticeship (Lave & Wenger, 1991), in which novices learn knowledge and practice alongside experts. GET City relies on four kinds of partners: host community organizations, community energy organizations, schools, and businesses. Providing opportunities for youth to work with partner experts situates the science knowledge and practices youth are developing. This process opens spaces for youth to collaborate with local experts in design-based work for learning and educating others (Kolodner, 2006), while supporting youth in crossing borders as they bring science to their communities. Science practices in which novices and experts work side by side support youth in developing core science practices and provide opportunities for them to practice leadership in science as they educate others, from siblings to teachers.

The fourth core component is to give youth opportunities to do something with what they know. Although adults support youth throughout the learning process, how they act on what they have learned is ultimately up to them. Youth have the power to take ownership. As one participant noted, "You listen, then start letting your community hear you [and] get your point across to the world. You are saving the world and its power. Think about it. I'm an 11-year-old sixth-grade girl, saving the world and its people."

Why Community Science Expertise Matters

Learning science is imperative for informed citizenship. It opens possibilities for improving one's community. It also opens doors to future STEM careers. The GET City model of youth engagement in science shows how urban youth can engage in complex practices at the intersections of culture, place, and science, in the process of becoming engaged CSEs.

> "You listen, then start letting your community hear you [and] get your point across to the world. You are saving the world and its power. Think about it. I'm an 11-year-old sixth-grade girl, saving the world and its people."

Statistics say that urban, low-income, and minority students are unlikely to access quality science education or move into science and engineering trajectories. GET City's CSE model offers an avenue for pushing back against these trends. It gives youth opportunities to engage in authentic, scientifically rigorous, and culturally relevant investigations and to educate others, on their own terms, about their findings. GET City youths' work as CSEs makes a difference both in their communities and in their own orientation toward science as a part of their current and future lives.

Acknowledgements

This material is based on work supported by the National Science Foundation under Grant No. 0737642. Any opinions, findings, and conclusions or recommendations expressed in this material are our own and do not necessarily reflect the views of the National Science Foundation. We would like to thank the staff at the Innovative Technology Experiences for Students and Teachers (ITEST) resource center who reviewed earlier versions of this paper for the ITEST summit on innovative models for engaging youth in STEM.

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