Becoming Community Science Experts in Green Energy Technologies

Angela Calabrese Barton, Ph.D. (Department of Teacher Education)
Michigan State University
Edna Tan, Ph.D. (Department of Teacher Education)
University of North Carolina at Greensboro
Scott Calabrese Barton, Ph.D. (Department of Chemical Engineering and Materials Science)
Michigan State University
NSF DRL #0737642

Abstract

In this white paper we describe youth engagement in cyber-rich science in a community setting, involving both knowledge/practice development and identity work through scientifically rigorous, culturally responsive, and generative activities. This model for youth engagement, which we refer to as the "becoming community science experts model" (CSE model) is grounded in critically-oriented sociocultural perspectives on learning which challenge traditional notions of expertise, and accounts for the ways in which the complex relationships between science, community/place and self frame science learning and engagement. Using longitudinal case study data of urban youth from lower-income and African American backgrounds who have participated in a community-oriented informal science program (GET City), we describe the model and suggest pathways towards CSE development in informal learning environments. We further use longitudinal data to make a case that this kind of engagement in science fosters science literacy as called for in current science education frameworks.

> *"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. The roof is probably the best example because we actually helped the club save money. They spent a lot of money getting the roof but now they have probably already saved enough to get that roof again. In the long run it saved money."*

> *"What I would like do in the future, what I want to be when I get older, 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."*

These two opening quotes are from Janis, a 13-year old African American and in-coming 9th grader who has participated in GET City for nearly 4 years, first as a student-participant and later as a youth leader. She refers to herself as a "make-a-difference expert" and wants to be an engineer as a future career. This identity is new for Janis, who, in 5th grade (when we first met her), openly expressed a dislike of science, was unfamiliar with engineering, and aspired to be a singer. Janis' emerging science/engineering identity is tied to her desire to use her artistic ability to contribute to the world. Janis describes GET City as the place where she learned what an engineer is and where she realized she could use art to do science and engineering. It was also a place where she learned that being smart in science was not something only for "geeks."

What does it mean to become a community science expert? Why should this matter in the world of informal science and engineering programming? In our white paper we develop and describe an empirical model – the "becoming engaged community science experts" (CSE) model – based in mixed methods longitudinal case studies that explains youth engagement in science in the context of the GET City program (see Calabrese Barton & Tan, 2010b). Green Energy Technologies in the City, or GET City, is a year round after school program that encourages participants to develop knowledge, skills, and dispositions needed for participation in STEM. In particular, GET City emphasizes youth development into *STEM experts and citizens* who use cyber tools to take on scientific problems of local relevance and global importance, and educate others on their investigative findings. 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 communicate and educate others about those investigations.

We seek to answer the following questions:

- What does it mean to become an engaged community science expert in the area of green energy technologies?
- What knowledge, discourses and practices related to green energy technologies do youth take up, and how does this frame their participation, decision-making, and learning?
- What is the relationship between becoming a CSE and becoming engaged in STEM?

After first presenting our conceptual framework, we describe the GET City Strategies Project, and offer a fairly descriptive set of design principles which guide our work on the project. We use these design principles to help us to describe and explain how and why we believe that youth identity development as community science experts is crucial to their learning and engagement in green energy technologies.

Conceptual Framework

While there is a growing body of research focused on identity development and science learning, little of this research looks at how such identity formation is framed by youth engagement across the different worlds that make up their lives, and in particular, how such identity is deeply situated in place-based science learning. We know that the influence of many out-of-school experiences that youth have are deeply influential in how they author possible selves in science. We draw from sociocultural studies of learning and identity, which frame learning as a cultural process (NRC, 2009) that involves guided participation (Rogoff, 2003) or apprenticeship (Lave &Wenger, 1991). Such work calls attention to learning as an embodied activity, involving the on-going recreation of practices, roles and identities among individuals in social networks and over time (Nasir &Hand, 2008). Identity work, which happens as a part of learning, involves the production and reproduction of identities via participation in activities and in relationships with others (Holland et al1998). A challenge in *understanding identity work as a part of learning*, is in understanding how identities become reified within and across communities as youth take up new ideas and understandings within and across communities.

However, not often discussed in the literature on science learning is the focus on the "horizontal dimensions" of learning – a focus which speaks to the cross community work that youth do. Gutierrez (2008) explains that, unlike a focus on vertical movement from "immaturity and incompetence to maturity and competence," horizontal learning focuses on expertise that develops within and across practices and communities (p. 149). Horizontal learning emphasizes the distributive nature of learning as well as the repertoires of practices that individuals cultivate as they move through space and time.

Horizontal learning raises questions around what it means to develop as science learners or to become expert in science. Such a view of learning is important because little attention outside of equity-driven research has focused on how learning is informed and transformed by the sociopolitical dimensions that shape everyday activity, and how and why youth come to understand their worlds. It is therefore important to note that as individuals gain access to new communities of practice, learning also involves a process of cultural production. We also know that when and how youth are supported in leveraging out-of- school resources, they increase their opportunities to learn science (Calabrese Barton & Tan, 2009; Rosebery, Ogonowski, DiSchiro & Warren, 2010). It is also important to note, however, that as an individual joins a community, he or she brings with them resources in the form of particular historical and cultural experiences, which by their activation can transform the discourses and practices of the community. As novices leverage resources from outside the community to develop expertise within the community, they create new discourses and practices that can transform its culture, discourse and practices, reflecting both vertical and horizontal development.

GET City Strategies Project

The GET City Youth-based program. Since 2007, GET City (http://getcity.org) has involved over 120 youth (~30 youth/yr) from low-income and under-represented backgrounds in Lansing, ages 10-14, in a year-round program that provides opportunities to develop scientific research skills and conceptual understandings related to green energy technologies, and job skills development for the growing IT market. Every Tuesday and Thursday, after school, for 24 weeks each school year, and for 3 summer weeks, youth have engaged in **authentic investigations** on locally relevant and globally important issues in green energy (e.g., Should our city build a new hybrid power plant?), translated their findings into powerful **cyberlearning tools** (e.g., digital public service announcements, wikis/webpages, etc.), and designed and implemented education lessons and workshops for peers and community members through the **GET City Education Network** on green energy in culturally relevant ways (e.g., teaching lessons about the technological design for energy efficiency in their school classrooms). These three components have been enriched by a powerful **GET City partnership**, which has provided youth with opportunities to interact and build relationships with engineers and IT specialists across the green energy sectors in their city, including research, education, business and the community (see Table 1 for an overview of the program).

Table 1: GET City Curricular Units

	Green schools & homes (Year 1)	**Green and Go** (Year 2)	**Science Ed & Climate Change Standards**	**IT skills and workforce standards**
Efficiency & Conservation	**Energy Crisis!** Investigation of electrical production, supply& demand; and how supply & demand are impacted by policies and practices	**Complete streets** Investigation into transportation and the environment using GIS to map access & impact of complete streets	*Energy and its forms:* • Energy is the ability to do work • Energy conversion *Energy and the environment:* • Traditional electricity production and use emits pollutants that cause health & environmental problems • Relationship between carbon emissions & climate change *Energy technology* • Compare & contrast forms of renewable energy: biomass, wind, solar *Climate change & environmental sustainability* • Strategies to reduce greenhouse gas emissions: alternative sources & change in how humans use energy. • Individual & community actions influence climate.	• Interaction with practicing IT professionals in multiple settings • Collaboration with peers and experts using IT tools • Content-specific tools & software to support learning & research GIS • Digital Probes • MS Excel • Digital photography & video production • Electronic concept mapping • Web surveys • Design, development, & publish communication products: • technical presentations • web authoring • digital videos • podcasting
Alternative Energy	**Powering the City!** Investigation into alternative energy through the design of a hybrid power plant.	**Cars of the Future** Investigation into the design of alternatively powered vehicles & environmental impacts		
Green Design	**Summer Synthesis** LEED-certified building design	**Summer Synthesis** Designing Fuel cell cars		

Design Principles

GET City has been built and refined on five design principles that align with IT Standards & Workforce Development Goals (U.S. Dept. of Labor, 1991), Cyberlearning and workforce development (Borgman et al, 2008), National Science Education Standards (NRC, 1996), Climate Change Standards (AAAS, 2009), and advances in informal learning (NRC, 2009; Friedman, 2008). The five design principles are:

1. Integration of cybertechnology and cyberlearning strategies develop scientific understandings, support complex reasoning, and foster increased interactions.
2. Local, authentic investigations that link scientific ideas with everyday practices and concerns support the development of STEM expertise in culturally relevant ways.
3. Taking action and positioning youth as experts in their community develop STEM citizenship.
4. Youth development is supported by continuous and complementary community based programming.
5. Distributed expertise and decision-making through involving local experts support expanded opportunities for learning and meaningful participation in STEM.

Framing Engagement & Motivation: Becoming Community Science Experts

We argue that youth engagement in GET City can be characterized by the process of becoming engaged community science experts (CSEs). This process is supported by the design features of GET City (described above) that work synergistically to support substantive youth learning and interest in green energy and that allow for youth to: 1.) Work side-by-side with practicing scientists and engineers to become experts on issues of green energy technologies as they collaboratively investigate real-world, real-time design-based problems of various scales, such as the design of a proposed hybrid power plant in their city or of a new green roof for their Club; and 2.) Use their expertise to author tools and resources for educating their community on these issues in ways that are culturally relevant, scientifically rigorous, and aimed at making a difference.

These features allow science knowledge and practices to be situated and progressively developed through activity in design-based work for *learning* and *educating others* (Brown, Collins & Duguid, 1989; Kolodner, 2006), while at the same time they support youth border crossing as they seek to bring science to their communities. Such side-by-side science and teaching practices support the youth in developing core science practices at the same time as they have opportunities to practice leadership and authority in science as they educate less knowledgeable others in locally meaningfully ways (i.e., siblings, parents, community members). For some of the girls in GET City, such engagement as CSEs appears to transfer to school settings, where they hold an "I'm an expert" attitude. We share the following example to help contextualize our point.

Jana: "Make a Change"

Jana is a vivacious 6th grader who attends the local elementary school adjacent to the Club. While small in stature, she exudes confidence. Jana joined GET City in the Fall 2008, in part because her older sister had participated in GET City the previous year and she was eager to participate in some of the activities and to gain access to the computers while learning more about the environment.

Figure 1: Make a Change

In Fall 2009, Jana participated in a unit investigating electrical production, supply and demand in her city and its relationship to energy conservation and efficiency. The investigation was framed through the "change a light, change Michigan" initiative that linked energy concepts with energy policy and practice. Jana conducted experiments comparing power requirements, heat and light output of compact fluorescent light bulbs (CFLs) and incandescent light bulbs using digital probes and spreadsheets. She made her own electricity using a hand crank and a bicycle, visited the local power plant to learn how the city was powered and how the plant worked to reduce the impact of burning coal. She conducted a light bulb audit in her school, documenting the number of incandescent bulbs that could be replaced with CFLs, then calculating how much money and carbon emissions would be saved. She prepared a 4 min documentary ("Make a change") explaining the differences between CFLs and incandescent light bulbs in terms of power consumption, fossil fuels, carbon emissions, pollution and monetary cost (see also figures 1 and 2). With other GET City youth, Jana used the movie and a demonstration experiment to educate her school's student government. With support from the Lansing Board of Water and Light, Jana provided over 50 CFLs to the school at no cost. She submitted her documentary to the "Show Green! Student Film Challenge," a *state-wide* competition organized by a Michigan nonprofit, and won first prize for the under-12 category.

Jana's participation at GET City illustrates how she built STEM expertise, created a cybertoolkit in her artifacts (PSA and movie) for STEM citizenship, and brought her expertise and toolkit to educate a broader school and internet audience as a community science expert (Sato, Calabrese Barton, Rose & Birmingham, 2011 for an in-depth description of Jana's experience). She said of her work on the video:

> You have to know about your community if you are going to make your investigation really make a difference. So, you have to know more than just the science you are doing. I mean no one really cares about

carbon dioxide. Really. They don't. But when you explain how it actually impacts the global warming and using the CFLs saves money too, then people will

Figure 2: Overview: Make a Change
The video begins with the song, "waiting on the world to change". The first image shows youth appearing to enjoy themselves as the text "Grove Street Elementary School" appears. Two additional images follow of an incandescent light bulb then a CFL bulb accompanied by the text, "MAKE A CHANGE".

The video transitions to the youth engaged in a light bulb audit as they visit the bathroom of their school to see how many CFLs versus incandescent light bulbs they can find. In between inspections, the youth infuse information about the number of watts used by incandescent light bulbs versus CFLs and playfully chastise their teachers for not being green. They discover that all but one bathroom had incandescent bulbs, helping set up their content storyline around how using incandescent lights requires more coal to be burned leading to environmental consequences of human action on climate change.

They explain how they were able to determine incandescent lights were less energy efficient by the heat they release and elaborate on the environmental effects. They situate the issue locally, reminding viewers that electricity for the city comes from burning coal. The video shows pictures of a strip mine as the song lyrics ask, "what have we done to the Earth?" The scenes alternate between the youth on camera continuing to tell the story of human impact on the Earth and images with text explaining how damage done from mining is not reversible. The youth pull in the problem of excess CO_2 being produced from the burning of coal as energy consumption goes up. The video places the onus on human actions but also offers a chance to the audience to remediate habits and be empowered to make a change. The next portion of the video uses images and text instructing the audience that they can make a change and that as the song suggested, "it's easy as 1,2, 3…A, B, C". A youth then explains the amount of money the school can save as well as how much CO_2 release can be prevented by switching light bulbs. The video closes with the scrolling text reviewing how incandescent light bulbs used more energy requiring more coal burning and CO_2 release that leads to global warming as the song played "I'm asking you to make a change".

Discussion of CSE Model

Asserting a CSE identity allowed the youth a platform in which to engage in scientific ideas and discourses while also offering students the freedom to work and be in their community in ways that mattered to them. Being a CSE was fashioned out of a hybrid discourse and practice that did more than blend the space of "science" with the space of the "personal/cultural." Analysis of our data further reveal several key points that help to flesh out the CSE model.

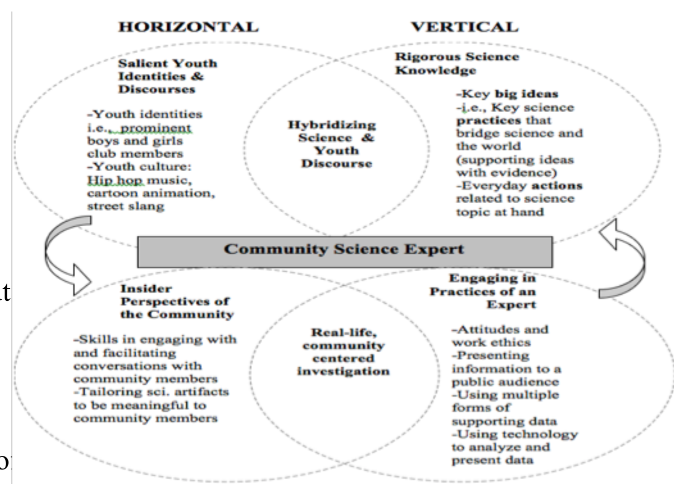

Figure 3: Vertical and Horizontal aspects of the CSE model

First, and perhaps most importantly, becoming a CSE involves the iterative development of **vertical** and **horizontal** expertise, or in other words the development of knowledge and practices central to the science investigation at hand (vertical) and an ability to leverage that expertise in culturally responsive and agentic ways across the communities of practice in which the youth live, learn and play (horizontal). Developing and leveraging both forms of expertise fosters the novel authoring of hybrid discourses and practices that give science particular local significance (see Figure 3).

Central components to vertical learning include: a.) developing understanding of core science ideas, b.) developing a fluency in science practices that help link those ideas to the real world, such as learning to reason and argue with evidence in persuasive ways, and c.) developing multiple ways of representing ideas in science in both qualitative and quantitative ways. Central components to horizontal learning include: a.) making sense of how scientific issues matter in the community & making sense of how community concerns set up or frame specific scientific problems, b.) leveraging cultural knowledge and practices in ways that make scientific ideas accessible to broader audiences, c.) generating science artifacts that appropriate knowledge and practice in locally meaningful ways.

Second, becoming a CSE involves **making science accessible** to others by situating scientific talk and thinking within the work a day lives of ordinary people, and by orienting the doing of science towards taking personal responsibility and action. In Jana's Make a Change video, she and her peers draw upon their knowledge of how the failure of individuals to use energy efficient light bulbs is connected to detrimental environmental impact, by mining for coal and by the burning of coal releasing greenhouse gases. She situates her explanation of the impact of energy use on the environment through narration, images, music and text, she also uses the light bulb audit of their school to ground their message in the community and begins to develop the story of how the personal choices have consequences – i.e., "save the school money". Part of making ideas accessible required a **localized knowledge** of the scientific phenomenon at hand. For example, carbon cycling is a big idea (and an abstracted idea) in science, and yet, to be a make-a-difference expert meant that Jana could explain its value in terms that made sense scientifically as well as contextually to their schoolmates,–by "changing watts to dollars."

Third, becoming a CSE involves a process of **re-inscribing symbols**, **of youth culture** (verve, playfulness, boisterous, etc.) as *necessary elements* of scientific expertise, **of science** as a *valuable commodity* within urban youth culture (Calabrese Barton & Tan, 2010a), and of **work in the community** as evidence of hard working, capable youth. Youth in this project face the stigma of being "club kids," which, in their community, is code for "poor and black." By enacting science expertise that draws upon hip-hop, youth-speak, loudness, art and creativity alongside traditional scientific practices, they co-opted undesirable meanings of being a "club kid" with an urgency to build a more just world, fashioning a practice that was respected across different worlds (e.g., peer culture, white corporate culture). Legitimized by peers *and* authority figures (e.g., the mayor's office), such maneuvering positioned science as relevant to the community and youth as smart and cool.

We believe the re-inscription of symbols is important as it allows youth to make problematic some of the master narratives in science that have been constructed (primarily in school science but not necessarily in the 'real world' of science) as being in opposition to their everyday lives in terms of a.) what it means to be scientific; b.) what it means to engage in scientific communication; and c.) how one can be both a producer and critic of science. With their science documentaries, the youth problematized common symbols in science (or things that carry symbolic meaning) and in so doing, turned their meanings around towards their own purposes. One of the symbols the youth critiqued and transformed involved the ways scientific ideas were communicated and represented. Scientific language, in schools, is often rendered as dense, technical, and abstract. The abstraction of science works especially to obscure concrete life experiences into conceptual entities and generalizations. In Make a Change, we see that the youth instead, chose to specifically place their scientific ideas in context and to situate the meaning of their knowledge claims, rather than to represent ideas removed from context. We also believe that such re-inscription is important because it works to unsettle the dominant narratives that unfairly suggest that lower-income youth from African American communities do not care about science or the environment or are not hard working, and opens up new possible pathways for youth to pursue STEM trajectories.

Scholarly significance

Learning science is imperative for informed citizenship and opens possibilities for affecting one'community. Yet, statistics predict that the urban, low-income, minority students are unlikely to access quality science education. This white paper offers a model for youth engagement in science based on 5 design principles that helps us understand how urban youth already engage in complex sets of practice at the intersections of culture, place, and science, and which frame what it means to become an engaged expert in science.

A contributing factor that led to the youth's authentic and sustained engagement with green energy science issues at GET City is a highly supportive environment provided by mentors from engineering, science education, and local institutions related to green energy issues, such as the Board of Water and Light. Mentors working closely with the youth on a weekly basis not only provided youth with expert knowledge resources, but more importantly, enabled the youth to engage in both scientific and socio-scientific investigative practices alongside experts who actively solicit and encourage their participation. Engagement in such a manner with mentors from various stakeholders in green energy technology issues empowers youth as *they* are repeatedly positioned as legitimate stakeholders as well in the discourse of local green energy technology concerns. Such an empowering position and identity no doubt fostered youth engagement in GET City, paving the way for their authoring of a CSE identity. Implications from our study include:

1. How do we recruit, increase, and sustain the number and (relevant) diversity of mentors for youth in such programs on a long-term (GET City is 3 years and running) basis?
2. How should mentors negotiate between sharing their expertise while encouraging youth participation in ways that address the development of both horizontal and vertical expertise in science issues?
3. What pedagogical practices are especially efficient for mentors to facilitate the authoring of positive identities in science for youth that are traditionally disenfranchised?

References

Birmingham, D. & Calabrese Barton, A. (in prep.). *Community science expertise and school science practices*.

Borgman, C. L., Abelson, H., Dirks, L. Johnson, R., Koedinger, K. R., Linn, M. C., et al. (2008). *Fostering learning in the networkedworld: The cyberlearning opportunity and challenge, Report of the NSF Task Force on Cyberlearning* (Publication No. NSF-08-204).

Calabrese Barton, A. & Tan, E. (2010a). We be burnin: Agency, Identity and Learning in a Green Energy Program. Journal of the Learning Sciences. 19(2), 187-229.

Calabrese Barton, A. & Tan, E. (2010b). The new green roof: Activism, Science and Greening the Community *Journal of Canadian Journal of Science, Mathematics and Technology Education*, 10(3), 207 – 222.

Fields, D. & Kafai, Y. B. : *A connective ethnography of peer knowledge sharing and diffusion in a tween virtual world* International Journal of Computer-Supported Collaborative Learning 4(1): 47-68, 2009.

Friedman, A. (2008). *Framework for Evaluating Impacts of Informal Science Education Projects*, Washington DC: National Science Foundation.

Gutiérrez, K. (2008). Developing a sociocritical literacy in third space. *Reading Research Quarterly*, *43*(2), 148-164.

Kolodner, J. L. (2006). Case-Based Reasoning. In K. L. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 225-242). Cambridge: Cambridge University Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Nasir, N. S., & Hand, V. (2008). From the Court to the Classroom: Opportunities for Engagement, Learning, and Identity in Basketball and Classroom Mathematics. *Journal of the Learning Sciences. 17(2),* 143-179.

National Research Council. (1996). *The national science education standards.* Washington, D. C.: National Academy Press.

National Research Council. (2009). *Learning Science in Informal Environments: People, Places, and Pursuits.* Committee on Learning Science in Informal Environments. Philip Bell, Bruce Lewenstein, Andrew W. Shouse, and Michael A. Feder. Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Rogoff, B. (2003). *The Cultural nature of human development*. New York: Oxford University Press, Inc.

Sato, T., Calabrese Barton, A., Birmingham, D. & Rose, S. (2011). *Horizontal and Vertical Learning Dimensions of Urban Youth Investigating Energy Efficiency.* A paper presentation at the annual National Association for Research in Science Teaching meeting, Orlando, FL.