NSF ITEST CONVENING: DEFINING AN AFTERSCHOOL RESEARCH AGENDA
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Voice, Choice, and Participation:
A comparative look at youth STEM experiences in and out of school

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Abstract

This white paper leverages data from two ethnographic studies supported as part of University of Washington's Learning in Informal and Formal Environments (LIFE) Center to inform research and development of informal science learning environments for groups underrepresented in STEM. Although one study focuses on high school youth in an informal science apprenticeship and the other on high school youth with disabilities across everyday settings, they both examine how students develop identities around STEM disciplines in settings outside of school. Students are interviewed and observed across a variety of contexts to determine how these different experiences either support or discourage interest and motivation in STEM-related subjects.

Overview of Issues

Increasing participation for youth in the fields of science, technology, math and engineering (STEM) is of major concern for scientists and science educators in the U.S. (BEST, 2004). Having access to science-related educational opportunities not only develops scientific knowledge but also helps young people form identities as science learners, identities which continue to be shaped by sustained participation over the course of their life span (NRC, 2009). For student populations who are under-represented in STEM, active participation invites youth contributions to scientific efforts, fostering a sense of agency from students who have been historically silenced or marginalized in traditional classroom settings. These experiences help develop identities around the scientific enterprise, encouraging them to have personal stake in scientific issues and view science as relevant to their everyday lives (NRC, 2009).

Out-of-school programs are well-positioned for extending and supporting learning experiences beyond the classroom, shaping youth identities in domain-specific ways over the course of their lifetime (NRC, 2009). They potentially provide an interactive, collaborative, and flexible setting that uses multimedia in ways the classroom cannot, which is valuable for capturing the interest of those who do not feel engaged in school. Unfortunately, participation in after-school programs decreases as students get older, particularly for students with disabilities in low-income, urban areas (Newman, 1999; Wagner et al, 2002). This is of particular concern because for many students with learning difficulties, school is not associated with a positive sense of identity or self-worth (Murtaugh, 1988). Informal, out-of-school contexts become important places where youth learn and develop socially, formulate interests, and build identities around certain enterprises. Young people from groups under-represented in STEM need opportunities to learn and apply scientific literacies that serve the interests and needs of their diverse communities (Barton, Ermer & Burkett, 2003).

This white paper aims to answer the question: How can STEM workforce development experiences be truly responsive to the needs of underrepresented groups? Since youth encounters with science in traditional classrooms often differ from the opportunities afforded by after-school activities, we look at youth experiences across these two contexts. We leveraged data from an ethnography of high school students with disabilities to understand their experiences in a traditional science classroom. These issues were compared to similar interview questions asked of high school students from diverse backgrounds in an after-school, science apprenticeship program. While these two studies were conducted separately, we hope to raise issues with regard to how students' identities as science learners are encouraged and supported both in and out of school.

Study Descriptions

Ethnography of Students with Disabilities Across Settings

A team of researchers from the LIFE Center are currently investigating how youth with disabilities experience their lives in a variety of contexts, with the support of funding from the National Science Foundation's Science of Learning Centers program. Through a two-year ethnography of 12 students with disabilities, we aim to understand how social institutions influence learning identities, learning pathways, goals, and future pursuits. Data collection includes two years of participant observation, interviews, and home visits, and focuses on students identified as having disabilities in three public high schools in California and the Pacific Northwest. Their diagnosed disabilities include autism, ADD/ADHD, speech processing disorder and learning disability. We first looked at these students in interactive educational programs including debate, music, and ecology and then followed them into their regular classes and after-school experiences.

For the first year of data collection in the ecology classroom, we focused on 7 students, 4 of which had either Autism or a learning disability and 3 other minority students without disabilities. While this class took place during the school day, they had a unique partnership with the University of Washington to bring oceanography graduate students into the classroom to provide an interactive experience for students. They were initially observed four hours a week for four months, before going into other academic classes and visiting their homes. Observations were both audio and video-recorded and help substantiate findings from interviews with students. In the first eight months, we performed three interviews per student, which were then transcribed and analyzed using open coding to understand themes relevant to their experiences with science.

Community-Based Science Apprenticeship Program

This pilot project follows adolescent youth through a year-long community-based science apprenticeship program (CBSA), composed of their peers and members of an oceanographic lab on a large university campus in the Pacific Northwest. The program aims to: positively influence the learning trajectory of adolescent apprentices from groups that are underrepresented in the sciences; engage the local community in scientific inquiry through community relevant, researchable questions; and cultivate and showcase the scientific skills and interests of the youth apprentices through presentations of findings through public venues. The guiding research questions are centered on identity development of individual apprentices as science learners and the affordances informal learning environments may be able to supply for young people from underrepresented groups. The research team believes this has potential significance for understanding how adolescent apprentices begin to solidify a scientific identity while leveraging that identity within their own community and has implications for future study design in informal science learning as a bridge the gap between school and community science.

Data collection in the pilot year, represented here, includes participant observation over the course of the year and interviews with participants during the last month of the program. Observers took field notes on the participation of adolescent apprentices throughout the program. Interviews were audio recorded, transcribed, and analyzed using the open ended coding framework described in the ethnography project above.

Review of Relevant Literature

Observations of youth meaningfully engaging in activity enables researchers to understand how they participate and make meaning of their experience. This data collection creates a recognizable web of relationships that help researchers and practitioners to see how people relate to each other, become engaged in activities, and pursue possible futures. To understand youth participation and perceptions in formal and after-school STEM environments, we must look across settings at factors related to engagement and participation. This approach illuminates the structures and supports of learning contexts such as after-school programs, which Luehmann (2009) describes as "rich identity resources . . . not typically available in traditional schools" (p. 51).

Luehmann's (2009) work utilizes the sociocultural perspective of learning to reconceptualize the deficit model of addressing achievement gaps. This shift seeks to capitalize on what youth bring with them to learning experiences, in turn providing meaningful opportunities for participation in activities that are relevant to their everyday lives (NRC, 2009). Addressing youth identity formation across settings takes into account Nasir and Hand's (2006) view of learning as "personal transformation -- about becoming" (p. 467). Youth from underrepresented groups often experience intrapersonal conflict associated with trying to bridge the gap that exists between their everyday lives and the culture of STEM activities, which Pomeroy (1994) describes as "border crossings" as youth struggle to adopt a new scientific identity without relinquishing their own identity (Brown, 2004; Gee, 2004).

The design of youth-centered co-construction of learning experience by adults and youth in after-school STEM settings helps youth negotiate these gaps by creating opportunities for youth to build relationships and try on different identities in a safe, authentic space. Reducing what Luehmann (2009) calls social distance between adults and youth,creates opportunities for youth to take on decision making roles, experience socially recognized success, and receive feedback regarding their learning and contributions (p. 55). These aspects of participation contribute to the aspects of scientific proficiency that are unique to informal science learning environments, including interest and identity development in science (NRC, 2009, p. 43). For these reasons, it is important to examine youth participation, and their perceptions of their participation, across settings of their lives in order to understand how youth develop and balance identities in STEM.

Research that focuses on how formal and after-school STEM activities afford these kinds of identity development has the potential to explain how the structures and supports unique to after-school environments can result in youth engagement, motivation, self-selection, and sense of ownership in STEM activities. These factors are crucial for engaging and retaining youth interest in STEM in ways that support the development of a personal stake and interest in the relevancy of STEM to their everyday lives. At the same time, additional research must be performed to understand student experiences across the informal and formal contexts that shape their lives as well as the multiple transitions they make throughout the day (Banks, et al., 2007; Phelan, et al., 1991). This involves capturing "the nature of interactions, conversations, and other forms of social activity that promote or impede learning" by using individuals and groups as the unit of analysis (Rennie et al., 2003, p.117). For example, current research on the participation of students with disabilities in after-school programs focuses on how many students attend or are involved in such opportunities, rather than the specific qualities of their experiences in these programs. Future efforts to understand these experiences must include youth perspectives and take a student-centered approach to exploring issues of learning identity (Honig & McDonald, 2005).

Findings: Comparisons Between Two Studies

Overview of Themes

Although students contrasted the many engaging opportunities to experience science after-school with often negative experiences in the classroom, it is not sufficient to say that the after-school factor alone encouraged youth interest in science. When describing what made the difference for them, all of the students stressed the importance of having a voice and a sense of agency in scientific activities. Several students felt silenced in large groups where they did not feel valued or appreciated due to ability or race. Others felt isolated and preferred to work alone in the classroom as opposed to the apprenticeship program where they understood the need to work together to discover scientific concepts. In either setting, youth appreciated equitable participation, strong relationships with adults who had high expectations of them, as well as multiple opportunities to demonstrate competence. To encourage their interests, these young people pointed out the importance of having a shared identity around science, where they had the freedom to choose their own scientific pathways in ways that were relevant to their everyday lives.

Choice, Freedom, and Images of Science

Students highlighted the importance of student choice in science- related activities. In the ecology class, students noticed the lack of choices in science classes offered at their school and expressed a desire for exposure to a variety of scientific disciplines. As one student said, "it would be good to just have a basic, general, overall science class…kind of like biology…but more broad…and then once they had that, they could choose a path that they wanted to go down." Students in the apprenticeship program setting saw the opportunities for choice as one of the most important affordances of the program. Lisa said, "I have a lot more of a say [here] than I do at school. We're actually heard here. Here if I expressed something, I would be heard." The informal setting allowed students to feel "responsible for a lot of things that give us a little bit of power." According to Kevin, "There is a lot of decision making power [here]. You'll give us a few ideas but if we want to make a new idea then we can make a new idea…we can pretty much choose what we want to do as long as it's in the guidelines." One student made a connection between student choice to her own interest and effort in educational settings:

> It meant a lot to choose the research project, to choose what we wanted to do

> because often times you don’t really get to choose until you get to college and that meant a lot to feel like we had a say in what we were going to do. When you’re forced to do a project and your heart and interest isn’t in it, you don’t do it as well as if you were able to choose what you were going to do. That was another reason we did it so well. A lot of times, you’re told what to do at school and they wonder why kids don’t always give 100% effort because they don’t notice how much caring about the project does for the project.

From the perspective of students, lack of choice is especially problematic where authenticity and relevance to their daily lives are concerned, particularly in the lack of discovery in science classes. As a student in the ecology class stated, instead of repeating things that could just been learned from a book, “I think we should do more research with things that haven’t been done.” In the apprenticeship program, Kevin said, “Really, honestly, some of the stuff in school I really don’t think we’re ever going to use. . . It’s kind of boring, plus you don’t get to pick anything everyday. There’s no choices.” Kevin also noted the difference between the authenticity of the science in school experience and the nature of the research he was able to do in the apprenticeship in the university lab, saying, “We do find something new here because we’re testing water samples from marine life [for plasticizers] and we’re the first to do that in the U.S.”

Though some students explained that science is a part of everything they do, most did not feel that science instruction was related to their everyday lives. Sahara said, “I think anyone who has a question looking for an answer is a scientist because being a scientist is having something you’re interested in and looking for the answer.” On the other hand, Saul, a student in the ecology class said, "People think it's boring...we did things too fast without really learning them, and then we'll go to a lab, so it's like, I still don't understand half the stuff we do. And, just not really interested in it."

Participation in Context

Students in both studies expressed their dissatisfaction with the traditional school setting. They highlighted what kind of learning and participation was valued in school as well as what they described as "being a good science student". As a whole, students described science classrooms in school as disengaging, focused on completing assignments, with teachers who appeared to value compliance above intellectual stimulation. According to one student in the ecology class (who also presents with a learning disability), school was a place where people only cared about your grades and did not value other forms of intelligence. According to students, school science classes often seemed to emphasize good behavior more than the science content itself. When asked why she considered herself to be a "good science student" as opposed to a "scientist", Tianna, responded "I'm a good science student 'cause I do all my work, but I'm not a good scientist 'cause I don't understand really no concepts of science." In the apprenticeship program, another student commented,"I guess you have to do whatever the teacher teaches and it is boring because you just sit there and listen to them talk and take notes."

Students also emphasized the role of the teacher in engaging students in science-related activities. While many wanted classrooms to be more flexible and teachers to be more interactive with students, students in both the ecology class and the apprenticeship program complained that teachers were too focused on "getting kids to pass" or spent too much time talking without including interactive activities. According to one apprenticeship program participant, "Teachers don't personally get to know you [in school]. They grade your work, they check you off as absent, but they don't really get to know you. They have too many other students. Even if they did have time, some are standoffish." Similarly, James, an ecology student with a learning disability commented

> There's the kind of bad teacher who doesn't teach and you get a good grade in the class 'cause it's really easy stuff. Then, there's the kind where stuff just wasn't explained so everyone was just failing. Then, the other kind is too strict and doesn't appreciate smarter people, who might not necessarily be good in rigid, turning-your-stuff in on time stuff.

In contrast to school-based science, student apprentices highlighted that the primary differences were in the amount of attention they received and the ease of collaborating with others. While in school, many students felt embarrassed to answer questions because they were unsure about getting the right answer, "here you'd never know there'd be an answer. Even if there was you couldn't do it on your own. You need people to help you." These students felt teachers listened to their questions, as opposed to school, where "sometimes I have a question and [the teacher] needs to move on."

Voice, Respect, and Social Perceptions

For students in under-served populations, having a voice and a say in the learning process was particularly important and allowed them to feel their participation was valued (Storz & Nestor, 2008). Many students wanted to have discussions where everyone was involved, but felt uncomfortable voicing their thoughts in class, where they knew there would be a right answer or where they felt overpowered by more vocal students. Several student apprentices thought their voices were heard in the program, either because of the smaller group or the fact they were all working together. Jerome adds, "We're responsible for a lot of things that give us a little bit of power. We can speak and say what we felt."

At the same time, many of the students in the ecology class appreciated the diversity in their classroom, applauding the teacher for encouraging multiple viewpoints. As opposed to their English classes (with majority White students), several students felt less afraid to contribute because their class was more racially diverse. According to Solomon, "In this class, whatever your difference is, it's not that you're stupid, it's just that you learn in a different way. I think in this class, people will help you understand it better." He continues, "Last year, it was kind of intimidating [in science class] because I was one of the only brown kids and I'd be kind of afraid to ask questions."

Students also wanted to feel respected and be seen as "smart". Several ecology students felt patronized by the graduate student when they oversimplified material they were already familiar with through outside pursuits. Others disagreed with the viewpoints presented by scientists or felt like they should have gone more in-depth. Many students also pointed out that in school, they were often judged by the language they used when they participated in class. Being labeled as "not smart" limited their range of participation, and people around them were often surprised if they ever displayed any interest in science. Tianna supports, "Just 'cause I act different outside of school doesn't mean I don't come to school and do what I have to do, that's the purpose of coming."

Recommendations

Much work has been done on equity in science education exploring engagement and meaning making for youth that suggests that taking into account previous experiences and backgrounds of youth as a way to understand how youth develop personal investment and exhibit agency matters. We believe that focusing on the activities of participation through youth voice and agency across settings will contribute to the gaps in this work by giving us a “detailed, fine-grained picture of learning” and engagement (Rennie et al., 2003, p. 118). To understand how to be responsive to the needs of underrepresented groups in STEM is to understand what those needs are. Prior research shows that a focus on the activities that support identity development across settings will provide insights into how we can best engage youth in after-school STEM activities. We recommend using ethnographic approaches that represent youth perspectives and leave room for unanticipated outcomes. These methods should be used to measure individuals and groups as they participate in the social endeavors of learning including how after-school STEM activities provide youth opportunities for:

- meaningful engagement
- equitable participation
- authentic practice
- student agency and voice
- demonstrating competence in a variety of ways
- decreasing in social distance for both adults and youth

Emergent questions

To further this discussion, we pose the following questions:

- How can a new after-school research agenda foster connections between in-school learning experiences and out-of-school programming in a way that leverages student interests across multiple settings?
- How can these opportunities operate within a high school culture that often discourages innovation and youth voice?
- How can STEM-related activities and experiences position all students in a way that upsets traditional ideas of what it means to be "smart"? What can teachers and after-school providers do to help students feel capable in science settings and as a result, begin to consider science as a possible future pathway in their lives?
- How can after-school STEM programs incorporate opportunities for meaningful and equitable participation into their programming?
- How can after-school STEM programs and in-school science classes encourage a sense of discovery and active forms of participation?

APPENDIX A
Youth Voices: Relevant Themes

Themes	Subcategories
1. Voice	
A. Participation	Providing opportunities for equitable participation Providing space for self expression and risk-taking Decreasing social distance for youth and adults
B. Diversity/Difference/Race	Sharing a common identity Differentiated Instruction
C. Respect	Sharing a common identity Differentiated Instruction High expectations of youth
D. Social perceptions	Opportunities to demonstrate competence Providing opportunities for equitable participation Rectifying several conflicting identities
2. Choice and Freedom	
A. Choice	Exposure to variety of choices Student-centered instruction Decision-making power
B. Discovery	Interest/engagement is based in student sense of discovery
C. Relevance	Science instruction could be more relevant to everyday lives
D. Interest in Content	Interest development
E. Content Rigor	Attention to prior knowledge Meaningful , authentic learning
F. Images of Science and Self	Rectifying conflicting identities Identifying as someone capable of doing science
G. Everyday connections to science	Science is a part of everyday life
3. Participation in Context	
A. Science in school	Opportunities to demonstrate competence
B. Contrasting with after-school experiences	Rectifying conflicting identities Providing opportunities for self-expression Informal settings afford flexibility
C. Teaching	Providing opportunities to demonstrate competence Creating nurturing relationships High expectations of youth Differentiated Instruction
D. Collaboration	Providing opportunities for equitable participation

References

Banks, J. A., Au, K. H., Ball, A., Bell, P., Gordon, E., Gutierrez, K., Heath, S. B., Lee, C., Lee, Y., Mahiri, J., Nasir, N., Valdes, G., & Zhou, M. (2007). *Learning in and out of school in diverse environments: Life-long, life-wide,life-deep.* Seattle: The LIFE Center (The Learning in Informal and Formal Learning Environments Center) and the Center for Multicultural Education, University of Washington.

Barton, A. C., Ermer, J. L., & Burkett, T. A. (2003). Teaching Science for Social Justice. New York, NY: Teachers College Press. Cohen, K.C. (Ed.). (1997). Internet links for science education: Student-science partnerships. New York: Plenum Press.

Brown, B.A. (2004). Discursive identity: Assimilation into the culture of science and its implications for minority students. Journal of Research in Science Teaching, 41(8), 810-834.

Building Engineering and Science Talent (BEST). (2004). The Talent Imperative: Diversifying America's Science and Engineering Workforce. Retrieved on October 27, 2009, from http://www.bestworkforce.org/PDFdocs/BESTTalentImperative_FullReport.pdf.

Gee, J.P. (2004). *Situated language and learning: A critique of traditional schooling.* New York: Routledge.

Honig, M.I., & McDonald, M.A. (2005). From promise to participation: After-school programs through the lens of sociocultural learning theory. The Robert Bowne Foundation Occasional Paper Series #5 Fall. New York City, NY: The Robert Bowne Foundation.

Luehmann, A. (2009). Accessing resources for identity development by urban students and teachers: foregrounding context. *Cultural Studies of Science Education 4*(1), 51-66.

Murtaugh, M. (1988). Achievement outside the classroom: The role of nonacademic activities in the lives of high school students. *Anthropology and Education Quarterly, 19*(4), 382-395.

Nasir, N.S., and Hand, V.M., (2006). Exploring sociocultural perspectives on race, culture, and learning. Review of Educational Research, 76(4), p. 449-475.

National Research Council. (2009). Learning science in informal environments: people, places, and pursuits. Committee on Learning Science in Informal Environments. P. Bell, B. Lewenstein, A.W. Shouse, & M.A. Feder (Eds.). Board on Science Education, Center for Education, Division of Behavior and Social Sciences and Education. Washington, DC: The National Academies Press.

Newman, L. (1991). *The relationship between social activities and school performance* *for secondary students with learning disabilities: Findings from the National Longitudinal Transition Study of Special Education students.* Chicago, IL: SRI International.

Phelan, P., Davidson, A. L. & Cao, H. T. (1991). Students' multiple worlds: Negotiating the boundaries of family, peer, and school cultures. *Anthropology & Education Quarterly, 22*(3), 224-250.

Pomeroy, D. (1994). Science education and cultural diversity: Mapping the field. Studies of Science Education, 24, 49-73.

Rennie, L. J. , Feher, E. , Dierking, L. D. , Falk, J. H. , (2003). Toward an agenda for advancing research on science learning in out-of-school settings. Journal of Research in Science Teaching, 40 (2), 112-120.

Storz, M. G., & Nestor, K. R. (2008). It's all about relationships: Students speak out on effective schooling practices. In F. P. Peterman (Ed.), *Partnering to prepare urban teachers: A call to activism* (pp. 77-101). Washington, DC: American Association of Colleges for Teacher Education.

Wagner, M., Cadwallader, T. W., Newman, L., Garza, N., & Blackorby, J. (2002). *The other 80% of their time: the experiences of elementary and middle school students with disabilities in their nonschool hours.* Menlo Park, CA: SRI International.

Motivated by Challenge or Challenged by Motivation?
Insights on Engaging Youth in STEM Learning Experiences

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Abstract

The task presented to us is to identify what factors support young people engagement in STEM learning and pursuit of STEM career pathways. To this end I present a summary of relevant information - statistical data, results from research and experience derived from an actual STEM program - and personal considerations to be used as discussion starters. A focus on older youth populations underrepresented in STEM seems especially important and it may well provide insights for how to promote STEM learning experiences among the whole population. Ultimately this paper aims to foster a conversation that is not only inter- and cross-disciplinary but also trans-disciplinary in order to critically examine and ultimately discuss the causes of both a shortage in the nation's STEM workforce and a lack of diversity among its people.

Human capability realization problem, versus STEM capacity building problem

A recent report from "America's Promise Alliance" shows that nationwide, nearly one in three U.S. high school students fails to graduate high school with a diploma. Among minority students, the problem is even more severe with nearly 50% of African American and Hispanic students not completing high school on time. When the nation's 50 largest cities are considered the average graduation rate is 53%. (America's Promise Alliance, 2009). This data should be of concern for most of us: in fact while dropping out of high school inevitably impacts the life of the individual involved (reason good enough to worry) it also impacts many aspects of our society and our economy (Afterschool Alliance, 2009).

Employment opportunities are not necessarily better for those who successfully graduate from high school though. 40% of high school graduates (independently of geographical or socio-economic distribution) lack work habits, ability to read and understand complicated materials, and math, science and writing skills, making them inadequately prepared to deal with the demands of employment and postsecondary education (Achieve, Inc., 2005).

In order to pursue STEM majors in college and STEM career pathways competence in mathematics and science at the end of high school is required. However, nationally, about 25% of all college freshmen fail to meet the performance levels required for entry-level mathematics courses and must begin their college experience in remedial courses (BHEF, 2005). Of those students entering college to major in science and engineering, less than 40% graduate with a degree in that field within six years and for underrepresented minorities the rate drops below 25% (2002 data, BHEF, 2005).

Results from a longitudinal study of Boston Public Schools students who graduated in 2000 points at another achievement gap: the percentage of female BPS graduates who enroll in college (67.9%) is significantly higher than that of males (59.9%). Women enrollees have a higher college graduation rate than men (36.6% compared to 33.9%). (Sum et al., 2008).

For young people to be prepared to successfully navigate today's job market and/or college education, they need more than content knowledge: they need adults who can advice them and guide them in personal and academic choices that occur in adolescence and the young adult years. They need exposure to professionals and work environments that they are not typically familiar with. They need skills that make them competitive for 21st century jobs: ability to communicate effectively beyond their peer groups, analyze complex information from multiple sources, write or present well-reasoned arguments, and develop solutions to interdisciplinary problems (Partnership for 21st Century Skills, 2004). Lack of social capital and status, especially during a person's late teen years, is a critical factor that often prevents young people from having both the exposure and long-term guidance to support them on a STEM career pathway.

As a logical consequence if we want to address STEM underrepresentation at its roots, we have to start thinking of addressing underrepresentation as a human capability realization problem, rather than purely as a STEM capacity building problem. An increase in STEM capacity among the U.S. population can be acquired through the well-rounded development of every young person's creative and social potential.

The Role of Out-of-School Time Learning

There is growing consensus in the education community that high-quality out-of-school time programming for older youth is an important tool to meet the need for increased engagement and success in high-school, enrollment in college and overall chances to become a productive member of society (Friedman & Bleiberg, 2007). Research suggests also that when youth are engaged in programs in meaningful ways, they are likely to learn more, experience better developmental outcomes, and stay in programs longer (Walkers et al., 2005).

What seems to emerge from a variety of research data is that what motivates older youth to stay in an OST program on the long term has more to do with the way the program is structured than with the content knowledge that is explored. For example, the number of leadership opportunities offered by a program was the strongest single predictor of retention in a recent study by the Wallace Foundation (Deschenes et al., 2010). An additional set of practices that relate directly to the youth experience included providing developmentally appropriate activities and incentives and matching program attributes to youth's needs. Finally, when asked to identify effective OST programs teenage youth mention those that engage them in challenging but fun activities, and that contribute to their learning and social development (TASC, 2008).

Youth are looking for opportunities for skills and knowledge development, and for positive relationships with adults, including skilled professionals and experts, who provide mentorship and serve as role models. Older youth require programming conditions, both programs offered and expertise of adult staff involved, different from those that serve younger children. Incidentally, this may in part explain why out-of-school time opportunities decline with age independently of demand (Afterschool Alliance, 2009).

STEM Learning in Out-of-School Time

If we apply what we understand about learning experiences in general to STEM, we derive that for STEM learning to have a lasting impact on the life of a teenage youth, it has to be fully owned by the learner (Larson, 2006).

For this to happen STEM learning needs to be integrated with the youth's personal development process: teens will develop new STEM understanding as they develop personal and interpersonal skills needed to fully participate in the life of our society. During this process youth will grow and mature both as citizens and as STEM advocates and potentially as STEM professionals.

To foster engagement in STEM learning and to support the pursuit of STEM career pathways among older youth, such learning needs first of all to be *meaningful*. This happens when the STEM learning experience offers youth the opportunity to share their knowledge with others and develop skills that they would not have developed otherwise. The learning experience is meaningful when through it youth are able to appreciate the value of STEM disciplines and the scientific enterprise because they affect their life, their community and society, and the world. Finally, the STEM learning experience is meaningful when it is based on effective interactions of the youth with professionals (in STEM but not only) and when through it they realize that they can pursue a career in STEM *if they want to* (opposed to *because they have to*).

This learning paradigm suggests that independently of individual motivation, OST programs can succeed in engaging older youth in STEM by providing a continuity of efforts that provide youth with opportunities for increased responsibilities and leadership roles. In addition, by promoting engagement in STEM for a large base instead of a selected number of youth with declared interested in STEM, the statistical odds for young people to become STEM advocates, and to also pursue STEM career pathways, automatically increase. These are key practices included in the model adopted for the Youth Astronomy Apprenticeship program.

Engaging in STEM learning: An example from the Youth Astronomy Apprenticeship

In the Youth Astronomy Apprenticeship (YAA) model equal effort is put in pursing science learning for academic enrichment and in stressing the link between employable skills and the skills developed in science and other professional fields – such as the performing arts and museum exhibit development. This approach allows us to reach out to older youth (ages 15-19) from underserved groups in a way that both satisfies their interests (create new knowledge and products from their experience, have a social component -Innovation by Design, 2002) and meets their needs (develop employable skills, earn a stipend - TASC, 2008).

A key strategy in this effort is to provide continuity of support and mentoring, and opportunities for deeper learning and increased personal responsibilities: YAA youth start as unpaid trainees, transition to paid apprentices, then to teaching assistants, and some of them eventually land intern positions at the MIT Kavli Institute. The YAA program progressively develops youth's science knowledge and 21st century employable skills through an apprenticeship model with several stages:

- After-School Training Program: *Youth as Trainees*
- Summer Apprenticeship Program: *Youth as Apprentices*
- YAA Outreach Program: *Youth as Science Ambassadors*
- Youth Assistant Program: *Youth as Agents of Change*
- YAA Internship: *The Future Generation of YAA Instructors and Informal Science Educators*

To provide practice in a range of employable skills and professions, YAA brings to the program professionals from a variety of fields to train and work with the YAA apprentices. Youth benefit from the expertise and support provided by:

- Scientists and science educators
- Members of the amateur astronomy community
- Staff from community-based organizations
- Theater and performing arts professionals
- Museum exhibit designers and planners
- Planetarium and science museum staff
- Marketing and advertising experts

Over three years, the YAA program recruited 178 youth (49% boys and 51% girls) with a 54% retention rate for the Training Program. Youth recruited in the training program include any youth who “show up”: YAA does not have any selection process based on specific motivation, academic performance, other after-school commitments or intention to continue after the training. 54% is then a very good retention rate compared to average expectations for high school age youth (Pearson, 2007). 71 YAA apprentices worked at MIT over three summers, and 17 of them became YAA assistants: 100% of the assistants returned to the YAA summer apprenticeship the following years and retention rates from one summer to the following are above 50% (note that the number of returning apprentices is capped because of the limited number of paid positions available). The long-term engagement rates that the YAA model produces show that the opportunity for personal growth, increasing responsibilities and leadership roles are indeed important factors in supporting youth motivation also in STEM learning experiences.

95% of the youth that took part in YAA so far are from populations historically underrepresented in STEM. Considering the challenges already faced by the formal education system in helping youth from underrepresented groups to overcome the achievement gap in many STEM fields, YAA emerges as an effective OST initiative to support not just academic enrichment, but also skills building and youth development opportunities (Summative Evaluation Report, 2009).

What’s Next

The Older Youth Working Group (an outcome of the *Older Youth & Science in Out-of-School Time Conference*, Cambridge, MA 2009) is circulating a survey with the goal to get a better understanding of the support structure, resources, and activities that are available to older youth in our country. The Working Group aims to take a "snapshot" of informal science, technology, engineering and math education programs serving high school age youth to create a database of information that will be used to positively influence engagement, attitudes and perception, learning and skill building, and direction for youth around STEM education.

Below are some highlights from preliminary results from 107 survey respondents (representing programs in 35 states):

- 28% of programs serve youth "18 and Older" with all four high school age groups highly represented (79-88% representing the fact that most programs serve multiple high school age groups with a slight emphasis on juniors).

- Regarding "Length of Desired Commitment from youth" the majority of programs (47%) desire a "less than 1 year" commitment though about 39% desire a commitment of "2 or more years".

- Most programs focus on STEM Enrichment, STEM Career Prep, Youth Development and College Prep in that order of prevalence (civic engagement and high school completion were at the bottom).

- Those focusing on "STEM enrichment" or "STEM career preparation" specifically identified one or more of the following disciplines: Various / multiple fields – 36. Engineering – 9, Environmental Science – 5, Biological sciences – 5, Computer science – 5, Chemistry – 5, Space science – 4, Robotics – 5, Technology – 4, Geosciences – 3, Ocean sciences – 2, Natural sciences – 2, Aviation – 1, Paleontology – 1, Physics – 1, Physical Sciences – 1, Math – 1, Pharmacology - 1

- Over 50% of programs were characterized by at least one of the following programmatic elements (substantial overlap within programs): Inquiry approach to STEM exploration, laboratory projects, teamwork (most prevalent at 83%), technology, mentoring by adults, public presentations by youth and career awareness. Community service projects, classes, science demonstration development and transferable skills development were listed as "Other" program components.

- Most programs were run in urban settings (48%; 12% rural, 19% suburban).

- Most programs targeted youth with an interest in STEM, economically disadvantaged youth/girls, minority youth from underserved populations, and/or ethnic minority youth (in order of prevalence; range 45-57%). Very few programs specifically targeted youth in the juvenile justice system or youth with disabilities.

- About 41% of programs have existing evaluation reports with 26% currently undergoing evaluation.

- 58% of programs have relationships with a college or other post-secondary educational institution.

These results indicate what STEM programs for older youth are currently offering, they do not necessary reflect the reasons why specific programmatic elements were included or not considered at all. A couple of results are worth noticing though: the 39% of programs that expect participation for 2 or more years are probably reflecting the need for continuity of effort to support older youth and these programs may also include possibilities for increased responsibilities and leadership roles. Opportunity for leadership roles is not explicitly mentioned in the survey though "Programmatic decisions made by youth" may be interpreted in a similar way. This programmatic element is reported by about 40% of the programs. Further analysis is needed to verify that expectation of long-term commitment and leadership roles are present in the same program.

The fact that a majority of programs declared to target "Youth with an interest in STEM" may represent a contradiction when we are concerned about increasing the number of youth engaging in STEM and pursuing STEM career pathways. Another potential contradiction arises from the small number of programs that specifically focus on math. While it is likely that math is included in some of the programs that specialize in other disciplines, it seems unlikely that that be the case for all of them. Additional research is needed to get a better sense of how seriously the OST community currently takes the challenge of keeping "M" in STEM.

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Bibliography

Achieve, Inc. (2005) Rising to the Challenge: Are High School Graduates Prepared for College and Work?

Afterschool Alliance, 2009. Afterschool Innovations in Brief - Focusing on Older Youth,

America's Promise Alliance (2009). Cities in Crisis 2009: Closing the Graduation Gap – Report.

BHEF (2005). A commitment to Americas Future: Responding to the Crisis in Mathematics and Science Education a report commissioned by the Business-Higher Education Forum)

Deschenes S. H., 2010. Engaging Older Youth. Program and City-Level Strategies to Support Sustained Participation in Out-of-School Time.

Friedman L. and Bleiberg M. (2007). Meeting the High-School Challenge: Making After-School Work for Older Students, The After-School Corporation.

Innovation by Design (2002). After-School Programs in Boston: What Young People Think and Want.

Larson, R. (2006). Positive Youth Development, Willful adolescents, and Mentoring. Journal of Community Psychology, Vol. 34, No. 6.

Norland E., Foutz S., and Krabill M. (2009). YAA Summative Evaluation Report. http://epo.mit.edu/resources/yaa.html

Pearson L. M., Russell C. A, Reisner E. R. (2007). Evaluation of OST programs for youth. Patterns of Youth Retention in OST Programs, 2005-06 to 2006-07.

Sum A. et al. (2008). Getting to the Finish Line - College Enrollment and Graduation: A Seven Year Longitudinal Study of the Boston Public Schools Class of 2000.

TASC (2008). Strategies for Success: A Plan to Align Out-of-School Time Initiatives with High School Reform, TASC & The Urban Assembly.

Walkers J., Marczak M., Blyth D. and Borden L. (2005). Designing youth development programs: Toward a theory of developmental intentionality.

Examples of Computational Thinking in the K-12 Experience

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Several years ago a working group of ITEST Principal Investigators and evaluators posed the question: What do ITEST youth know and what do they do with technology? A short survey of ITEST projects indicated that ITEST youth were using a wide variety of technology tools and systems, from simple to highly sophisticated; and many to high degrees of skill. As we dug deeper we began to explore the impact this use of technology had on youths' patterns of thinking, processing information and problem solving. We began to discuss some of the commonalities we were observing among the ways youth approached problems and used computational tools/systems to develop various solutions. We talked about this as a type of technologically enabled and enhanced thinking. About the same time Jeannette Wing's article on Computational Thinking was published in Communications of the ACM. (Wing, 2008) We found the concept of Computational Thinking (CT) closely aligned to what we were observing in the behavior of participants in our projects, and began to discuss our observations in light of the CT framework. A new working group, focusing on Computational Thinking emerged within the ITEST community of practice. Over the past year this working group has explored Computational Thinking within ITEST and other NSF EHR programs and identified several examples of what Computational Thinking looks like in action. This paper shares those examples and some of our thinking on this topic.

Computational thinking (CT) promoted by Jeannette Wing (2006) describes a set of thinking patterns that emerge from computer science but that are useful in much broader contexts, as they involve systematically and efficiently processing information and tasks, with or without a computer. CT involves defining, understanding, and solving problems, reasoning at multiple levels of abstraction, understanding and applying automation, and analyzing the computational tools we develop to solve problems.

There are three main pillars of CT: abstraction, automation, and analysis.

> **Abstraction** may take the form of stripping down a problem to what is believed to be its bare essentials. Abstraction is also commonly defined as the capturing of common characteristics or actions into one set that can be used to represent all other instances.

Automation is using the computer as a labor saving device in which processes are used to execute a set of repetitive tasks quickly and efficiently compared to the processing power

Analysis, as described by Cuny, Snyder, and Wing (2010), is a reflective practice. It refers to the validation of whether the abstractions made were correct. One might ask "Were the right assumptions made when narrowing the problem to its bare essentials?" or "Were important factors left out?

It is also important to note at the outset that CT shares elements with various other types of thinking such as algorithmic thinking, engineering thinking, and mathematical thinking. As such, CT draws on a rich legacy of related frameworks as it extends previous thinking skills to include concepts unique and specific to computational media.

In layman's terms, computational thinking is an evolving construct that is intended to capture and define foundational ways of thinking that are increasingly relevant in the digital age, where ubiquitous use of technology continues to change the ways we live, learn and work. While some think computational thinking is only developed after years of progressively intense studies of computer science, others believe that today's youth – many of whom are power users of technology – are developing computational thinking through their daily intensive use of technology over a long term. In either case, many consider computational thinking to be a set of basic skills, a type of analytic, procedural and algorithmic thinking, that will enable our students to harness the power of our cyber-infrastructure to become the idea makers and innovators of the future, enabling us as a nation to understand and address the daunting issues we face in the 21st century and compete and succeed in a global economy driven by technology. If computational thinking is, indeed, a key to developing the capacity to discover, create and innovate, then teachers and other youth leaders need to understand computational thinking, how it connects to their curriculum, and how to recognize, nurture and assess these talents in today's youth. To that end, this paper seeks to address the following questions:

- *What does computational thinking for youth look like in practice?* And,
- *How can we support growth in computational thinking, both in and out of school?*

What does computational thinking for youth look like in practice?

Much of the existing literature on computational thinking focuses on formal computational thinking such as one might encounter in a college-level computer science course. In this paper, we take a different approach, considering how computational thinking appears to be evolving among pre-college youth in and out of school. A wide range of activities build CT skills. Distilling the rich and complex legacy of formal computational thinking, we base our understanding of computational thinking for youth as an approach to framing problems or issues that relies on three main pillars: abstraction, automation, and analysis (Cuny, Snyder and Wing, 2010). Phrased more tangibly, Dave Moursund (2009) suggests that "the underlying idea in computational thinking is developing models and simulations of problems that one is trying to study and solve." In addition to the model-based approach promoted by Moursund, we will consider computational thinking in two other domains: with robots, and with game design. Although we recognize that a wide range of activities bild CT skills, we found several examples from these three domains in our projects involving innovative work in computing being done with middle- and high-school students.

> In a Project GUTS (Growing up Thinking Scientifically) middle school students actively engage in computational thinking through the modeling and simulation of real-world issues within their communities. Within Project GUTS clubs, students investigate local issues in their community, create agent-based models in StarLogo TNG with which they investigate the issues further and test potential mitigation strategies virtually. For example, in an investigation of epidemics, Project GUTS club members collected data on student circulation within their schools, the physical layout of their school, and researched various contagious diseases. Using this data, they customized a computer model of a simple contagion to reflect local conditions and match a chosen virulent. Their computer models were used as experimental test beds with which they tested strategies to mitigate potential epidemics within their school community. Interestingly, club members showed great creativity – some chose gossip, bullying behavior, and the spread of fads and fashions as contagious elements.
>
> A second key application area of computational thinking with pre-college student is designing and programming robots and other physical devices with embedded code. In iCODE (Internet Community of Design Engineers) middle and high school children complete a variety of microcontroller-based projects, beginning with a simple project with programmable flashing lamps, to a musical memory game, to fully autonomous (self-controlled) robots that enter a contest. In many respects, the type of CT that students engage in when developing these projects is similar to the thinking involved in creating agents in game programming, but with iCODE and other similar work, students will focus on one agent -- their project -- and the immediate world that surrounds it and provides input to its sensors. With game programming, students are more likely to think about interactions among a collection of game agents.
>
> A third key application area of computational thinking is computer game design. In the iGame after school program, middle school children engage in computational thinking by programming computer games using Storytelling Alice. Building a computer game requires not only programming, but the ability to think at multiple levels of abstraction and in terms of scale. Salen (2007) says that "knowing how to put together a successful

> game involves system-based thinking, iterative critical problem solving, art and aesthetics, writing and storytelling, interactive design, game logic and rules, and programming skills" (p. 305). When students program their games using Storytelling Alice, they engage in relevant CT concepts such as algorithmic thinking, as they solve problems related to game programming using conditionals, iteration, and sequential execution. Game programming also engages students in abstraction, because students must create a model of their world, and set up variables to define the state of the world. Finally, game programming engages students in an understanding of scale, when they create a list data structure so they don't have to program each object individually.

For example, Squire (2004) has shown how the game Civilization has used a mass-market simulation game to promote historical understanding. Students then use the game's modification tools to create their own game scenarios. Likewise, the Community Science Investigators program engages youth in "augmented reality" games that provide an overlay of an environmental mystery game scenario within their neighborhood. As the players seek clues to solve the mystery, they are engaging in simulated science within a game context. Later in the program participating students build on their experience with simulations to design their own games.

Use-Modify-Create Learning Progression

Based on our observations in several youth projects across the US, we propose a three-part model or framework that illustrates a learning progression of how CT skills develop.

USE: The outcome of this initial phase is that youth learn how to use the technology, including the interface and tools, and the kinds of products that others have made. This is a first step that must happen before higher levels of engagement with CT.

MODIFY: As comfort is gained in using the tools, youth begin to experimient and explore, modifying existing programs or projects. The outcome of this phase is that students to begin to understand how they can control underlying mechanisms to bring about different results, a skill the they will later use in making original creations.

CREATE: In this phase, youth apply their growing computational thinking skills to create an original product. Implicit in the development, of course, is that the creation will be used and modified over time.

In the Use phase of iGame program, middle school students learn how to use the programming environment, in this case Storytelling Alice. To do this, they take the interactive tutorials and play games made by their peers. The outcome of this phase is that youth learn about the software interface, and the kinds of games they might make. In the Modify phase, they complete self-directed "challenges," which are step-by-step instructions for modifying and expanding on existing programs. The outcome of this phase is that students begin to understand the mechanisms they will use to program their game. They learn to use tools, such as the clipboard to copy and paste code. The challenges get increasingly more difficult, with more complex and abstract concepts, and with fewer and fewer instructions. In the Create phase, they program original games, with varying degrees of complexity. There is a continuum of CT within this phase, with some students engaging in high-level abstraction (creating complex new methods or embedded loops) and others creating more linear code. For instance, many students apply the concept of conditionals using simple If/Else commands. Others use nexted If/Else commands, suggesting a high level of mastery of these concepts. As stated in the NAS report (2010), programming is learning a language that one can use to express new ways of thinking and to learn to express ideas in a precise way. Learning that language in iGame involves not only creating, but also analyzing, testing, and revising their games, as well as testing games made by their peers.

EcoScienceWorks is an in-school curriculum that features SimBiotic Software's EcoBeaker™ agent-based ecology simulations re-designed for Maine's one-to-one middle school laptop program. These simulations (*Maine Explorer*) and the accompanying teacher-designed field exercises and lesson plans were designed to replace ecology curriculum currently being taught in Maine thus were aligned with state and national learning standards and the topics (succession, species interactions, habitat fragmentation, eutrophication and invasive species) were influenced by the teacher teams that were part of the EcoScienceWorks ITEST project. Students learned the interface and how to perform directed experiments in the USE phase of the project. This involved using the simulation's tools to discover important features of the habitat. For instance, the microscope tool is used by students to hover over an individual agent's icon to discover its gut contents as they work out the habitat's food web. The Use phase of the project also involved performing experiments using the simulation. In the eutrophication lab students discovered the impact of different levels of phosphorus pouring into a simplified lake ecosystem on population sizes for algae, zooplankton and trout and uncovered an explanation for the decline in trout population sizes by measuring the simulated lake's dissolved oxygen content. Thus, this phase of the project was rich in the CT aspects of abstraction and concepts such as control of variables, replication of experiments and data analysis. In order to increase student interest and understanding of the underlying design of computer models, a separate programming challenge lab was included with *Maine Explorer*, called Program a Bunny. A series of challenges in StarLogo TNG-like CodeBlock programming are presented to students. In this Modify phase of the project students learn how to use conditional commands, randomization and recursion to program a single bunny to forage for carrots in a field. The challenges culminate in a competition between the student programmed bunny and a pre-programmed bunny.

Learning CT in School and Out

As we explored NSF funded programs we found most of our examples of CT in the K-12 experience in out-of-school (OST) environments.

As noted above, the Use, Modify, Create progression is developmental. Computational thinking projects like those mentioned above support an iterative cycle that enables increasing sense of agency, where learners are empowered to imagine, create, play, share, and reflect on what they are learning (Resnick, 2007). As this iterative cycle progresses, it is important to maintain a level of challenge that supports growth. As Repenning (2008) notes, students can maintain their sense of cognitive flow (Csikszentmihalyi, 1990) as they progress iteratively through a series of projects. In this work, a student tackles progressively higher challenges as her skills and capacities increase. What was once "too hard" and anxiety-inducing becomes possible with appropriate, incrementally challenging experiences.

Conversely, Repenning argues, boredom will set in if challenges don't keep pace with growing skills. In fact, most students relish this challenge in their out-of-school lives, seeking out challenges that help them to grow and to demonstrate increased mastery. As Seymour Papert (1998) noted, most young people willingly pursue "hard fun." This process of increasing challenge and complexity—engagement with a long-term project— is not easily compatible with a curriculum packed with many topics. Curricular flexibility that allows for deep exploration is part of the culture change needed for computational thinking to take root in schools.

With few curricular constraints, the capacity to hire staff with the requisite technology skills, and the necessary technological infrastructure, it's not surprising that many of the best examples of CT-rich learning happen outside of a traditional school day. Projects designed to support computational thinking can marshal the resources needed to overcome the limitations often found during the school day.

This is not to say that OST programs are the ideal environment. First, access to high quality out-of-school time learning spaces is far from evenly distributed. In particular, rural areas rarely have these spaces, which essentially keeps the school as the sole provider of educational opportunities. Until broadband penetration becomes more common in rural areas, virtual learning opportunities won't provide meaningful programs either, further exacerbating the opportunity gap faced by rural communities.

Also, many of the most ambitious programs tend to be funded through expensive, time-limited grants from government and foundation sources that serve only a very small portion of the potential base of participants. Continuation past the grant cycle is often dependent on next grants, as is replication in other locations, or it requires a significant outlay of human and financial resources that favors communities with the economic wherewithal to take on such a responsibility. Relying on grants is also problematic in that the low funding percentage for most grant competitions makes it uncertain that a next grant is in the offing. Also, grant support to continue a successful program is usually much harder to procure than is funding to start something perceived as new or innovative.

Given the equity, access, and continuity limitations associated with specialized out of school environments, we need to continue looking at ways to make CT environments more universally accessible through the school environment.

As a community of practice, we recommend moving forward by leveraging what is possible in both formal and informal learning environments to advance our collective work.

To that end, in the next section we share lessons learned along the way and offer the potential next steps for practice and research.

Conclusions

In this paper, we have contributed to the dialogue about computational thinking for youth by using examples from several youth projects to describe what CT looks like, and to consider strategies for engaging youth in CT. Given the importance of CT, we need to deepen our collective understanding to guide our steps forward. We are not yet at the point where we have a set of best practices to recommend, but we do hope this paper will move us closer to that point by start a national dialogue about effective strategies for engaging youth in computational thinking.

At this point we are confident that existing, broad definitions have utility for understanding CT, but there are developmental considerations that need to be addressed. We know from the examples cited here and from other projects that youth can engage in abstraction and automation, but these processes need to be viewed in light of each child's age and prior experiences. More generally, attempts to list fundamental CT skills, such as those articulated by the National Academies of Science (2010), need to be interpreted accordingly. Computer and learning scientists need to collaborate with practicing educators in thinking through and articulating sets of foundational skills and developmental progressions. These can then be considered in light of how they might be used to guide computational thinking in different domains and learning environments. The work here focuses on models and simulations, robotics, and game design; these and other application areas will benefit from such a framework.

As a foundation moving forward, the Use-Modify-Create framework offers a helpful model for understanding how CT develops over time; and provides a useful trajectory as youth engage in progressively more complex tasks and increase ownership of their learning.

Discussion Questions:

- What is computational thinking?
- What does computational thinking look like in practice among youth participating in NSF projects?

•What role does informal learning play in the development of foundational competence in computational thinking?

•How can formal educators assess CT competence in their students and determine where they are in the CT learning progression of Use –Modify-Create?

• How can we support growth in computational thinking, both in and out of school?

References

Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience.* New York: Harper.

Moursund, D. (2009). Accessed online at: http://iae-pedia.org/Computational_Thinking.

National Academies of Science. (2010). *Report of a workshop on the scope and nature of computational thinking.* Washington DC: National Academies Press.

Papert, S. (1998). Does easy do it? Children, games and learning. *Game Developer* (June 1998). Available online at http://www.papert.org/articles/Doeseasydoit.html accessed April 19, 2010.

Repenning, A. and Ioannidou, A. (2008). *Broadening participation through scalable game design*, ACM Special Interest Group on Computer Science Education Conference, (SIGCSE 2008), (Portland, Oregon USA), ACM Press. Available online at http://www.cs.colorado.edu/~ralex/papers/index.html. Accessed April 19, 2010.

Resnick, M. (2007). *All I really need to know (about creative thinking) I learned (by studying how children learn) in kindergarten.* ACM Creativity & Cognition conference, Washington DC, June 2007. Available online at http://web.media.mit.edu/~mres/papers.html accessed April 19, 2010.

Squire, K. and Jenkins, H. (2004). Harnessing the power of games in education. *Insight (3)*1, 5-33.

Wing, J. (2006). Computational thinking. *Communications of the ACM 49*(3), 33-35.

Wing, J. (2008). Computational thinking and thinking about computation. *Philosophical Transactions of the Royal Society A 366,* 3717-3725.

Imhotep Academy: Photonics Pre-college Program Model (3PM)

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Abstract

Imhotep Academy is a science learning and career exploration pre-college program at The Science House-North Carolina State University for middle and high school students from groups underrepresented in the sciences and engineering. Our goal is to prepare students to take advanced mathematics and science courses throughout high school and to mentor students throughout their secondary and postsecondary experiences. To achieve this goal, the program model integrates practical and theoretical strategies to prepare students for the global workforce and college enrollment. The Photonics Pre-college Program Model (**3PM**) guiding principles and program outcomes are presented in this white paper to justify using a participatory approach to equip students and to empower teachers, STEM professionals and parents to address the demands of our technologically driven society.

Potential Research Significance

Our complex society requires students to analyze and respond to problems through the application of critical thinking skills and collaboration. One must be adept to participate in experiences that extend beyond the standardized testing system within the traditional public school system. To transition into technology and science careers, students are to acquire resourcefulness, communication and research skills. An inquiry–based learning environment infused with partners from varying backgrounds and expertise creates an environment for students to develop skills needed for transition into the 21st century. **3PM addresses the question of how to integrate scientific content, student encouragement, and parental support to ensure underrepresented minority (URM) high school students experience success in STEM disciplines.** The goal is to increase college preparation, access, and academic success of high school students through immersion of physics content, virtual learning environments, internships and leadership development experiences.

Photonics Program Overview:

Photonics program goals are to prepare underrepresented minority (URM) high school students for science, technology, engineering and mathematics (STEM) careers, equip teachers and parents with resources to engage learners in these disciplines, and put forth projections for effectively addressing the shortage of STEM professionals, and information technology workers.

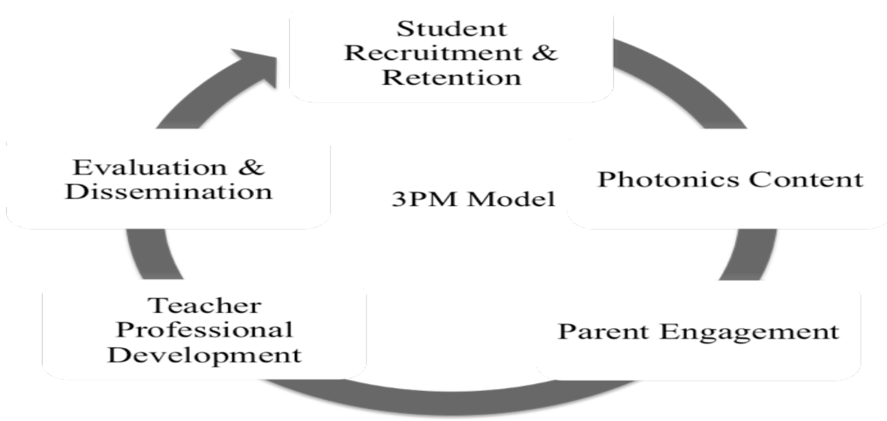
The method for addressing the program goals are grounded upon the collaboration among teachers, parents, and URM STEM professionals strategically embracing the unique needs of the high school students. **3PM** follows a limited group of students through an extended period to document changes in the students' achievement and outlook. Student indicators recorded over time include science and mathematics course selection, scientific writing, communication, and research skill progression, students' dispositions and scientific knowledge. To measure these variables, pertinent data is examined and provided to parents and participants (both students and teachers) to build an awareness of higher education requirements, demands of the global society, and STEM expectations.

Parents are provided educational seminars to address the three major gatekeepers for students' pursuit of higher education and STEM fields, which are academic achievement in rigorous coursework, ACT/SAT preparation, and financial/college planning. Research indicates parents from low socioeconomic status (SES) and ethnically diverse backgrounds possess limited knowledge of these factors impact students transition throughout the STEM programs. Hosseler et al (1999) and Spera et al (2009) noted parent encouragement and academic involvement as the single largest predictor of students' educational aspirations and academic preparation preceding college.

3PM Conceptual Model

The 3PM model (see Figure 1) used to prepare students for STEM opportunities is grounded within five components

Figure 1. Conceptual Model of Program Factors Affecting College Enrollment and STEM Participation



Each program factor is operationalized through one or more of these guiding principles: (a) immersion in traditional and non-traditional hands-on investigations, (b) engagement in a supportive, safe and challenging environment, (c) participation in leadership and professional development training and (d) integration of professionals from academia, industry and schools. The program model incorporates synergistic science, technology, engineering, and mathematics activities among participants to determine which strategy best predicts student preparation, selection, and pursuit of STEM areas. The underlying assumption is that knowledge shapes attitudes, which alter behavior, (i.e., skills, knowledge, persistence, college enrollment)

Component 1: Recruitment and Student Selection

Enhanced and expanded strategic outreach will be incorporated to aggressively recruit students with a strong emphasis on African-American, Hispanic and Native American students. New or expanded personal contacts will be established with the NAACP, El Pueblo, North Carolina Society of Hispanic Professionals, Native American tribal councils, and the North Carolina Association of Guidance Counselors to make presentations and distribute information directly to prospective applicants or their parents. Informational brochures and flyers, tailored to the emphasis groups, will be disseminated to high school counselors for referrals and recruitment. Follow-up emails and announcements will be sent monthly to guidance counselors, science and mathematics department chairs in all school districts, other STEM programs, the NC School of Science and Mathematics, and through the Science House electronic newsletter to its 2300 subscribers. Graduates of the Photonics teacher's program are invited to become photonics teachers to prepare the high school Photonics participants.

Component 2: Photonics Content

Photonics participants will investigate how the physics of light and the technology of solid-state electronics intersect in devices such as TV remotes or telescopes. They will wire simple devices such as an optoelectronic interface, simulate projects with scientific software, learn to use technology tools and work in virtual learning environments that make real-world scientific investigation possible. Program activities will enhance students' abilities to communicate orally and in writing through preparation of presentations and reports based on research projects, which they plan and conduct. Students will serve as interns in research or technology laboratories at NCSU or partnering companies in the Research Triangle Park.

Under the tutelage of Photonics program teachers, students will engage in traditional and nontraditional hands-on, problem-based investigative experiences concentrated in photonics and engineering using Elluminate, virtual learning environments, visualizations and video conferencing. The activities are designed to encourage participants to develop the types of skills needed in the global workplace; among these are teamwork, problem-solving, mathematics and research skills, leadership development, critical thinking, communication and technology skills.

Research shows that learners are able to construct their knowledge when placed in environments that trigger their prior knowledge and that requires several levels of processing to reach intended goals (Mayer, 1996). Using the nature of light and its applications as the basis for students' prior knowledge will actively engage learners in the wonders of optical recording, communication, electronics, imaging and laser technology. These strategies integrate critical information, communication and technology skills with real time collaborative learning environments like Elluminate, interactive visualizations (Java Applets, Physlets), and hands-on investigations to produce a resource-rich environment for students to engage in a paired synchronous and asynchronous learning setting. The purpose of visualizations (Physlets) is to help learners gain access to ideas that normally would be too complex or difficult to grasp (Land, 2000). Students utilize sample optics, waves, and electronics, to study new questions (Christian & Melloni, 2007). These learning strategies are used to track students' self-efficacy over time.

Component 3: Parental Support

Parental support is critical to student success and is often an under-utilized resource in programming initiatives. Parental involvement and exhibition of positive attitudes toward mathematics and science help young people realize the relevancy and value of learning and motivate students to be successful. The most accurate predictor of a student's achievement in school is the extent of the family's involvement and participation in school-related matters (Russell & Atawater, 2005, Miles & Watkins, 2004 & Smith & Hausafus, 1998). Parental support is critical to students' success and because parents will be responsible for transporting students to NC State each month and in the summer, mileage reimbursement will be offered to parents as a gesture of appreciation and encouragement to keep that commitment. It is necessary to maintain parental and student interest and on-going contact through workshops, field trips, celebrations and special events, homework, newsletters and supportive correspondence, face-to-face communication, telephone conferences, email and electronic message boards.

Component 4: Teachers Professional Development

Classroom teachers are recruited and participate in a 5-day professional development session from participating students' home schools and schools across North Carolina. Informational brochures and flyers targeting middle and high school teachers are sent to NC high school principals with a request to distribute them to science, math and technology teachers. The professional development introduces educators to the wonders of Photonics, emerging STEM fields, careers and workforce demands of global society.

Component 5: Evaluation and Dissemination

The evaluation team uses a mixed-methods approach (Creswell, 2003; Patton, 2002). Methodological pluralism permits a rigorous, multifaceted examination of the extent to which progress and success is achieved, particularly in STEM related projects (Lawrenz & Huffman, 2006). The evaluation plan provides feedback to Project Staff and evaluation team to guide data-driven decisions and allow continuous judgments for photonics programs. Instruments for collecting important program data are constructed and adapted to meet the project goals. Instruments include assessments, surveys, interviews, participant observations, and document/content analysis guides used with various photonics program constituencies (students, parents/caregivers, teachers, and project administrators) to assess progress on program goals and objectives. The evaluation of photonics program activities determines whether objectives are being met.

Imhotep Academy **3PM** demonstrates achievement in preparing diverse students for STEM and college endeavors. The model adapts to accommodate unique needs of participants (students and teachers) and to confront emerging challenges of the global workforce. For instance, enhancement of the 3PM includes integration of virtual learning environments and learning management systems to develop 21st century and college readiness skills of participants. In addition to improving learning opportunities for participants, the model provides program flexibility from a schedule, dissemination and partnership perspective.

By using a variety of strategies, students, teachers, and parents are exposed to science and information technology instruction to promote selection of and academic achievement in challenging science and engineering courses. The following strategies and recommendations have evolved as a result of working with diverse students, K-20 STEM professionals, and policy makers:

1. Communication is critical in developing of an awareness of formal and informal learning resources and opportunities related to higher education and STEM education.
2. URMs would benefit from aggressive recruitment and retention methods that expose students to a supportive, safe and rigorous learning environment (National Academy of Engineering, 2005).
3. Pedagogically and culturally sound learning environments should integrate skillful professionals who provide appropriate content instruction in all core subject areas with ongoing sustained academic support and prepare for the global workforce.
4. Parent engagement is critical in developing youth to excel in their educational endeavors through parent associations, participation in school activities, college planning and preparation classes.
5. Intensive teacher professional development is paramount in preparing URMs youth for success in K-12 and college settings that specifically address unique learning needs through application of culturally relevant curriculum, constructivist, and transactional approaches.
6. Ongoing and centralized evaluation of formal and informal learning programs for URMs will provide a platform for all stakeholders to collaborate and identify methods and strategies which equip the URMs for academic achievement in STEM disciplines and college enrollment.

Conclusion

The challenge for policymakers is to make sure that, especially for children, they have all the opportunities and resources they need to become productive adults. With this in mind, our technologically and scientifically driven nation must identify ways to effectively educate and prepare all citizens including URM populations for the future, which requires one to be creative, respectful, disciplined, ethical and analytical to compete in our global society (Gardner, 2008).

Intervention must occur early to help all children realize that science and technology are a good "fit" for them before something else "hooks" their attention and distracts them from remaining in the STEM pipeline. Application of the participatory approach will meet the diverse challenges ahead in preparing learners for emerging areas as well as technologies not offered or envisioned within the public school system.

Hence, America must identify ways to effectively educate and evaluate efforts to prepare the growing minority populations for global society. America's economic stability and national security is dependent upon harnessing the diverse talent of all citizens. A healthy approach could begin by collaborating together in preparing and supporting more enrollment and participation of URM for academic achievement in STEM courses, college programs, and careers. Currently, more research is needed among K-20 professionals in designing afterschool initiatives to prepare the diverse citizenry for participation into the knowledge-age society. The role of the community and all stakeholders are to bridge the gap for access for all in pursuit of higher education and most importantly, STEM disciplines. This demonstrates the case for providing academic rigor in afterschool programs as well as engagement and fun.

References

Christian, W. & Belloni, M. (2007). *Physlet physics: Interactive illustrations, explorations, and problems for introductory physics*. Reading, MA: Addison-Wesley.

Creswell J (2003). *Research design: Qualitative, quantitative and mixed methods approaches*. Thousand Oaks CA: Sage.

Gardner, H. (2008). The five minds for the future. Boston, MA: Harvard Business Press Publishing.

Hossler, D., Schmit, J., and Vesper, N. (1999). *Going to college: how social, economic, and educational factors influence the decisions students make*, Johns Hopkins University Press, Baltimore, MD.

Ison, R. L., & Russell, D. (1999). Agricultural extension and rural development: breaking out of traditions. Cambridge, UK: Cambridge University Press

Land, S. M. (2000). Cognitive requirements for learning with open-ended learning environments. *ETR&D, (48)*3, 61-78. Retrieved from http://www.springerlink.com/content/e271r654564h34x9/

Lawrenz, F. & Huffman, D. (2006). Methodological pluralism: The gold standard of stem evaluation. *New Directions for Evaluation 109*, 19-34 doi: 10.1002/ev.176

Miles R. and Matkins J. J. (2004). Science enrichment for african-american students. *The Science Teacher 71*(2) 36-41.

National Academy of Engineering (2005). Educating the engineer of 2020. The National Academies Press, Washington, DC.

Patton, M. Q., & Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage Publications.

Russell, M. L. & Atwater, M. (2005). Traveling the road to success: a discourse on persistence throughout the science pipeline with african american students at a predominantly white institution, *Journal of Research in Science Teaching*, *42*(6): 691-715. Retrieved from http://www3.interscience.wiley.com/cgi-bin/fulltext/110480419/PDFSTART

Smith, F. M. & Hausafus, C. O. (1998). Relationship of family support and ethnic minority students' achievement 1998, *Science Education*, *82*(1) 111-125. Retrieved from http://www3.interscience.wiley.com/journal/32129/abstract

Spera, C., Wentzel, K. R., & Matto, H.C. (2009). Parental aspirations for their children's educational attainment: relations to ethnicity, parental education, children's academic performance, and parental perceptions of school climate. *Journal of youth and adolescence* doi: 10.1007/s10964-008-9314-7

Role Models Matter: Promoting Career Exploration in After-school Programs
Or If it's Worth Doing, It's Worth Doing Right

Linda Kekelis and Jennifer Wei

Abstract
Role models can play a critical role in helping inspire students in science, technology, engineering, and mathematics (STEM), expanding their options for the future, and providing guidance on how to successfully prepare for a professional career. After-school programs are an ideal venue for introducing role models who can transform excitement from a hands-on project into a career interest in STEM. In this white paper we will share the resources and best practices from the Techbridge program on partnering with industry and academia on outreach. We will also share lessons learned and challenges involved in outreach and raise questions about next steps needed for promoting workforce development in after-school programming.

Introduction

"Changing one life at a time is the biggest difference we can make." –Techbridge role model

Most of today's youth make important academic and career decisions with little, if any, guidance at school or home (Csikszentmihalyi & Schneider, 2000; Ferris, 2002). Technology careers can seem very abstract to youth, especially those who are first in their families to attend college and have no role model in technical fields (Margolis, Estrella, Goode, Holme, & Nao, 2008). Many students want to make the world a better place but don't see how their interests connect with science or engineering (Eccles, 2007). Role models can play a critical role in helping inspire students in STEM, expanding their options for the future, and providing guidance on how to successfully attain a technical career (Packard & Nguyen, 2003). After-school programs are an ideal venue for exploring career options and introducing role models who can transform excitement from a hands-on project into a career interest in STEM (Dorsen, Carlson, & Goodyear, 2006). In this white paper we will share the resources and lessons learned on partnering with industry and academia on outreach from the Techbridge program as well as raise questions and challenges regarding STEM workforce development, outreach, and sustainability in the after-school environment. While the mission of Techbridge focuses on girls, the training and resources for outreach have been used by our corporate partners in their outreach programs for girls and boys.

Techbridge: Program Description

Techbridge was launched in 2000 with a grant from the National Science Foundation by Chabot Space & Science Center to expand the options of girls in underserved communities and to address the shortage of women and underrepresented groups in technology and engineering. The program reaches out to girls in underserved communities and offers after-school and summer programs with hands-on projects, career exploration opportunities, and academic and career guidance. Jolly, Campbell, and Perlman (2004) identified three factors that are needed for success in science, technology, and engineering. These include: 1) awareness, interest, and motivation; 2) knowledge and skills; and 3) continuity of resources and opportunities. Techbridge offers all of these elements along with a highly qualified team and a 10-year track record of success in engaging girls in technology, science and engineering.

Techbridge has served over 2,500 girls in grades 5-12 in after-school programs, primarily from socio-economically disadvantaged areas in Oakland, California and surrounding communities. Our philosophy is to change girls' lives, one girl at a time, reflecting our desire to bring about significant change in a student's life through consistent, personal support and a dedication to increasing her choices for the future. Techbridge also works to build a strong network of support for girls, and has reached thousands of educators, role models, families, and partners through professional development, trainings, publications, and other dissemination activities across the country.

Curriculum is developed and implemented with girls in mind and is introduced with practices like collaboration and pair programming (Liston, Peterson, & Ragan, 2007; Werner & Denner, 2009). Projects include Green Design, where girls design and build green studios and learn about renewable energy; Electrical Engineering, where girls learn about circuitry and electronics through soldering and building Blinky robots; and Product Design, where students learn the engineering design process through a series of design challenges.

Techbridge has been designated as a "high-quality complementary learning program" by Learning Point Associates and selected by the Coalition for Science Afterschool as a program "offering high quality science, suitable for the after-school space." Techbridge's evaluation results demonstrate the program's success. Last year, results showed that 96% of participating students knew more about how things work, 94% felt more confident trying new things, and 94% believed that engineering is a good career for women.

Role Models are the Key

"The field trip...really helped me understand what I want to be…I've decided that I want to go into engineering. And specifically mechanical. Through Techbridge…I've come up with what I want to do." –Techbridge alumna, junior at MIT

Early in Techbridge, we discovered that even with positive experiences in the program, most girls did not aspire to a technical career. We learned that while hands-on projects can spark an interest in a young girl, they are not necessarily sufficient in leading to career goals. In exploring why some girls did not see STEM careers as compatible with their interests and identities, we discovered that girls face a number of hurdles in the educational pipeline for technology and engineering careers (Kekelis, Ancheta, & Heber, 2005). Negative stereotypes about careers along with lack of guidance and support contributed to the girls' opting out of the STEM pipeline. In addition, expectations for success and the value placed on different careers influence decisions about studies and careers (Eccles, 2007). Since many of our students are the first in their families to consider college, they do not have a role model at home in the science or technology fields who can help them make informed decisions or encourage them to follow in their footsteps.

We responded to this challenge and developed a comprehensive career exploration program to combat stereotypes and help girls make connections to STEM careers. Key to this effort has been role models and field trips to worksites. Techbridge partners with industry and universities in outreach efforts to introduce role models and careers to girls. Partners include Carollo Engineers, Chevron, eBay, Apple, Yahoo!, Facebook, Microsoft, Google, Intel, IDEO, University of California, Berkeley, and Stanford University.

Techbridge's evaluation data and research show that the opportunity for girls to see real-world applications of technology, science and engineering and meet with role models who work in these fields is extremely impactful and can have a strong influence on a girl's career path. The last two years in evaluation surveys, nearly 90% of participating Techbridge girls cited a greater interest in a career in technology, science or engineering because of a role model they met or a company they visited. In addition, a longitudinal study commissioned by the Gordon and Betty Moore Foundation documented how the impact of role models and field trips from years past continues to be impactful for Techbridge students. Nearly two-thirds of respondents cited field trips and role models as the top two factors from their experiences in Techbridge that inspired their interest in technology, science, and engineering (Ancheta, 2008).

Training and Support are Key to Success

How can I be engaging and inspiring for the next generation of computer scientists? How do I connect with a 7th grader? What can I do to get students excited about my career?

While the literature highlights role models as key in encouraging females and other underrepresented minorities in STEM (Thom, 2001), there is little reporting on the challenges involved or the types of support required for success. The majority of programs that offers training and support are directed at mentors who work with college-age students or early-career professionals. For example, programs like MentorNet provide training, coaching, and support and promote positive outcomes for protégés and mentors. However, there are limited resources for role models who are interested in doing outreach to encourage young students. A resource like *Making the Connection* by the Women in Engineering Programs & Advocates Network offers some helpful advice for teachers and engineers who wish to introduce engineering to K-12 students (Metz & Samuelson, 2000). Engineer Your Life offers career messages, which are based on market research to help role models motivate girls to consider engineering. Techbridge's model includes training and follow-up support to help role models plan their outreach that introduce science, technology, and engineering to students.

We often hear from professionals in industry and academia about their desire to conduct outreach but they do not know how to start, and the prospect of planning and hosting an event for a group of middle school students seems daunting. We have also witnessed interactions in which well-intentioned role models fail to connect with students because they don't know how to communicate their passion for their work or don't know how to make a presentation that is developmentally appropriate for their audience. Knowing how to interact with students and lead an activity for a roomful of sixth graders isn't something that most scientists or engineers learn in college or on the job. This is, however, a skill they need to know to make their outreach a success.

From our experience and research we have learned that training and support are key to success, allowing both students and hosts to make the most out of role model visits and field trips. Without these resources, role models are less likely to make an impact and more likely to give up on public outreach. With personalized training and follow-up support, role models can learn how to present themselves in ways that will have the most successful impact on students.

Techbridge fills this need by offering training, follow-up support, a resource guide and toolkit for role models. The Techbridge training model and resources, which offers practical tips and suggestions as well as successful case studies in outreach to K-12, have been successfully adapted for a variety of partners. For example, we have supported employees from Lockheed Martin with their DiscoverE outreach during National Engineers Week, role models who participate in Girl Scout career fairs, and workshop leaders at Expanding Your Horizons events. In partnership with other groups, our training has been presented and archived via webinars to Girl Scouts, National Girls Collaborative Project, Global Marathon, and Society of Women Engineers.

A Recipe for Success

With each role model visit and field trip over the past 10 years, we have learned lessons for introducing role models to girls which have helped us fine-tune our efforts. From follow-up conversations with role models, feedback from students and teachers, observations of interactions, and survey and interview data we identified the following key ingredients for success for outreach: 1) be personal and passionate about the career, 2) introduce engaging, interactive activities that relate to work, 3) explain why technology, science, and engineering matter, 4) dispel stereotypes by sharing hobbies and social pursuits; 5) discuss challenges and ways to overcome them, and 6) fill a gap with academic and career guidance. The key message that we want role models to take away: It's personal stories—told with passion and honesty—that help students relate to role models and see technology, engineering, and science in a new light.

In our interactive training we highlight these principles and help prepare role models for an outreach event. The training consists of background information on the need for outreach along with practical advice and resources to ensure an experience that is meaningful to students. Training elements include: 1) an overview of research that highlights students' needs and interests, 2) a brainstorm activity to assist professionals in understanding how role models can help students, 3) case studies of a variety of successful role model visits and field trips, 4) hands-on activities to experience sample projects that successfully engage students, 5) practical advice on scheduling and organizing events for students, and 6) time to brainstorm ideas to plan their own outreach and receive input from staff and participants.

Resources for Role Models

For those who can't personally attend one of our trainings, we developed a resource guide and toolkit for role models entitled *Get Involved. Make a Difference. A Guide for Classroom Visits and Field Trips for K-12 Students*, (Countryman, Kekelis, & Wei, 2009) with support from the National Science Foundation and Google. These resources offer ideas for icebreakers, sample role model and student biographies exchanged in advance of visits, hands-on activities that provide snapshots of careers, practical tips for company tours, and questions to promote interactions. They are available online as well as in print format.

Evaluation Results for Techbridge Role Model Training and Resources
The effectiveness of Techbridge's training and resources is supported by quantitative and qualitative data. Evaluation methods included interviews and surveys of role models who had participated in Techbridge's trainings and/or used the role model guide and toolkit.

A survey with both open- and closed-ended questions was created for online administration in June 2009. Ratings from 100 role models on Techbridge training showed the percentage of respondents who "strongly agreed" or "agreed" to the following: 98% said their confidence in doing outreach increased, 96% said their outreach experiences are more successful, and 91% reported they are likely to do more outreach because of the training. With regard to the role model guide and toolkit, 94% stated that these resources have improved the quality of their outreach, 90% said the information in the role model guide or toolkit has increased their confidence when doing outreach, and 84% stated the role model guide or toolkit has encouraged them to visit schools as a role model.

In addition, telephone interviews were conducted during the spring and summer of 2009 by our external evaluator with seven key partners who had participated in trainings and utilized the information in the *Get Involved. Make a Difference* guide. Respondents described how Techbridge supports role models and partners in ways that stand out from other groups. When asked to compare the training provided by Techbridge with other organizations they have worked with, interviewees described how Techbridge training works well for busy professionals; it is practical, efficient and a good use of partners' time. This is particularly important in an economy when companies have fewer people and less time for volunteer activities. They also mentioned the importance of the follow-up support offered by Techbridge. Regular phone calls helped keep partners on track and anticipate what would likely be successful and what might not work. Partners also noted that Techbridge staff anticipated how they could best maximize the investment of time by professionals. By purchasing and organizing material and handouts, and managing the logistics, Techbridge made the outreach much easier to conduct. The training and follow-up support gave partners the tools to do outreach, by teaching them the necessary steps for successful interactions with students. This helps to ensure the success of this and future outreach, and makes it more time and cost effective for the organization to carry out.

Impact of Outreach on Role Models and Corporate Partners
"Through the enthusiastic response of the girls, the role models rediscovered the excitement they felt when they first chose engineering. Morale at our company improved." –Mechanical engineer, Carollo Engineers

Not only do girls benefit from interactions with professionals, but we have also seen how corporate partners and role models gain from volunteering. Participating in outreach helps satisfy the desire of professionals to support the next generation of scientists and engineers. We have heard from partners that supporting girls who are part of an ongoing program like Techbridge is a productive way to accomplish this goal.

The training and resources provided by Techbridge have helped some organizations enhance their outreach, and in other cases, have helped launch their first efforts at community service. For example, the trainings provided to Google and the support we provided to help plan their outreach events in the early years have been successfully employed for hundreds of students. Techbridge training also helped Carollo Engineers launch its first-ever National Engineers Week event, and inspired the organization to continue with community outreach. In fact, the partnership with Techbridge showed Carollo how rewarding and achievable outreach can be, so much so that outreach is now a part of its corporate Sustainability Plan: sustainability in what they design, sustainability in how they do business, and sustainability in their industry by cultivating the next generation of engineers through outreach.

When outreach efforts have been embraced by an organization like Carollo Engineers, we have heard from partners how company morale is boosted and employees benefit from the opportunity to collaborate and develop leadership skills. After successful experiences, many role models are reenergized and reminded of why they chose their jobs. Outreach also helps enhance the outreach and mission of partners and promotes visibility and improves community relations of the host organization.

Challenges, Questions, and Recommendations

Getting outreach right takes time and requires commitment and resources. Role models need to make time, often outside work, to plan and conduct outreach, students need to be prepped for meeting role models, and the after-school programming community needs to embrace career exploration. The details involved in successful outreach matter and it takes a village to recognize the value of doing outreach right and to assign resources for preparation and successful execution. In the remainder of this paper, we would like to introduce food for thought—challenges, questions, and recommendations—to engage the community of after-school providers, the ITEST community, role models and their organizations, researchers, policymakers, and funders in collectively helping today's youth to embrace the study and work of computer programming, chemical engineering, and environmental science. If we don't take up the challenge of doing a better job of promoting and supporting outreach, we are missing an opportunity to support the next generation and help build and diversify the STEM workforce.

Making Time and Dedicating Resources

Having worked with a wide range of partners such as technology companies, engineering professional organizations, diversity groups, and individuals, we have offered a variety of venues for training and follow-up support that include group trainings in the evenings and weekends, on-site training during lunchtime, and webinars for just-in-time support. While some volunteers have received release time to participate in training and outreach, we have also heard from role models that it is hard to attend training or visit an after-school program because of work commitments. Having to take vacation days or add extra hours to a 40+ hour work week while juggling family obligations can make outreach a challenge to take on. How do we engage managers and CEOs and help them recognize that it is good for a company's workforce and bottom line to support outreach? How do we ensure impactful outreach when employees are so busy with work they have minimal time to plan a quality event?

Training is Essential

A computer programmer isn't expected to succeed on the job without education and support. So why expect a role model to be able to walk into an after-school program without training? For those who are new to outreach, training can eliminate some of the common mistakes we have seen like using industry lingo that goes over the heads of kids or getting wrapped up in doing activities but forgetting to discuss personal stories and provide career guidance. It is important that an organization or professional group that supports outreach also invests resources in training. While Techbridge provides trainings and webinars to its local partners and a network of professional and girl-serving groups, how do we get the word out about the importance of training and help support role models across the nation, from large corporations in urban areas to small technology companies in rural communities?

Training can also help accommodate the changes in staff that coordinate outreach at organizations. While there are frequent changes there is not always a system in place to save the knowledge institutionally or transfer the lessons learned. In part, change may be due to the fact that there is not a position dedicated to outreach and those who volunteer may feel overextended and need to pass the responsibilities to a co-worker. In some cases, the position that oversees diversity and outreach efforts is a rotating position within an organization. How can we support companies or professional organizations so that they can oversee outreach in a manner that maintains stability? How can we collectively influence policy and practice to allocate sufficient resources for training and support for outreach so that people can do it right?

Diversity Counts

When recruiting role models for a diverse after-school program such as Techbridge, it can be a challenge to find those that students can identify with. Role models from underrepresented minorities and underserved communities are themselves underrepresented in STEM careers, yet it is their life experiences that resonate with these students. Seeing a successful engineer or scientist who looks like them and who is from their community can have a significant impact on students' outlook and their ability to visualize themselves in those careers. Data on the career aspirations of students are not generally broken down by ethnicity or other demographics such as socioeconomic class or immigrant status; disaggregated data is needed to better understand what kinds of support are needed for different groups to expand their career options. In our pre-surveys in fall 2009, Latina girls were less likely than other groups to know what scientists and technology workers do, or to have talked to a scientist, engineer, or technology worker about her/his job. How do role models influence different groups of students and how do these groups make career choices?

After-school Community

After-school programs can serve as the perfect venue for introducing youth to new career options in STEM. Staff can build upon hands-on activities and work with youth before and after visits with role models to help them make the connection to careers. How can we make career exploration a priority and support professional development for the after-school workforce so that they can develop the skills to work with their partners to plan outreach that is effective and includes all the elements of our recipe for success? Who will support the professional development and fund the resources for role model visits and field trips? Techbridge staff devotes considerable time, which we believe is well spent, to working with partners to support each and every outreach event. If after-school staff works part-time or has limited capacity, how can they find the time to set up after-school visits with role models or field trips? Will this addition of time in after-school programming be recognized for what it's worth and be made a priority that warrants additional staff time and funding?

How Do We Measure our Impact?

Role models want to know that their visit to an after-school program really does make a difference. Their managers are especially interested in the bottom line if they host a field trip that requires a number of staff to plan and host. A funder wants to know that its investment is well spent. How do we know that outreach matters? In order to measure short-term impact, after-school providers need assessment tools that are easy to administer and simple to analyze. If we want to consider long-term benefits, then an investment is required to follow students over a year or longer. How can evaluators, the research community, and the after-school workforce come together to measure the impact of outreach and also identify best practices to support STEM career exploration in after-school programs?

Make a Pledge

In closing, we would like to propose tangible goals for all of us to work on as we return to our communities. On behalf of youth in after-school programs, we would like to advocate for quality after-school programming that makes technology, science, and engineering engaging for all. We would also like to recommend sustained support for outreach that transforms an interest into a career goal that is held onto long after a field trip or visit with a role model.

For Funders

Field trips to worksites require funds and training for role models takes resources, but they are well worth the investment. There is nothing like getting the chance to meet a role model who loves working with technology or seeing engineers in action to launch a dream. Ensure career exploration is a component of grants that you fund. Support professional development for the after-school workforce and training for role models so that outreach efforts are likely to inspire kids in STEM careers and have lasting impact on career aspirations. Encourage other funders to recognize the value of after-school programming and to share the lessons from this convening.

For the After-school Programming and ITEST Community

Support your staff's professional development in STEM. And, make it a priority to include experiences that give your kids a chance to try on different roles, talk about the future, and explore career options across a range of fields. Remember that it takes more than engaging hands-on activities to generate a career interest in STEM. Be on the lookout for scientists, engineers and computer programmers in your community and help them make a connection to your after-school programs. Build your staff's capacity to work with role models and develop career exploration activities so that your programs promote STEM workforce development on a regular basis.

For Corporations

Help your employees get involved in outreach. Show your interest and commitment by recognizing their time and effort in supporting the next generation of STEM workers. When a group of students visits your site, welcome them and let them know about the opportunities that await them at your site. Kids do recognize the importance of meeting a CEO and will value the experience. From the top down, it is important to demonstrate that outreach is valued. You can provide incentives like gift certificates or give your staff time during the work day to get trained and plan their outreach. The middle school group that comes to your site is the next generation of workers who may have the best new idea that revolutionizes your business.

For Role Models

Don't be afraid to get involved. You can change the life of a student with an afternoon of your time. Remember that hands-on activities are an important hook to capture the attention of students but it is your personal story and your passion for your work that students will most remember. Don't try to do it all yourself; find colleagues to share in planning and hosting events so that you don't burn out.

For Researchers

Help make the case for outreach and conduct research that can be shared with role models and corporations and demonstrate the value of their engagement with youth in after-school programs. Examine the long-term impact of role models on career plans and look at differences across groups including race/ethnicity, socioeconomic, immigrant, and first-language status.

For Public Policy Advocates

Visit after-school programs and get informed on the possibilities that after-school STEM programs have to offer in workforce development. Advocate for and influence policy and practice so that sufficient resources are available for training and support for outreach so that people can do it right.

References

Ancheta, R. (2008). *2008 Qualitative and Quantitative Longitudinal Evaluation of Techbridge*.

Countryman, J., Kekelis, L., & Wei, J. (2009*). Get Involved. Make a Difference. A Guide for Classroom Visits and Field Trips for K-12 Students.* Chabot Space & Science Center.

Csikszentmihalyi, M., & Schneider, B. (2000). *Becoming Adult. How Teenagers Prepare for the World of Work*. New York: Basic Books.

Dorsen, J., Carlson, B., & Goodyear, L. (2006). *Connecting Informal STEM Experiences to Career Choices: Identifying the Pathway*. ITEST Learning Resource Center.

Eccles, J. (2007). Where are all the Women? Gender Differences in Participation in Physical Science and Engineering (199-210). In S. J. Ceci & W. M. Williams (Eds.), *Why Aren't More Women in Science?* Washington, DC: American Psychological Association.

Engineer Your Life. A Guide to Engineering for High School Girls. http://www.engineeryourlife.org/

Ferris State University's Career Institute in partnership with the National Association of Manufacturers, the Precision Metalforming Association Educational Foundation, and the Associated Equipment Distributors Foundation. (2002). Decisions *without Direction. Career Guidance and Decision-Making among American Youth*. www.ferris.edu/careerinstitute/report.pdf

Jolly, E.J., Campbell, P.B., & Perlman. (2004). L. *Engagement, Capacity, & Continuity: A Trilogy for Student Success*. GE Foundation. http://www.smm.org/ecc/ecc_paper.pdf

Kekelis, L. S., Ancheta, R. W., & Heber, E. (2005). *Hurdles in the Pipeline, Girls and Technology Careers*. Frontiers, Vol. 26, 1, 99-109.

Liston, C., Peterson, K., & Ragan, V. (2007). *Guide to Promising Practices in Informal Information Technology Education for Girls*. National Center for Women and Information Technology.

Margolis, J., Estrella, R., Goode, J., Holme, J.J., & Nao, K. (2008). *Stuck in the Shallow End. Education, Race, and Computing*. Cambridge, MA: MIT Press.

Metz, S.S., & Samuelson, K. (2000). *Making the Connection. Presenter's Guide. Hoboken, NJ: Women in Engineering Programs and Advocates Network*. http://www.wepan.affiniscape.com/displaycommon.cfm?an=1&subarticlenbr=38

Packard, B.W., & Nguyen, D. (2003). *Science Career-Related Possible Selves of Adolescent Girls: A Longitudinal Study*. Journal of Career Development, 29, 4, 251—263.

Thom, M. (2001). *Balancing the Equation. Where are Women and Girls in Science, Engineering, and Technology?* The National Council for Research on Women.

Werner, L., & Denner, J. (2009). *Pair Programming in Middle School: What Does it Look Like?* Journal of Research on Technology in Education, 42, 1, 29-49.

STEMRAYS: Exploring the Role that Teacher Preparation and Authentic Science Research Play in OST Program Effectiveness

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Abstract

Can authentic research-based science in an after-school setting lead to students and teachers who think of themselves as scientists and as someone who knows about and contributes to science? Answering this question is the goal of STEM RAYS (Science, Technology, Engineering and Mathematics Research Academies for Young Scientists.) and has guided the University of Massachusetts and its partners in their research as they worked with over 25 classroom teachers and 800 students in the Connecticut River Valley region of Massachusetts. STEM RAYS challenges teachers to work alongside college science research faculty and engage a group of after school students in ongoing research at their school during the academic year. STEM RAYS can be an instructive model for OST science at school sites using experienced classroom teachers leading groups of students in science research clubs. Understanding and leading authentic science research is the keystone of our teacher professional development and a major strength of the STEM RAYS model. Each club has up to 12 elementary or middle school students in grades 4-8 working with one classroom teacher. Prior to the program start, teachers are trained by college faculty in their area of science research. Time is spent in these training sessions learning the basic science and in the lab learning necessary techniques. No set curriculum is provided, except for example activities to teach basic concepts. Teachers lead their clubs for one year in a science research question (or questions) connected to research of the mentoring faculty. Some have science backgrounds and most have a history of supportive and engaged relationships with students. College faculty train and mentor the teacher leaders, meet with them monthly and keep in email contact, visit the clubs several times throughout the year, host campus visits for the clubs and serve as role models for both students and teachers.

The results of our research and evaluation indicate that STEM RAYS can be an effective model for achieving both student and teacher development as scientists. Surveys asked teachers to rate their research skills, identification as scientists and understanding of the nature of science at the beginning of their involvement in STEM RAYS and again at the end of the academic year; the results showed significant gains in almost all areas. Parent studies indicate that students increased their understanding of the nature of science and the particular topics studied, increased their interest in science careers and their identification as scientists.

Issues that remain to be addressed include (1) the cost/benefit of using higher paid teachers in OST science programs, (2) long-term impacts on student and teacher interest in science and student interest in science as a career, (3) the sustainability of a college faculty driven model of authentic science research and (4) the role of student self-selection in the success of this model. It would also be interesting to compare and contrast the model of year-long, teacher–led authentic science research to kit-based or curriculum-based programs using staff with less science and classroom experience.

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Can authentic research-based science in an after-school setting lead to students and teachers who think of themselves as scientists and as someone who knows about and contributes to science? Answering this question is the goal of STEM RAYS (Science, Technology, Engineering and Mathematics Research Academies for Young Scientists.) and has guided the University of Massachusetts and its partners in their research as they worked with over 25 classroom teachers and 800 students in the Connecticut River Valley region of Massachusetts. STEM RAYS challenges teachers to work alongside college science research faculty and engage a group of after school students in ongoing research at their school during the academic year. STEM RAYS can be an instructive model for OST science at school sites using experienced classroom teachers leading groups of students in science research clubs.

Introduction and Background

In late 2006 the University of Massachusetts STEM Education Institute and Greenfield Community College received National Science Foundation support for an innovative new program called STEM RAYS (Science, Technology, Engineering and Mathematics Research Academies for Young Scientists.) The NSF grant funded after-school science and engineering programs from January 2007 through June 2009, and state funding extended the program through May, 2010. The STEM RAYS model is built around teacher-led, after school clubs that conduct original research on a particular research thread under the direction of college faculty. Each club has up to 12 elementary or middle school students in grades 4-8 working with one classroom teacher. There are approximately equal numbers of boys and girls, and minority participation mirrors the school populations. The clubs meet in the schools the children attend, avoiding the transportation and scheduling issues that arise when they are held at museums or other non-school facilities. Teachers were initially recruited after outreach with school districts and principals and were all self selected. Prior to the program start, the teachers are trained by college faculty in their area of science research. Time is spent in these training sessions in both learning the science behind the research as well as experience in the lab to learn necessary techniques. No set curriculum is provided, except for example activities to teach basic concepts. Teachers are expected to lead their clubs for one year in a science research question (or questions) that is tied to the research area of the mentoring faculty.

In the spring of 2007 ten clubs were piloted in Franklin County, one of the poorest and most rural in Massachusetts, exploring two research themes, Arsenic in the Environment and Pioneer Valley Watershed. These were led by UMass Chemistry faculty member Julian Tyson and Greenfield Community College faculty member Brian Adams, respectively. Because the National Science Foundation was piloting the concept of "Research Academies for Young Scientists", there was a formative and summative evaluation of the project and also research on teacher and student impacts.

In fall, 2007 STEMRAYS was scaled up to a full year and approximately 20 teachers operated clubs for students in 16 elementary and middle schools, impacting over 200 students. In the subsequent three years, research themes have included weather and climate, air quality, bird study, global environmental change, engineering and sustainability. Each of these themes has had one or two faculty mentors and four or five teachers who worked together for the entire academic year. After the initial training, teachers met monthly with their faculty mentor to share challenges and relay progress. Student clubs met weekly for two hours after school. In March, 2008 the project received a Massachusetts Department of Higher Education Pipeline grant to fund a continuation of the program for 2009-2010. It also enabled adding Smith College as a partner (offering engineering design as a theme), plus middle schools in Amherst and Northampton. These towns have substantial numbers of minority and low income students. With the inception of the Massachusetts Dept. of Higher Education funding, research on student content impacts was added. Formative evaluation continued as well as research on teacher impacts.

Particular attention to teacher professional development is a major strength of the STEM RAYS model. Most importantly, the teacher leader is usually an experienced teacher from the participating school. Some but not all have science backgrounds, all are paid the standard rate for sub-contracted teachers and are given one hour of preparation time per week. Each September, two Saturday workshops provide initial training by college research faculty on the research threads the teachers have selected. Subsequent monthly after school teacher meetings provide time for further training and for discussions about research progress. The professors, and in some cases their graduate or undergraduate students, provide additional help via email or visits to the schools, and host visits of clubs to their laboratories. Note that these research threads do not have a "curriculum." The college faculty mentor offers the teachers basic knowledge of the fundamental concepts and tools, and they in turn teach these to the children. The teachers and children develop the specific questions they want to address as they make observations, conduct preliminary experiments, make field studies and visit appropriate sites, gather information from the internet, etc. With the support and involvement of the faculty mentor, they engage in authentic research and grow in their understanding of the nature of scientific research. A science conference on a June Saturday at UMass for the students and families provides a forum for presenting their results in the form of displays, PowerPoints, and in some cases, hands-on activities.

Two examples of research themes, teacher approaches and student research serve to illustrate the program model.

Arsenic

Dr. Tyson is an Analytic Chemist at UMass and has spent many years working on arsenic contamination. Arsenic occurs naturally in the environment and is also introduced into water and soil by leaching of arsenic-containing herbicides and materials (such as pressure treated wood in decking, telephone poles, etc). His research interest includes arsenic testing systems that are small and easy to use in the field, especially rural areas (e.g. in Bangladesh where extensive natural arsenic contamination is destroying local water supplies). During professional development, teachers were given a crash course in chemistry and in sampling techniques. This was followed by teacher-only research projects done with close supervision by Dr Tyson. During the academic year both teachers and their students worked on research projects very closely tied to Dr Tyson's own work. At the end of the year, during the science conference, the students were able to provide several new insights into arsenic contamination and testing protocol, contributing to his body of knowledge. Research questions by teachers and/or students included the ability of vegetative matter to take up arsenic in soil, arsenic levels in rice sold in area stores, the extent of arsenic contamination in soil around telephone poles and the levels of arsenic found in hardware and commonly used household products. The arsenic research theme was a very rich classic science research approach with both teachers and students providing data and ideas to their mentoring faculty member. In most cases a club carried out only one or two projects throughout the entire school year.

Weather/Climate/Global Environmental Change

Originally led by UMass Geosciences faculty member and expert on Climate Change, Distinguished Professor Raymond Bradley (co-author of the Nobel prize winning IPCC Climate Change White Paper), the Climate and Global Change thread spanned three years with 10 teachers participating for at least one year at a time. Teachers were introduced to basic climate system content, toured the Climate Systems lab and labs of other earth scientists on the UMass campus and were provided resources such as movies, data sets and computer resources. In subsequent years, a UMass plant biologist specializing in climate impacts on invasive species was added to the team and co-PI Brian Adams of Greenfield Community College added sustainability as a thread for mentoring teachers. Unlike the Arsenic research thread above, teachers had a wide range of research topics to choose from that included a study of local weather conditions, phenology (the study of when plants leaf out or bud over time), climate change impacts on the local environment, and the efficacy of certain CO_2 reduction strategies. Students and teachers tied the research they were doing to the work of the faculty members and eventually shared their results with others in the local scientific community. For example, one group surveyed the impacts of climate change on the local maple sugar industry and this information was reported to the regional sugaring industry organization. Another team surveyed invasive plants in their town and passed the information on to their conservation commission. The interaction with Professor Bradley was a source of great pride for the students. In the year when the Nobel Prize was awarded, Prof. Bradley had to travel quite extensively to speak on the subject and the students in his research thread kept a map of his travels entitled "Where in the world is Professor Bradley". The Weather/Climate/GEC thread was a more diverse research thread and differed significantly from the Arsenic theme. Teachers guided students in carrying out a research project and in most cases there were several projects handled by small teams of students.

Program Impact

The core of the STEM RAYS model is in the use of trained and certified teachers combined with ongoing professional development in authentic science research. This contrasts STEM RAYS with other out of school time programs where club leaders may be young volunteers or informal educators; sometimes professional development occurs only at the onset and involves a set curriculum or program of activities. Many times this personnel is also new to the school with little or no connection to the administration or parent/teacher organization. The widespread use of this model is highlighted in recent evaluations of OST youth worker training and professional development. They describe programs that use mostly young, non-certified staff, mostly low paid with high turnover rates. (Bowie & Bronte-Tinkew, 2006), (Bouffard & Little, 2004). They in turn, point to the need for high quality training, better career path options and mentoring to address the inherent problems with using untrained/unskilled youth workers. Using classroom teachers can help to resolve these issues; whether it is cost effective is yet to be determined. We have found the approach warranted as using teachers from the school site also promotes a personal connection with the student participants. Often students register for the clubs precisely because of the particular teacher leader. Research on youth involvement and retention in OST bears this out. Ferrari and Turner interviewed youth in afterschool programs to find out why they joined and why they stayed in after school programs and found that the biggest factors in both cases was the relationships with the adult leader and the level of engagement with the materials and activities.(Ferrari & Turner, 2006).

Further, classroom teachers start out as experts in how children learn and in classroom management, which is very important, and they have access to the full range of facilities in the school building. In a study that analyzed 35 after school programs to show the impact of quality after school instruction on positive outcomes for disadvantaged students, the term quality was used to describe the following program inputs; supportive relationships between staff and children, evidence of rich academic support, high student engagement with program activities, leaders structure activities to maximize learning and behavioral disruptions are managed calmly and constructively. (Vandell, Reisner and Pierce, 2007). These descriptors all support the use of classroom teachers as leaders in order to positively influence student learning outcomes. Vandell, et al found that within these 35 quality programs, positive outcomes included, middle school students made significant gains in standardized test scores, had significant gains in work habits and had reductions in school based misconduct. Chaskin and Baker also support the use of both teachers and administrators as partners in the OST program as well as the importance of using schools as sites for their familiarity, safety and convenience. (Chaskin and Baker, 2006). A sidenote for STEM RAYS provided further credence to our assumptions. Two club leaders who participated and did not have prior classroom experience had great difficulty both with classroom management and with bringing a research project to fruition. Neither teacher returned after one year of participation.

Challenges in using classroom teachers as leaders include making the distinction between a class on science and an after school club about science, maintaining a high energy level at the end of a long school day, willingness to try new approaches to teaching science, and, perhaps, the higher cost associated with hiring professional teachers.

Participating in authentic science research spanning the academic year is also unique to STEM RAYS. Rather than provide professional development and support centered around a set curriculum or kits, teachers are provided with the essential skills necessary to carry out a long-term group-based research project. This requires a minimal level of science literacy and flexibility when working with students. The club's success depends on the teacher's willingness to facilitate and lead instead of lecturing and directing. It also means that each club and theme unfolds in dramatically different ways. Some teachers chose to facilitate a whole group research effort with students taking on special tasks within the team, others split students into small research teams based on personal interest and still other teachers allowed each student to explore a research question on their own. In almost all cases students and teachers worked together to formulate a research question to test and the questions usually connected in some way with local conditions or personal interest. At the close of the year, all students and their teachers present their results at a Science Conference held at UMass that is also attended by their parents and faculty mentors.

Due to favorable funding decisions at the federal and state level STEM RAYS has enjoyed considerable longevity in the communities it serves. We now have more than 25 students who have participated in the program for 3 or more years. Many students who leave a K-5 or K-6 school sign up to participate at the middle school, something we find very encouraging since both the teachers and research themes will change at that level. We have also been successful in retaining teachers, with only a small handful of teachers not continuing, and usually because of changers in their personal circumstances. These factors will make evaluating long term effectiveness more straightforward and have contributed to a high level of parental and student support.

Research and Evaluation Results

Results of our research and evaluation indicate that STEM RAYS can be an effective model for achieving both student and teacher development as scientists. We see this by examining outcomes from two sources, the outside summative evaluation done by SageFox Consulting Group and project research under the direction of STEM RAYS co-PI Prof. Allan Feldman. Data sources included teacher interviews and surveys; reviews of session reports; observations of research group meetings, workshops, club meetings, and the annual research conference; student surveys, focus groups, and pre- post-tests; and parent and administrator surveys.

Teacher Impacts

Teacher goals included:

1. increasing teachers' understanding of the process of doing scientific research
2. improving the ability of the teachers to engage students in scientific research
3. exposing teachers to new instructional methods
4. increasing teachers' knowledge of science content

The teacher goals were evaluated through interviews, survey instruments, and observations of club meetings. Interviews of the teachers, analysis of the session reports and observations of the clubs indicated a large and rapid growth in the teachers' abilities to understand the processes of science and to engage students in scientific research (teacher goals 1 & 2). In addition, for the majority of teachers this was the first time that they used instructional methods that prepared the students to engage in authentic research activities (Pirog and Feldman, 2009). A survey that asked teachers to rate their research skills at the beginning of their involvement in STEM RAYS and again at the end of the academic year showed significant gains in almost all areas. Parents also reported that their children became engaged in scientific research activities (teacher goal 3). Data from the sources above also showed that the teachers learned science content (teacher goal 4).

One particular research tool that Feldman, et al., tested was the use of a new instrument called the "Nature of Science" to determine how well the project achieved the four goals above. This test asked teachers, for example;

> 1a. What, in your view, is science? What makes science or a scientific discipline such as physics, biology, etc. different from other disciplines of inquiry (e.g., religion, philosophy)?
>
> 1b. Do you expect your students to learn what science is and how it differs from other forms of inquiry? Yes or no.
>
> 1c. If yes, describe how you help your students learn what science is and how it differs from other forms of inquiry.

Feldman summarized the results as follows, (Feldman and Pirog, 2009). "Overall we found that the teachers increased their knowledge of science content and methods, they increased their comfort with open-ended science projects, and they reduced their reliance on pre-packaged science activities and worksheets. The teachers were also more likely to discuss their research projects and findings in scientific terms and language when in their group. This could be seen, for example, in their talk about how to use specific equipment, such as Hach test kits and probe ware, to measure arsenic concentrations, temperature, pH, and other quantitative data In summary, we have found that:

1. There has been little change in teachers' beliefs about NOS.
2. However, teachers' reasons for their beliefs have changed – they now have more of an emphasis on science as an empirical activity.
3. The teachers' descriptions of the ways they teach the NOS changed.
4. They report an increased use of inquiry activities.
5. They report an increase in their use of references to the work of scientists.
6. A web-based, open-ended survey can provide usable information about teachers' beliefs about the NOS."

The evaluation performed by the summative evaluator, SageFox Consulting, had this to say. "When asked to cite the areas in which the program had the largest positive impact, the following came out as the most important results (along with percentage of respondents citing them as important):

- Encouraged new ways for students to think about science (100%)
- Increased student interest in science (75%)
- Increased teacher interest in doing authentic scientific research (75%)
- Heightened institutional awareness of STEM RAYS (75%)
- Increased teacher interest in reading about science (75%)
- More students were interested in joining the program than were originally accepted (68%) Increased teacher interest in pursuing future professional development activities (63%)"

Student Impacts

STEM RAYS student goals included:

1. stimulating interest among students in grades 4-8 in science careers
2. providing challenging educational experiences in science
3. increasing students' appreciation of the role that the sciences play in the world
4. increasing students' knowledge of science content

Student goal 1 was evaluated using students' responses on a pre-posttest, and with teacher, parent and administrator surveys administered by SageFox. The pre-posttest data showed little change in students' choice of potential careers (Feldman and Pirog, 2009a). However, the teachers and parents observed that participation in STEM RAYS increased students' interest in science (SageFox, 2009). SageFox reported that "Parents consistently noted an increased interest and understanding of important environmental questions" and that "There were numerous comments about students' increased interest in studying particular scientific disciplines in college and pursuing careers in science." Administrator surveys also indicated an increase in students' interest in science.

Student goal 2 was evaluated using observations of club activities by project staff and the research assistant, teachers' session reports of club activities, and the parent and administrator surveys administered by SageFox. The observations found that teachers consistently engaged the students in challenging science activities. At the beginning of the academic year, the activities focused on preparing students to engage in science research by introducing them to the content and context of the research theme and by teaching them research skills. The focus then shifted to the development of research questions. During the final part of the year, students and teachers collected and analyzed data, and prepared their reports and posters for the STEM RAYS Annual

Research Conference (Pirog and Feldman, 2009a). Parent and administrator surveys also noted the value of these hands-on experiences (SageFox, 2009).

Student goal 3 was evaluated primarily using teacher and parent surveys. Both surveys indicated that students increased their understanding of the role of science.

Student goal 4 was evaluated through the use of pre- and post- content tests in year 3, analysis of student products, and parent surveys. The content portion of the pre- and post-tests was specific to each of the year's themes: birds, engineering, global environmental change, and sustainability, and was developed collaboratively with the teachers and researchers in the theme group. Statistical tests of significance on the content questions showed significant gains in content knowledge.

Two other measures of student interest are attendance and the number of applicants; absences have been uncommon except for conflicts with sports teams or medical appointments, and many schools have had to select students using lotteries or schedule multiple groups. We have funded a second club in some schools, and two schools currently have a third club funded by the school itself. Students frequently return for a second, or in some cases, a third year of participation. Some students attended the summer programs in addition to participating in the school year clubs.

Further Research / Unanswered Questions

Further study to determine long term impacts and a deeper understanding of the program's influence will be the focus of future research if supplemental funding is obtained. Questions such as: "Does a program like STEM RAYS achieve its objectives *in the long term?"* will guide this effort. The importance and difficulty of evaluating the impact of out-of-school-time (OST) programs was stressed recently at an NSF funded conference, *Out-of-School-Time STEM: Building Experience, Building Bridges (Bridges)*, October 19 & 20, 2009. It was also highlighted in the recent National Academies of Sciences report, *Learning Science in Informal Environments: People, Places, and Pursuits (LSIE)* (National Research Council, 2009) and by the NSF *Framework for Evaluating Impacts of Informal Science Education Projects (Framework)* (Friedman, 2008). In particular, both documents targeted longitudinal studies as a high priority. The LSIE report proposed a six strand framework of science learning that articulates science-specific capabilities supported by informal environments. Learners in informal environments:

> *Strand 1: Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world.*
>
> *Strand 2: Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science.*
>
> *Strand 3: Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world.*
>
> *Strand 4: Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena.*
>
> *Strand 5: Participate in scientific activities and learning practices with others, using scientific language and tools.*
>
> *Strand 6: Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science.*

References

[1] Bowie, L. & Bronte-Tinkew, J. (2006). The Importance of Professional Development for Youth Workers. *Reseach to Results, Practitioner Insights*. #2006-17

[2] Bouffard, S. & Little, P.M.D. (2004). Promoting Quality Through Professional Development, A Framework for Evaluation. *Issues and Opportunities in Out-Of-School Time Evaluation*. Harvard Family Research Project. #8.

[3] Ferrari, T.M. & Turner, C.L. (2006). An Exploratory Study of Adolescents' Motivation for Joining and Continued Participation ina 4-H Afterschool Program. *Journal of Extension*, 44-4.

[4] Vandell, D.L., Reisner, E.R. & Pierce, K.M (2007). Outcomes Linked to High-Quality Afterschool Programs: Longitudinal Findings from the Study of Promising Afterschool Programs. *Child Trends*. Atlantic Philanthropics.

[5] Chaskin, R.J. Baker, S. (2006). Negotiatin Among Opportunity and Constraint, The Participation of Young People in Out-of-School-Time Activities. *Chapin Hall Working Paper*. Chapin Hall Center for Children at University of Chicago. CS-132.

[6] Pirog K. & Feldman A. (2009) Transition: From Science Teacher to Scientist. Annual Meeting of the Association of Science Teacher Education. 2009. Hartford, CT.

[7] Feldman, A. and K. Pirog, 2009. The Nature of Science in Afterschool Science: The Development of Two New Instruments. *Annual meeting of the National Association for Research on Science Teaching*. 2009. Garden Grove, CA.

[8] Feldman, A.(2009) *STEM RAYS Final Research Report*.

[9] SageFox Consulting Group 2009, *STEM RAYS Year 3 Evaluation Report*. SageFox Consulting Group: Amherst, MA.

[10] 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, Editors. Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

[11] Friedman, A. (Ed.), 2008. Framework for Evaluating Impacts of Informal Science Education Projects, http://insci.org/resources/Eval_Framework.pdf

Planning for Scaling and Sustaining Afterschool STEM Programs

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Abstract: This paper develops a sustainability framework for afterschool STEM programs. The framework draws primarily from research on supports needed to scale and sustain innovative programs in schools. It also addresses challenges to and strategies for promoting sustainability unique to the afterschool context. The framework highlights that, to achieve implementation depth and program evolution, programs must be designed with usability in mind. Designers must consider up front the capacity of the organizations that will be implementing the program. We present illustrations of five successful strategies afterschool STEM programs have used to achieve scale and sustain themselves: (1) achieving depth through co-design; (2) achieving spread through partnerships; (3) developing ownership from the beginning rather than transferring ownership; (4) sustaining programs through professional development infrastructure; and (5) developing and aligning frames to allow programs to evolve. This paper concludes with a call for developing credible plans for sustainability in program proposals and for more research on scaling and sustaining afterschool programs.

Most STEM afterschool programs begin with innovation plans and funds for a single project. That project supports development, implementation, and sometimes a limited amount of dissemination. At some point, all projects face the question of how to grow and sustain the program. After school programs where projects are implemented often have limited capacity to sustain programs on their own given high turn over in staff and the costs of continuing the program. This lack of capacity may be intensified if staff lacks STEM knowledge needed to understand concepts, discern important learning goals, and effectively enact curricula. As a consequence, many high-quality projects in informal science education do not last beyond the grants that fund their development.

Education research has articulated the features for scaling and sustaining innovations in schools (Coburn, 2003; Schneider, 2007; St. John, 2003), even focusing on the sustainability of science programs in school (Fishman & Krajcik, 2003; Blumenfeld *et al*, 2000). Missing from the informal science research field are models for how programs in the innovation phase of a first project can plan and prepare for scaling and sustainability. Just as the absence of a clear plan for implementation and scaling hampers efforts to scale STEM innovations in schools (Confrey, Lemke, Marshall, & Sabelli, 2002; McLaughlin & Mitra, 2001), so too does the absence of such plans for afterschool programs.

A key idea we present here is that developers should imagine the innovation as unfolding in multiple stages that anticipate and prepare for the challenges of becoming a scalable, sustained program. Rather than leaving thinking about sustainability and dissemination plans until after a program design has been articulated, scale and sustainability plans should be integral to the conception of the innovation. Policymakers and funders can encourage these plans for the sustainability and scalability of these innovations in order to help build a strong infrastructure for STEM afterschool programs.

Establishing a Sustainability Framework
Frameworks for scaling and sustaining school-based innovations provide insights for developers of afterschool STEM programs as they plan the stages of their innovation through sustainability and scaling. Coburn (2003) outlined four interrelated dimensions for scaling and sustaining education innovations--depth, spread, shift, and sustainability--and Dede (2007) added a fifth dimension to Coburn's framework: evolution. Together, these five dimensions highlight specific areas that can be thought of sequentially by developers as well as collectively as they can reinforce one another. *Depth* refers to the impact of the innovation on youth learning and educators' practice. Coburn (2003) states: "reform must effect deep and consequential change." *Spread* is the traditional notion of scale: the spread of a reform to a greater number of afterschool sites. *Shift* in innovation ownership requires that practitioners responsible for the implementation, not developers of the innovation, have full authority for the innovation, including ongoing support, professional development and future implementations. *Sustainability* means maintaining the depth of the program (and allowing for acceptable adaptations) over time under less than ideal conditions. *Evolution* of the innovation for sustainability involves three types of innovators: developers, researchers and practitioners. Practitioners' implementation influences future research and development. Evaluations and assessment tools that

informed the original innovation for all three types of innovators can help practitioners to adapt and evolve the innovation as well as provide data for seeking funding for the sustained program. Evaluation plays multiple roles in the scaling process (Harvard Family Research Project, 2010).

Cutting across all five of these dimensions, researchers at the University of Michigan (Blumenfeld et al., 2000; Fishman & Krajcik, 2003) developing science curricula have identified usability of the innovation—by teachers, students, and administrators—as key to the sustainability of an innovation in schools:

> If an innovation is "usable," this means three things: (1) that the innovation is adaptable to the organization's context, (2) that the organization is able to enact the innovation successfully, and (3) that the organization is able to sustain the innovation. (Fishman & Krajcik, 2003, p. 565)

These researchers note that the innovation is more than the curriculum materials; part of the innovation is the understanding, building, and planning for ongoing support of the capacity of the organization to implement effective science curricula. The curriculum materials must be usable by the audience, but often the capacity of the organization needs to be increased in order to use the program. Other researchers of in-school science learning have noted the importance and interplay of both the usability of the curriculum and the building of the organization's capacity to offer the curriculum (St. John, 2003; Cohen & Ball, 1999). This capacity refers not only to the capabilities of the educators but alignment with the organization's culture and policy and management's initiatives (Blumenfeld et al., 2000; Fishman & Krajcik, 2003).

In this paper, we construct a sustainability framework that draws upon research on the sustainability of in-school science curriculum innovations but that also addresses challenges to and strategies for promoting sustainability unique to the afterschool context. These examples from the field of afterschool science learning include lessons learned from several afterschool programs and from our own work on Build IT, a collaboration between SRI and Girls Inc., a national organization that reaches more than 800,000 girls in K-12 each year. Build IT is supported with funding from NSF's ITEST and the Noyce Foundation and is an after school and summer youth-based curriculum for middle school girls to develop IT fluency, increase their interest in taking mathematics and computer science courses, and encourage their pursuit of IT careers. Evaluation data from the Build IT program's development, implementation, and scaling successes and challenges over the past five years in the Girls Inc. network of affiliates indicates a process for achieving scale and sustainability of informal science learning programs in afterschool settings (Koch *et al*, 2010).

Achieving Depth through Co-Design

To achieve 'deep and consequential change' in afterschool STEM learning, our experience and research point to a co-design process in which developers from the learning sciences and youth development collaborate to develop a learning science-rich curriculum that fits well in a youth development environment. At first glance, engaging in co-design as a means to achieve sustainability may seem counter-intuitive:

collaborating with practitioners takes time, agreement on curricular goals and how to achieve them, and a structured process for iterating. Yet co-design, in which developers lead a highly-facilitated, team-based process with practitioners to design and implement prototypes of the innovation, can help develop greater ownership over designs, strengthen STEM content, and make it more likely that designs will be usable in real settings (Penuel, Roschelle, & Schectman, 2007).

An example of a project that is employing co-design to develop powerful STEM afterschool programming is the NSF-funded Science Learning through Science Journalism (SciJourn) Project. This project aims to apprentice students to the practice of science journalism. The project's strategies are being developed by a partnership among education researchers, science journalists, teachers, and youth development staff at a local science museum. The perspectives and expertise of researchers, science journalists, and educators is incorporated into the program. In particular, the museum youth development staff's expertise in the museum space for learning and the needs of the participants helped to strengthen engagement in the STEM content and fit with the museum's program offerings.

In Build IT, SRI's and GIAC's philosophies and pedagogical approaches from the learning sciences and youth development, respectively, met in the development of a constructivist, problem-based curriculum that provides youth with hands-on experiences that are not solely computer based but enable youth to use their bodies, creativity energy, and visual representations to act out computational approaches to solving problems and designing the world around them. Build IT incorporated two main processes for developing a robust curriculum: identification of learning goals and how to achieve them using *Understanding by Design* (Wiggins & McTighe, 1998) approach and an iterative co-design process between SRI (learning sciences) and Girls Inc. (youth development). The co-design process allowed constant checking of the program's usability for youth and youth development leaders. These processes enable curriculum features, such as embedded assessments and Eccles' Expectancy Value Model (Eccles, 2009) for STEM workforce learning and interest, to have compatible qualities of both the learning sciences and youth development that encourage sustainability in the youth development environment: the youth development approach is visible and learning goals, assessments, and activities are articulated in a language consistent with youth development.

Using a co-design approach for both the curriculum and professional development has provided a systematic way to approach usability and capacity building in Build IT. In our scaling experience, the curriculum first appeared daunting to many of the affiliates. The professional development structure and ongoing supports were critical to getting over this hump. The evaluation of the scale up also showed some consistency in what each affiliate struggled with the first year of implementation: the mathematics and securing IT professional visits. Most sites were able to overcome these hurdles by the second year with the curricular and professional development supports provided by the Girls Inc. national office.

Achieving Spread through Building Partnerships

For spread or scaling of an innovation to occur, the innovation must influence the norms and principles, such as policies, curricula enactment, and professional development within the organization (Coburn, 2003). The proven impact of the innovation, ease of use, and fit with the organization are critical factors in achieving scale. Partnerships can support and reinforce these factors with the organization implementing the innovation.

For example, The John W. Gardner Center for Youth and their Communities at Stanford University partners with communities to improve youth development programming at a systemic, organizational, and individual level. Its partnership with the community of Redwood City, California, now spans over 10 years and multiple projects that evidence a shared commitment to working together to improve the lives of young people in that community beyond the life of a single grant. What sustains the work, which spans projects in schools, community-based organizations, and local government agencies, is a shared commitment to the partnership, its goals, and recognition that the work of community change takes time. The role of the researchers in the partnerships has been to provide data and analytic support that can inform community members' questions about how best to improve youth outcomes across the multiple institutions of the community.

A report on the sustainability of 21^{st} Century Community Learning Centers (21CCLC) by The Finance Project (2006) also highlights the importance of partnerships. Grantees emphasized that partnerships are essential for long-term sustainability, specifically partners that have shared goals, clear roles in program development and refinement, and credibility with funders. Partnerships also have the potential to expand the capacity of programs to coordinate educational and social services many young children living in poverty need, so that afterschool programming can be as effective as possible (de Kanter, Adair, Chung, & Stonehill, 2003).

The importance of partnerships for the scaling of a program is also evident in Techbridge, a program that has encouraged more than 2500 middle and high school girls in science, technology, and engineering learning and career exploration over the past 10 years. Techbridge, developed out of the Chabot Space & Science Center in Oakland, CA, has cultivated ongoing partnerships with schools, parents, teachers, STEM organizations, and afterschool programs. The partners provide feedback and research data to Techbridge in order to continue to improve the program and refine its fit with these organizations.

For Build IT, the work began with key partnerships among SRI International, bringing expertise in information technology and the learning sciences, Girls Incorporated of Alameda County, CA, a Girls Inc. affiliate that brought expertise in youth development and a strong youth development program in which to develop the innovation, and Girls Inc., the national office for the more than 150 Girls Inc. affiliates nationwide that could provide professional development and scaling support for its network of affiliates. As part of the Build IT curriculum, girls meet and engage in hands-on activities with women STEM professionals in order to encourage their interest in STEM learning and careers. Embedded in the Build IT program is guidance for youth development organizations on how to foster ongoing relationships with these STEM professionals and their organizations. This strategy for establishing ongoing partnerships with the local STEM community, as well learning scientists and STEM experts, has the potential to keep the program current with STEM changes, rather than insular to the one organization implementing it, and attract new funding opportunities.

Developing Ownership from the Beginning Rather than Transferring Ownership

During the initial stages of design, typically curriculum developers and researchers drive improvements to designs. External grant funding typically supports the work to revise initial designs to reflect what developers are learning from testing them in programs. When the grant ends, however, there may be no additional revisions to designs, since follow-through depended on funding the time of developers and researchers. To sustain the ongoing revisions needed to keep designs fresh and responsive to learners' interests and needs, projects need to transfer ownership to practitioners for revision before the grant ends.

One way to shift ownership for continuous improvement is to build processes for revising learning activities into designs themselves. Japanese lesson study (Lewis, Perry, & Hurd, 2004; Lewis, Perry, & Murata, 2006) is an example of such a design that targets instructional improvement in schools. The design is itself structured as a process of continuous improvement: teachers develop a lesson targeting specific knowledge and skills, teach it in front of colleagues who are part of the lesson study team, and then revise the lesson on the basis of feedback from the whole team. It offers what has been called a "local route" to scaling (Lewis, et al., 2006), since the model requires every local team to engage in lesson design and revision, in ways that reflect local goals for student learning. The process of engaging in lesson study, while intensive, often builds a level of ownership necessary for improving designs.

A related strategy is to build mechanisms of assessment into learning activities that provide learners with feedback that they can use to guide their own learning, and give program leaders evaluation tools to see and make modifications to the curriculum as needed. Many arts-based after-school programming organize opportunities for youth to plan and manage collaborative activities and to modify their performances or products on the basis of external review and critique (Heath, 2001; Heath & Roach, 2000; Soep, 1996). Feedback from professional artists and from older youth creates an atmosphere of challenge and collaborative critique in which young artists learn to question their own work (Heath & Roach, 2000). The practice of critique is also characteristic of the work of professional software engineers in their design activities, a practice that has been adapted and modified in the Build IT program with much success. In Build IT, youth have frequent opportunities to give each other feedback on their designs as well as show themselves, their peers, youth program leaders, families, and their communities what they know and can do.

Sustaining Programs through Professional Development Infrastructure

Professional development supports play a key role in sustaining a program. As programs move towards sustainability, resources for professional development and other assistance to facilitate implementation often dissipate, especially for programs attempting to achieve scale as well as sustainability (Coburn, 2003). In youth organizations, turnover is high.

Organizations may train staff to implement a program one year, only to lose those staff the next year. That organization may not have the capacity to implement the program anymore, unless it has a process for inducting new staff to support specific programs and providing opportunities for ongoing professional learning.

A strategy some programs have employed is to share professional development responsibilities with sites from the beginning. In the Build IT project, a program manager, who supervised the staff implementing the program, worked side-by-side with the Principal Investigator and her staff from SRI to design and deliver professional development. With the first implementation of a Build IT unit, SRI led the professional development; the second implementation, SRI and Girls Inc. co-led the professional development. By the third implementation, Girls Inc. led the professional development, inducting staff new to the organization into the program.

The Build IT program is successful in part because ongoing professional development is part of the Girls, Inc. infrastructure – at each affiliate and nationwide. Like many other youth-serving organizations, affiliates experience frequent turnover in program staff but also have a relatively stable core of program managers who supervise these program staff. At the national level, Girls Inc. provides affiliates with professional development on many of their programs, including Girls Inc.'s Operation SMART™ (Science Math and Relevant Technology) Girls Inc. is comfortable providing professional development for STEM programming and includes Build IT in its suite of Operation SMART™ programs. Girls, Inc.'s ability to provide professional development through its own staff, as well as its national infrastructure for curricular innovation and implementation, make it a youth-serving organization with strong capacity to sustain innovations that fit within its mission and rely on this infrastructure.

Developing and Aligning Frames That Allow a Program to Evolve

A single project that initiates a cycle of program development typically presents a single "frame" to a potential funder, in order to win support for the project. The term frame draws from the writings of Goffman (1974) and from social movement theory (Snow & Benford, 1988); it refers to a specific definition of a problem to be solved, a path to its solution, and a rationale that makes the solution a compelling one to the audience. The need for a youth program related to science and technology program, for example, might be defined in terms of the need for more widely accessible pathways into STEM careers for youth of color, or in terms of the need for a more compelling entry point into engineering careers for women. The solution proposed is typically a curriculum, a program, or a design for professional development, and the rationales include appeals to past work and expertise that make the developers the right team.

A proposal frame is rarely enough to sustain a program across multiple projects or to convince new groups to fund new development related to the program or to implement it in new settings. A key task for sustainability is to develop multiple frames that establish congruence among the frames for defining problems that funders and implementers may bring. This activity of aligning frames cannot be simply "chasing the money," but rather must be a genuine bridging or extension of activity in ways that allow for the program to be shaped, grow, and even transform, as it moves to a new context.

A strategy that selected institutions and teams often use to develop an understanding of a problem across multiple projects is to conceptualize a "program of research and development" that guides their activity. Two successive projects involving a partnership between the Santa Fe Institute (SFI) and Santa Fe area schools focused on exploring how modeling and participatory simulation tools can help students learn about complex systems. The first project involved a partnership with software developers and researchers at the Massachusetts Institute of Technology; it built capacity of staff at SFI in educational outreach and among local teachers to help students build models of complex systems. With this solid foundation, the local team, led by SFI, pursued a second grant that did not include the MIT researchers and that shifted the focus to after school programming. Because of the enduring involvement of local schools in the partnership, the second project was able to offer unique opportunities to students, such as receiving school credit for participating in afterschool programs.

For Build IT at scale, the frame for funding varies according to the affiliate and its surrounding community's needs and resources. Build IT has shown to be a fundable program in many locations, even acting as a marketing tool to fund programs in addition to Build IT. At the national Girls Inc., national funding frames are used. Evaluation data captured at the local and national levels through evaluation and assessment tools developed in the project support the evolution of the program for learning as well as providing important data for future funding.

Directions for Research for Improving Sustainability

Designing for sustainability requires that we anticipate from the earliest stages of innovation development and beyond initial funding the following: the contexts of use and usability of the innovation in that context, the organization's capacity to support implementation in those contexts, and the types of future contexts.

The process can begin with careful attention to developing plans for dissemination and sustainability. Such plans require more than plans for sharing what is learned with relevant communities of practice and more than a strong institutional partner that makes a promise to sustain the program on its own. It requires a well-specified theory of implementation that delineates roles and responsibilities for implementation and a plan to conduct research on implementation that identifies the strengths and weaknesses of the program as well as the frequently invisible work required to sustain programs. The work of supporting programs is ongoing; making visible the scope and nature of that work during the life of the program can help programs better plan for sustainability. Programs need to consider business models for continuing to sustain an innovation's ongoing implementation, and when appropriate, plans for building research programs to support the innovation's evolution in ways that carry across multiple projects.

Research on implementation activities and sustainability can contribute toward a "science of broader impacts," that is, a knowledge base for how programs can achieve broad reach, especially among underrepresented communities. At present, many programs consider the heart of their contribution to science in terms of the teaching and learning growth that can be accomplished under conditions of high support from researchers. We hope that programs will begin to consider the science of sustainability as an equally worthy goal for knowledge building in the field.

Discussion Questions

1. How must these frameworks developed for innovations in schools (i.e. Coburn and Dede's *Scaling Framework* (depth, spread, shift, sustainability, evolution); University of Michigan researchers' sustainable science curriculum innovations through usability and capacity building) be adapted for afterschool programs? Is there something missing in these views for the afterschool?

2. What do afterschool science programs that do last have in common?

3. Based on this whitepaper, what advice do we have for policymakers in developing an infrastructure that supports the maturation of innovations into sustainable programs?

    2a. What advice do we have for implementers? (informal learning organizations)

    2b. What advice do we have for researchers of these environments?

References

Blumenfeld, P., Fishman, B. J., Krajcik, J., Marx, R. W., & Soloway, E. (2000). Creating usable innovations in systemic reform: Scaling-up technology-embedded project-based science in urban schools. *Educational Psychologist, 35*(3), 149–164.

Coburn, C. E. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. *Educational Researcher, 32*(6), 3-12.

Cohen, D. K., & Ball, D. L. (1999). *Instruction, capacity, and improvement (CPRE Research Report Series RR-043)*. Philadelphia, PA: University of Pennsylvania Consortium for Policy Research in Education.

Confrey, J., Lemke, J. L., Marshall, J., & Sabelli, N. (2002). *A final report on a conference on models of implementation research within science and mathematics instruction in urban schools*. Austin, TX: University of Texas, Systemic Research Collaborative for Education in Mathematics, Science, and Technology.

Dede, C. & Rockman, S. (Spring 2007). Lessons learned from studying how innovation can achieve scale. *Threshold*. Washington, D.C.: Cable in the Classroom.

de Kanter, A., Adair, J. K., Chung, A.-M., & Stonehill, R. M. (2003). Ensuring quality and sustainability in after-school programs: How partnerships play a key role. *Yearbook of the National Society for the Study of Education, 102*(2), 201-220.

Eccles, J. (2009). Who am I and what am I going to do with my life? Personal and collective identities as motivators of action. *Education Psychologist, 44*(2), 78–89.

Fishman, B., & Krajcik, J.(2003). What does it mean to create sustainable science curriculum innovations? A commentary. *Science Education, 87* (4), 564-573.

The Finance Project (2006). *Sustaining 21st century community learning centers: what works for programs and how policymakers can help.* Washington, D.C.

Goffman, E. (1974). *Frame analysis: An essay on the organization of experience*. Boston, MA: Northeastern University Press.

Harvard Family Research Project. (Spring 2010). *The evaluation exchange*. *XV*(1). Boston, MA: Harvard Graduate School of Education

Heath, S. B. (2001). Three's not a crowd: Plans, roles, and focus in the arts. *Educational Researcher, 30*(7), 10-17.

Heath, S. B., & Roach, A. (2000). Imaginative actuality: learning in the arts in the non-school hours. In E. B. Fiske (Ed.), *Champions of Change: the impact of the arts on learning* (pp. 20-34). Washington, DC: The Arts Education partnership and the President’s Committee on the Arts andHumanities.

Koch *et al*. (January 2010). *Pilot scaling of Build IT: Girls developing information technology fluency through design*. Final reports to National Science Foundation and The Noyce Foundation. Menlo Park, CA: SRI International.

Lewis, C. C., Perry, R., & Hurd, J. (2004). A deeper look at lesson study. *Educational Leadership, 61*(5), 18-22.

Lewis, C. C., Perry, R., & Murata, A. (2006). How should research contribute to instructional improvement? The case of lesson study. *Educational Researcher, 35*(3), 3-14.

McLaughlin, M. W., & Mitra, D. (2001). Theory-based change and change-based theory: Going deeper, going broader. *Journal of Educational Change, 2*, 301-323.

Penuel, W.R., Roschelle, J. & Shechtman, N. (2007). Designing formative assessment software with teachers: An analysis of the co-design process. *Research and Practice in Technology Enhanced Learning*, *2*, *1*, 51-74.

Schneider, B., & McDonald, S.-K. (Eds.). (2007). Scale-up in Education: Issues in Practice (Vol. 2). New York: Rowman & Littlefield Publishers, Inc. Snow, D. A., & Benford, R. D. (1988). Ideology, frame resonance, and participant mobilization. *International Social Movement Research, 1*, 197-217.

Snow, D. A., Rochford, E. B., Jr., Worden, S. K., & Benford, R. D. (1986). Frame alignment processes, micromobilization, and movement participation. *American Sociological Review, 51*, 464-481.

Soep, E. (1996). An art in itself: Youth development through critique. *New Directions for Child Development, 12*(4), 42-46.

St. John, M. (2003). The legacies of the LCSs. *Third Annual Conference on Systemic Reform.* Retrieved on April 23, 2010: http://sustainability2003.terc.edu/do.cfm/247/show

Wiggins, G., & McTighe, J. (1998). *Understanding by Design*. Alexandria, VA: ASCD.

Broadening Assessment Possibilities in the Afterschool

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Abstract

This white paper discusses some of the key difficulties in assessing learning in the out-of-school time settings, focusing on afterschool programming designed to engage students with STEM concepts and practices. The paper notes the importance of assessing learning in afterschool environments in ways that can meet the criteria for informal STEM assessment set forth in the recent NRC volume on informal science learning. The authors outline a three-part typology of assessment types for consideration in relation to afterschool STEM and describe an approach through which *naturalistic assessment* practices—participants' own on-going judgments of who can do what—can be leveraged to serve the learning, programmatic, and documentation goals of afterschool programs. The authors also posit that the development of an afterschool research agenda with serious implication for STEM workforce development has to take into account the importance of STEM learning practices and outcomes that extend beyond traditional notions to target interest, identity, and the symbolic and experiential potency of being a legitimated participant in STEM-related activities. Overall, we offer that the appropriate assessment approach for the afterschool should function naturalistically as part of the learning practices that advance participants along trajectories towards outcomes that serve personal and social needs and simultaneously should allow for documentation sufficient to capture the strengths and successes as well as the points of improvement needed to improve programs and better support their participants.

The Challenge

Assessment in the afterschool needs an approach distinct from typical school measurement practices. The recent NRC report *Learning Science in Informal Environments: People, Places and Pursuits* (Bell et al., 2009) and other publications (Allen 2002; Allen, Gutwill, Perry, et al. 2007; Falk & Dierking 2000; COSMOS Corporation 1998; Leinhardt & Knutson, 2004; Martin 2004; Michalchik & Gallagher, 2010; Pekarik, 2010) point to many of the issues associated with assessing learning in informal settings, particularly as these pertain to out-of-school STEM learning environments. A general consensus across the literature as we read it (see, for example, Bell et al., 2009: 76-78), is that out-of-school assessments should:

(1) Fit within the social, behavioral, and learning-related norms of the setting

(2) Account for participants' own goals and initiatives, and

(3) Provide valuable feedback for developmental and learning trajectories.

At the same time, researchers in the field of informal learning have highlighted the need to think broadly about outcomes—beyond the traditional categories of knowledge and skills. For example, building on the four key categories of outcomes defined in its earlier volume, *Taking Science to School* (NRC, 2007), the NRC offered an expanded view of STEM learning outcomes in its consensus report on informal learning (Bell et al., 2009). This more recent volume presents evidence for learning along six strands of outcomes that include scientific interest, understanding, skills, awareness, agency, and identity.

Concerned with both the nature of the assessment practice and the targeted outcomes, the NRC report offered the recommendation that:

Researchers and evaluators should use assessment methods that do not violate

> participants' expectations about learning in informal settings . . . [and should] address the science strands, provide valid evidence across topics and venues, and be designed in ways that allow educators and learners alike to reflect on the learning taking place in these environments (2009, 310).

In our white paper, we address the key points within this recommendation by describing an approach to assessment that can capitalize on particular ongoing and ordinary practices common in afterschool settings. By leveraging these *naturalistic assessments*, we can potentially assess learning in afterschool programs in ways that comply with the criteria set forth above—ensuring that the norms of the setting are maintained, the goals of participants are accounted for, and that the assessments support participants along a learning trajectory.

Developing innovative approaches to documenting learning is especially important at this time of increasing interest in and scrutiny of informal STEM learning environments from policymakers (Bartels, Semper & Bevan, 2010). Without practical and meaningful approaches to showing what is being learned in their programs, afterschool STEM providers can be hindered in their efforts to improve programs and demonstrate the value of their programs to policymakers and other stakeholders, risking serious set-back at a time of particular promise for the field.

A Typology[1] for Characterizing Assessments

In order to clarify what we mean by naturalized assessments, the authors of this white paper propose categorizing the universe of assessments into three primary types:

1) *Activities specifically designed by evaluators to primarily be assessments, whether they are administered apart from curricular learning activities or embedded within them.* Examples here include formal tests, as well as interviews and surveys by evaluators.

Type 1 assessments are specialized activities specifically designed to elicit information

[1] A version of this typology is presented in Michalchik & Gallagher (2010).

about knowing and learning, and participants are generally aware of the activity's primary purpose. Type 1 assessments are also characterized by a strict asymmetry of power relations – program authorities are conducting an evaluation of program participants' knowledge.

2) *Assessments derived from an outsider's analysis of ongoing, ordinary activity.* One example would be an evaluator collecting digital artifacts created by youth in an afterschool setting and analyzing them to determine the degree and nature of the technology skills developed. Type 2 assessments are characterized by a) participants engaging in naturally occurring activities (activities that were not specifically designed for assessment purposes), and b) cases in which judgments about knowledge and capabilities are made by external observers.
3) *Participating persons' own in situ assessment of one another's capabilities, within the frame of ordinary activity.* For this type, participants might identify the most knowledgeable choir member who could help them in learning a vocal part. They might spontaneously create peer commentary on the technological skill of a child designing a computer game. Type 3 assessments are characterized by naturally occurring activities (as in Type 2), but where the primary judgment of ability is made by participants as a seamless part of their ordinary, on-going activity. Type 3 assessments may be conducted by either peers or authority figures, but in either case participants understand that the assessment is in service of a larger, ongoing activity.

Although each of these types can be useful for certain functions and they overlap somewhat, this third category of assessment—naturally occurring in the course of ordinary activity—may prove to be especially important for accounting for the learning that occurs in afterschool programs.

Embedded in ongoing practice and often unnoticed, “Type 3” assessments, by definition, fit within the social, behavioral, and learning-related norms of a setting since they are integrally part of social practices through which participants are able to accomplish some of the most basic forms of coordination in dynamic environments, particularly: setting goals; accounting for the human capital available in those settings to reach those goals; and engaging in situated, and, typically, just-in-time teaching and learning practices. Type 3 assessments inherently account for the development and display of capabilities that participants themselves, rather than program designers or evaluators, find valuable. This quality is crucial for capturing the full and largely uncharted terrain of the types of outcomes generated through interest-based learning activities and the developmental features characteristic of informal learning environments. Additionally, Type 3 assessments intrinsically function to provide participants in a given setting the information they need to ascertain, cultivate, and take advantage of human capacities, and therefore they serve as a primary process for feedback in supporting development along key learning trajectories. .

Focusing on this type of assessment puts researchers in the position of understanding how knowledge and know-how are put to use, centering analyses not on inferred representations of knowledge inside persons’ heads, but on the capacity of persons to get particular jobs done—generally by locating, taking up, and functionally mobilizing resources towards valued ends. As a category, these valued ends encompass the range of possibilities for what participants work to achieve in informal learning environments—including in the afterschool.

Linking Naturalistic Assessments to STEM Workforce Development

Afterschool and other informal learning programs share the well-known characteristic that participants “vote with their feet, choosing to attend scheduled programs and events of their own accord ” (cites). While there are undoubtedly multiple factors influencing any individual youth regarding her participation in afterschool activities, recent studies have focused on interest-driven participation and noted particular and robust patterns of development that occur when youth engage in activities that are based on interest—such as tenacity in pursuing progression towards greater competence and self-direction in achieving of high levels of mastery (Gee, 2010; Ito, Horst, Bittanti, et al., 2009; also see Hidi & Renninger, 2006, for a definition of interest). At the same time, characteristics of the afterschool setting as developmentally supportive—addressing the social, emotional, intellectual and physical well-being of participants—have been documented to show the importance the afterschool environment plays in attracting and retaining participants (Halpern, 1999, 2002; Honig & McDonald, 2005; Lerner, Dowling, & Anderson, 2003; Mahoney, Larson, Eccles, & Lord, 2005; Vandell, Reisner, Pierce, et al., 2006). The choice to participate—and therefore learn —in STEM-rich afterschools is, we contend, a joint function of individual personal interest and the affordances of the environment for engaging willingly, joyfully, and meaningfully in the activities of the setting.

Our contention, therefore, is that the burden for engagement of young hands and minds in STEM-related activities rests on the design and execution of programs. The burden for understanding what particular features of afterschool STEM learning environments will attract and retain youth—and ultimately create greater possibilities for workforce development—lies with the research, evaluation, and program design community.

The emotional and experiential qualities of afterschools that can make STEM learning (and, ultimately, the STEM workforce) a plausible option for participants are, we believe, reflected in the socio-intellectual norms related to assessment. Specifically, learning (e.g., observing systematically, locating evidence, justifying conjectures) and development (e.g., feeling safe, trusting adults, taking risks) depend on the social feedback systems that naturalistic assessments provide; they are a functional and supportive part of authentic practice within informal settings, in particular, directly facilitating growth. (Similar types of practices as features are made explicit as critique sessions in many arts based programs: e.g., Heath, 2001; Heath & Roach, 2000; Soep, 1996).

We propose that naturalistic assessment practices—their forms, structures, and impacts—can be used, therefore, as a *framework for investigating* how afterschool learning environments afford certain types of growth by leveraging these practices to validate participants' STEM-related capabilities in personally and socially meaningful ways. The goals and outcomes that participants orient to (children all trying to copy the same sturdy design first created by a peer), the marked successes ("Hey, how'd you do that?"), and the clear moments calling for retries or revision after early attempts to understand, create, or prove together form a structural core in the epistemological framework of the afterschool environment and the basis for documentation of learning practices and outcomes.

Putting the Framework to Use

A potentially valuable tasks facing our research community, this white paper concludes, is showing how naturalistic assessments can be understood systematically as part of the learning environment and, therefore, used by program staff and researchers to document practice-based evidence of learning. This work would need to draw both from the tradition of ethnographic studies that show how learning is supported in everyday life and, simultaneously, from current approaches to principled design of innovative assessments for inquiry-based science. By combining key methods from these two fields, it would be possible to systematically link outcomes for participants in informal settings to the features of the activities in which participants learn and to the evidence needed to demonstrate that learning has occurred (see Appendix). Beyond this, we believe it will eventually be possible to work with practitioners in the field to design and test a toolkit of instruments and techniques through which program staff and researchers can collect evidence revealing types of participant-valued outcomes, the extent to which learning outcomes are attained, and how program characteristics promote the learning outcomes observed. Such a research program would be able to deliver to practitioners (program staff, leaders, designers, and evaluators) the knowledge and tools they would need to provide evidence of learning outcomes in a way that is consonant with the values of the informal science community and the principles of evidence-centered assessment design.

References

Allen, S. (2002). Looking for learning in visitor talk: A methodological exploration. In Leinhardt, G., Crowley, K., and Knutson, K. (Eds.). *Learning Conversations in Museums* (pp. 259-303). Mahwah, NJ: Lawrence Erlbaum.

Allen, S., Gutwill, J., Perry, D.L., Garibay, C., Ellenbogen, K.M., Heimlich, J.E., Reich, C.A., and Klein, C. (2007). Research in museums: Coping with complexity. In J.H. Falk, L.D. Dierking, and S. Foutz (Eds.), *In principle, in practice: Museums as learning institutions* (pp. 229-245). Walnut Creek, CA: AltaMira Press.

Bartels, D., Semper, R. & Bevan, B. (2010). Critical questions at a critical time: Reflections on the contributions of LSIE to museum practices. *Curator, 53*(2).

Bell, P., Lewenstein, B., Shouse, A., & Feder, M. (Eds.). (2009). *Learning Science in Informal Environments: People, Places and Pursuits*. Washington, DC: National Academy Press.

Bevan, B. & Michalchik, V. (in press). Out of school time: It's not what you think. In Eds., Learning in out of school time. London: Routledge.

COSMOS Corporation. 1998. *A report on the evaluation of the National Science Foundation's Informal Science Education Program*. Washington, DC: National Science Foundation. Retrieved 3/8/2005 from http://www.nsf.gov/pubs/1998/nsf9865/nsf9865.htm

Falk, J. H. & Dierking, L. D. 2000. *Learning from museums: Visitor experiences and the making of meaning*. Walnut Creek, CA: Alta Mira Press.

Gee, J. in press. V. Human action and social groups as the natural home of assessment: Thoughts on 21st century learning and assessment. In V. Shute & B. Becker, Eds., *Innovative Assessment for the 21st Century: Supporting Educational Needs*, New York: Springer.

Halpern, R. (1999). After-school programs for low-income children: Promise and challenges. *The future of children, 9*(2), 81-95.

Halpern, R. (2002). A different kind of child development institution: The history of after-school programs for low-income children. *Teachers College record, 104*(2), 178-211.

Heath, S. B. (2001). Three's not a crowd: Plans, roles, and focus in the arts. *Educational Researcher, 30*(7), 10-17.

Heath, S. B., & Roach, A. (2000). Imaginative actuality: learning in the arts in the non-school hours. In E. B. Fiske (Ed.), *Champions of Change: the impact of the arts on learning* (pp. 20-34). Washington, DC: The Arts Education partnership and the President's Committee on the Arts and Humanities.

Hidi, S., and Renninger, K. (2006). The four-phase model of interest development. *Educational Psychologist, 41*(2), 111-127.

Honig, M., & McDonald, M. (2005). *From promise to participation: Afterschool programs through the lens of socio-cultural learning theory*. New York: The Robert Bowne Foundation.

Ito, M., Horst, H., Bittanti, M. boyd, d., Herr-Stephenson, B., Lange, P.,Pascoe, C. & Robinson, L. (2009). Living and learning with new media: Summary of findings from the Digital Youth Project. (John D. and Catherine T. MacArthur Foundation Reports on Digital Media and Learning). Cambridge: MIT Press.

Leinhardt, G. and Knutson, K. 2004. *Listening in on museum conversations*. Walnut Creek, CA: AltaMira Press.

Lerner, R. M., Dowling, E. M., & Anderson, P. M. (2003). Positive youth development: Thriving as a basis of personhood and civil society. *Applied developmental science, 7*(3), 172-180.

Mahoney, J. L., Larson, R. W., Eccles, J. S., & Lord, H. (Eds.). (2005). *Organized activities as developmental contexts for children and adolescents*. Mahwah, NJ: Lawrence Erlbaum Associates.

Martin, L.M. 2004. An emerging research framework for studying informal learning and schools. *Science Education, 88* (Suppl. 1), S71-S82.

Michalchik, V. & Gallagher, L. (2010). Naturalizing assessment. *Curator, 53*(2).

National Research Council. (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington DC: National Academies Press.

Pekarik, A. (2010). From Knowing to Not Knowing: Moving Beyond ‘‘Outcomes.’’ *Curator, 53*(1).

Soep, E. (1996). An art in itself: Youth development through critique. *New Directions for Child Development, 12*(4), 42-46.

Vandell, D. L., Reisner, E. R., Pierce, K. M., Brown, B. B., Lee, D., Bolt, D., et al. (2006). *The study of promising after-school programs: Examination of longer term outcomes after two years of program experiences.* Madison: Wisconsin Center for Education Research, University of Wisconsin-Madison.

Yackel, E., & Cobb, P. (1996). Sociomathematical norms, argumentation, and autonomy in mathematics. *Journal for Research in Mathematics Education*, *27*(4), 458–477.

Appendix

Below, we describe a handful of preliminary findings regarding the forms and functions of naturalistic assessments, indicating how the ethnographic aspects of our research might systematize the occurrence of these events in support of the development of evidence-based assessment techniques suited to informal settings. We have generated a set of guiding questions and initial findings on the basis of observed instances of naturalistic assessments that we documented during pilot observations of a physical science summer camp (which we see as analogous to practices in afterschools).

What are the circumstances under which naturalistic assessments occur in the setting?

Preliminary findings: Naturalistic assessments occur when whether or not someone knows or has learned something comes to be at issue. People, of course, use their knowledge, skills, and capabilities all the time, but only sometimes does showing what one knows matter in a way that is marked or distinctive. Children working through cycles of design, testing, and redesign while they undertake projects in the camp are subject to periodic assessment by staff who coach the children with typically unsolicited remarks and feedback about their projects.

What is the structure of these types of assessments?

Preliminary findings: Naturalistic assessments get "set up" in social interaction through questions or other openings for display and, by definition, are consequential, even if the consequences are minimal and immediate. All naturalistic assessments involve a display behavior where someone shows what he/she knows or knows how to do and an evaluative moment. Even though the assessments are ongoing and drive changes in the behavior of the children and the facilitators, most of the evaluations result in relatively subtle consequences for children's participation in activities in the camp.

What are the relationships of naturalistic assessments to other events within the setting?

Preliminary findings: The naturalistic assessments are fully integrated into the learning process and not at all "test-like." They can occur in the different learning contexts provided (e.g., large-group discussion, facilitators' explanations, device design time, and device testing time). The building of skills and understanding is support by the staff's knowledge of where the child starts and where she goes, which the staff uses to shape the local learning environment for the child (e.g., providing new resources for the accomplishment of a task).

How do these assessment practices provide indications of valued cognitive outcomes?

Preliminary findings: Evidence of cognitive outcomes can be derived from conversations among children and between children and facilitators, from improvements in the design of artifacts, and from the alignment of the artifacts' improvements with standards.

How do the displays of learning revealed within social interaction affect assessment-related decisions made by line staff during program sessions?

Preliminary findings: At some times more than others, staff gear their activities, instructions, and guidance to be better able to know what children are learning. Although the possibility of arranging for students' display of knowledge always exists, staff only sometimes do so.

How do the naturalistic assessment practices feed into and support learning within the setting?

Preliminary findings: In this camp, staff assess when the children will be most receptive to hearing them explain formal scientific processes. The children assess their own learning to determine when to seek help and what coaching to give to and take from their peers.

How can and do practitioners make note of naturalistic assessment events?

Preliminary findings: Many naturalistic assessment events go unnoticed in the course of interactions between staff and learners, even when they have an impact on learning practice and outcomes. Practitioners can be trained to better recognize, cultivate, and document naturalistic assessment events and outcomes, and to make inferences about the effects of the relevant learning activities.

Building on an initial categorization of functions and features of naturalistic assessments such as the one above, it will be possible, based on in-depth fieldwork, to define the times and places when naturalistic assessments characteristically occur in order to develop solid techniques for (1) finding and documenting qualitative evidence of learning outcomes, and (2) linking this evidence to the learning activities in relation to which they are generated.

Title: The continuum of participation in meaningful, purposeful out of school experiences mediating identity development as STEM learners, consumers and producers

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Abstract: This whitepaper presents a case for a research agenda around the continuum of youth participation in out-of-school programs in an informal science institution and its implications for STEM workforce development. Applying a theoretical framework of identity development in collaborative practices, we argue for a research agenda that examines how youth participate in science-related out-of-school activities during a span of their K-12 years and how this shapes identity in and motivation to pursue science related activities and careers. The following questions frame our discussion: how does long-term participation in out-of-school programs at an informal science institution shape science-related identities? How does youth participation in out-of-school change over time (with changing identities, interests and level of engagement)? What keeps youth participating in these science-related out-of-school activities and how could this contribute to increasing the numbers of immigrant/underrepresented people in the STEM pipeline? Using the New York Hall of Science (NYSCI) as a context, we examine the participation of youth (elementary, middle and high school students) beginning with the Afterschool Science Club and continuing into the nationally replicated Explainer program for high school and college students. We end our whitepaper with a discussion of implications for research and funding policy.

Introduction

Science education research often points to the disconnect between school science and students' day-to-day lived experiences as reasons for a lack of interest in science (Lemke 2001, Roth & Tobin, 2007). In one study, even after controlling for academic achievement and student background, the most predictive factor in students dropping out of high school and ultimately out of the STEM pipeline is the *lack of student engagement* with real world problems and solutions in the coursework being taught in their high schools (Connell, Halpem-Felsher, Clifford, Crichlow, & Usinger, 1995; Rumberger, 2004). Minority and immigrant students are often at greater risk as there is the added cultural and linguistic disconnect between school, school science and their lifeworlds (Olitsky 2007; Rahm 2007; Pitts 2007). However, many of these same students participate in science-related activities in informal settings with great success (Basu & Calabrese-Barton, 2007; Rahm 2002). Ranging from early childhood through college, many informal science institutions offer out-of-school programs that engage young people in science in developmentally appropriate ways. For example, programs for younger children focus on exploratory hands-on activities while older children may serve as interns in scientists' labs or in roles where they lead and mediate science learning for self and others. In some institutions, youth have opportunities to engage in this continuum of participation from their early years until they are in college. Many of these programs and activities aim to and are successful at supporting students, especially from underrepresented areas, in developing self-efficacy, interest, and motivation in STEM careers (Dorsen, Carlson and Goodyear 2006), we believe it is important to study this continuum of participation. As such, using a framework of identity-in-participation, we will demonstrate the value of and need for meaningful, long-term sustained out-of-school programs that invite students to participate and contribute over time. Using the context of one program at the New York Hall of Science (NYSCI) called the *Science Career Ladder* program, we will present the existing research, and describe the activities, opportunities and challenges that exist both from a program development and research perspective.

Rationale and Theoretical Framework

Researchers have begun to examine issues around identity in science education. This is important because if students cannot view themselves as somehow connected to science—whether as people who like science or some one who will pursue a science-related career in the future—students will not be likely to be successful in school science (Roth & Tobin, 2007). Students are able to build positive science-related identities when they have successful interactions and experiences around science (Olitsky 2007). Out-of school experiences allow students to participate in science in ways that are fun, socially mediated, and meaningful to their lives (Rahm 2002; 2007). Through participation in these activities, students begin to view themselves as people who a part of the science community—people who are knowledgeable about science and who are able contribute to their communities in meaningful ways, such as teaching others and making salient science-related decisions. Anna Stetsenko (2010) writes "activity is inevitably and profoundly social and collaborative through and through – being carried out with the help of collaboratively created cultural tools and artifacts (e.g. language, literacy, writing, technology, rules, norms, and patterns of acting and thinking), motivated by social contexts and circumstances of one's life (i.e relational with other people) and directed at social goals" (p. 85). A framework of identity-in-practice recognizes that identity development is shaped in activity and in relation to others.

Guiding Framework of Learning and Identity

A central goal of STEM out-of-school programs is that youth learn and participate in STEM activities. Through program design and enactment, they learn STEM content, the process of doing science and engage in STEM in personally meaningful ways. In other words, in out-of-school STEM contexts, youth are participating in a culture of science. Describing culture as a system of schemas and corresponding practices (Sewell 1999), learning is a means of acquiring and adapting new cultural practices. Learning is a highly social and culturally embedded practice—it happens as people are trying to make meaning of their world (Stetsenko 2008). Youth engaged in science-rich out-of-school programs are active agents in producing culture as they learn and understand science as a meaningful part of their lives; they are developing a "science learner identity" (Bell et al. 2009). Once we ascribe a sense of agency to the learner, even a young child, we could begin to view learning as tied to identity development, "learning then appears as the pathways to creating one's identity by finding one's place amongst other people and, ultimately finding a way to contribute to the continuous flow of social practices" (Stetsenko 2008, p. 487). Thus learning as an ongoing process of producing culture and contributing to the collaborative practices of a community. By situating oneself amongst others and finding ways to contribute to the social practices of a community is the process though which one develops an identity (Stetsenko 2008), therefore learning and identity development is an embodied collaborative practice of being and learning in a particular environment or context. This description of learning is salient to this proposed study because we are looking at the ways ongoing participation in a science-rich learning community mediates science-related identity development in youth as they grow from children to young adults; as they learn science in multiple contexts over time (Bell et al. 2009). At the New York Hall of science, kids go/grow from being participants in the After-school Science Clubs (ASSC), to Explainers, floor facilitators for the science center. They have multiple opportunities to participate in science while they learn the cultures of science and learning science in an ISI. As people mature, they play more of a role in "organizing, regulating and shaping social life and practice." When they youth get older, some decide to pursue the role as an Explainer, thus contributing to the collaborative practice of mediating science learning in a role where they are more central to shaping and guiding the learning experiences of others.

The Science Career Ladder

The New York Hall of Science (NYSCI)'s Science Career Ladder program serves as useful case study for this research agenda because it presents a case for studying youths' long-term participation in different science-related afterschool activities in a single institution where they move from being an active learner (club member) to an active facilitator of learning (Explainer) as they grow into young adults.

At NYSCI, approximately 150 elementary and middle school students participate in After-school Science Clubs (ASSC). Developed to instill a sense of scientific curiosity and improve science literacy during one of the most crucial periods in a child's life, the clubs are designed around the following three key principles: to provide underserved youth with a safe, supervised, informal education activity during after-school hours; to present positive role models; and to increase science literacy in math and science among girls and minority youth. The clubs offer students the unique opportunity to experience out-of-school time STEM learning in a science museum setting, where they can apply learned principles by experimenting in onsite discovery labs and hands-on exhibits on a variety of science topics. The clubs meet weekly during the school year over the course of eight-week semesters, which are complemented by meetings during holiday and February school breaks and one-week intensive summer camps. Many students re-enroll year after year into the program and thus spend many of their elementary and middle school years engaged in new and innovative activities developed and conducted in the program.

Most *After School Science Club* participants are schoolchildren from the local communities of Corona, Flushing, and Jamaica in the borough of Queens, NY. According to the most recent data collected from the *After School Science Clubs*, 44% of participants are Hispanic/Latino, 22% are Asian/Pacific Islander, 3% are African American, 18% are white, and 13% are multi-ethnic or not identified. Some of the youth who begin in the ASSC later become Explainers, in a manner that is similar to a documented program at Queens Community House that retains a practice of hiring former youth participants as program facilitators and leaders (Matloff-Nieves, 2007). In the Explainer program, the older youth take more responsibility not only for their own learning and professional development, but also the learning of others (visitors to the Hall, and as we learned, standing in for teachers, therefore responsibility of learning for their peers). Thus, there is a trajectory from guided learning to guiding learning with increasing agency in their degree of participation.

The Explainers are part of a formal youth employment program at the science center where students are recruited from local high schools and colleges and represent the diversity of the community, many of them being immigrants, first or second generation Americans with 91% minority, including 24% Hispanic, 40% Asian American, 15% African American, 7% West Indian, 5% other, and 9% Caucasian. The Explainers work in the science center to facilitate learning interactions between visitors and exhibits, conduct demonstrations, and facilitate hands-on lab activities that allow visitors to explore scientific phenomena. Some of the Explainers are assigned to work alongside instructors, with the ASSC youth. These two programs (ASSC and the Explainer program) constitute the *Science Career Ladder*, a nationally replicated program of training, employment, and mentoring, that encourages students to consider careers in science and technology. Selection criteria for the program primarily consist of looking for students are interesting in work with people and are able to work throughout the year. The program is advertised as a job particularly to attract low-income at-risk students who may need to work to support themselves or their families.

Evaluation of the After-school Science Clubs

In 2001, The New York Hall of Science engaged the Institute for Learning Innovation (ILI) to conduct an evaluation to examine the impact of the ASSC on participants in grades 5-8. The guiding research question for this phase of the study was to assess how participation in the NYSCI ASSC has mediated changes in the students in the areas of: attitude towards, interest in, and/or perception of science and scientists, personal goals and aspirations, and leisure time choices. The findings of this study revealed that children who participated in the NYSCI ASSC demonstrated a greater interest in and more positive attitude towards science than did students not involved in the program. Similarly, the parents of the participants also noted that their children were increasingly eager to go to the ASSC because, as one mother put it: "he tells me he's learning a lot here." This finding is particularly important in light of the fact that for many parents, the initial motivation to bring their children to the program had more to do with the safe, interesting, and child-friendly environment the NYSCI represented, rather than any expressed interest in science.

Mostly all of the children who participated in the evaluation liked to play computer games, surf the web, watch television and socialize with friends. However, children who participated in the NYSCI ASSC were more likely than the control group to express interest in reading. Evidence also suggests that students in the NYSCI program are more able to work together whether or not they know others in their group and that the program helps children develop their problem solving skills. In addition, these students seemed to be more focused and engaged in an interactive exhibition that they had never seen before compared to the control groups.

Evaluation of the Explainer Program

In 2009, ILI conducted a retrospective impact study of the Science Career Ladder Program in order to understand the long-term impact of the Explainer program in supporting and encouraging its participant's personal, professional and academic development. The study focused on many key areas: academic achievement, career/professional development, skills and abilities, science literacy and engagement, and program design and data were gathered from 27% of alumni who responded to an online survey. In this paper, we report on findings related to academic achievement, career development, and science literacy and engagement.

Nearly all of the program participants who participated in the study go on to attain advanced education at a far higher rate than the general population of New York City, with particularly stark contrast among those identified as Latino, where program alumni attain advanced education at a rate five times higher than those in the general population. The strongest impact on academic achievement was developing knowledge, skills, and confidence that they have successfully applied to academic settings, including: science content knowledge, study skills, learning habits of mind, confidence in oral presentations, and problem solving skills. While for some, the program influenced their careers decisions to pursue STEM or teaching jobs, for many others, the program served as a testing-ground for their choices. In regards to science literacy and engagement, over 60% of the alumni participate in leisure time science activities (watching television programs about science, talking to family or friends about science issues, and reading science articles in magazines or online). In addition 76% said that they visit informal science learning settings several times a year. This suggests that Explainer alumni are on par with and sometimes surpass the general science museum visitation rate of college-educated adults and are above average compared to the general public (National Science Board, 2008). Eighty-two percent indicate that they pay more frequent attention to science in their everyday life after being an Explainer. All of these results are especially noteworthy because so many of these students state that they didn't have an interest in science, and in some cases, disliked science. For 61% of the alumni, needing a paying job was their motivation for working as an Explainer.

As can be seen, patterns that emerge from the two evaluation studies, one for the ASSC and one for the Explainer program, overlap. In both programs, students develop a positive attitude and excitement for learning science and the role of science in their everyday lives. They have increased problem solving skills and ability to engage with scientific ideas whether it is with a new exhibition they haven't seen before or with current events through media or journals. These patterns urge us to consider program design and a research agenda where students move into higher levels of responsibility, engagement and involvement as they grow.

Implications for further research

We believe that researching the continuum of participation could provide insights on engaging youth in STEM activities. First, it has implications for creating out-of-school opportunities for youth across the age continuum with the intent to scaffold experiences to support science-related identity development. Out-of-school STEM agencies could develop programs with the intent of youth participating in different, age-appropriate activities over time in ways that foster a sense of them contributing to the collaborative practices of the institution, to science and to their communities. This would not only keep youth engaged in STEM learning, but it could also strengthen the capacity of institutions to offer programs for younger children and provide "home-grown" role models from the community. If an individual institution does not have the capacity to offer a range of programs, perhaps research about the continuum could provide incentives for such institutions to partner with other local agencies and institutions that serve youth of different ages. This has the potential of strengthening the capacity of a community to provide STEM-rich out-of-school learning opportunities that afford ongoing engagement, and build sustaining partnerships across contexts (e.g. between a children's museum and an environmental center), thus youth science learning would truly become a collaborative practice of the community.

Studying the continuum of participation in an out-of-school context could also provide opportunities for studying learning progressions as suggested by Bell et al. (2009). One could not only study the learning of major scientific ideas across developmental milestones, but one could learn in what ways people engage in the process of doing science at different developmental levels. Also, considering the notion of learning and identity development as participating in the collaborative practices of a community, studying learning progressions could document in what ways people engage in the collaborative practices of the science community over time—as they learn deeper content and broader concepts and develop skills in the process of doing science.

It is important to learn what keeps youth engaged in out-of-school STEM learning if it is a means to diversify the STEM career pipeline. Researching the continuum would provide many entryways and opportunities to learn ways to keep diverse young people engaged in science. Currently, although the NYSCI has a diverse population of participating youth, African Americans are still underrepresented. Researching the continuum could provide insights about what it would take to interest, recruit and retain these youths.

As research is an ongoing process of learning and generating questions, researching the continuum could open up questions and concerns that have not arisen while looking at programs at discrete ages. For example, we have learned about childhood afterschool programs and we have learned about high school afterschool programs—the ASSC and Explainer research described above is an example—but we have not researched youth who have sustained participation from a young child to a young adult.

Finally, researching the continuum could help us to learn more about how ongoing contribution to the collaborative practices of a community shapes science identity and participation in school and in students' lifeworlds. This would have powerful implications for creating science-rich programs that would bridge formal/informal science contexts.

Implications for funding policy

In order for use to efficiently research the continuum, funding policy would have to change to accommodate programming and corresponding research that would allow us to learn how youth identity develops and changes as their participation in science related OST activities during their key developmental years. Funding-agencies would need to fund long-term (7-10 years); targeted projects that allow a smaller cohort of participants to participate over a longer period of time. It would also have to consider that the nature of the project's activities would change to meet the developmental and interest needs of the participating youth as activities that would interest 10 year olds and 13 year olds would look quite different. Centers such as Learning in Informal and Formal Environments (LIFE) and the Center for Informal Learning and Schools (CILS) have done seminal work in learning and documenting how people learn science across contexts and the intersections between formal and informal science teaching and learning. Funding projects that focus on program development and research across the child to young adult continuum build on this research and allow us to go deeper into learning what keeps diverse youth engaged in pursing the STEM pipeline.

References:

Basu, S.J. & Barton, A. C. (2007). Developing a sustained interest among urban minority youth. *Journal of Research in Science Teaching*, 44, 466-489.

Bell, P., Lewenstein, B. Shouse, A. W., & Feder, M. A. Eds. (2009) *Learning science in informal environments: People, places, and pursuits.* Washington, D. C.: National Academies Press.

Buchner, K., Luke, J., Adams, M (2001). New York Hall of Science: Assessing the impact of an after-school program. Annapolis, MD: Institute for Learning Innovation.

Connell, J.P., Halpem-Felsher, B.L., Clifford, E., Crichlow, W. & Usinger, P. (1995). Hanging in there: Behavioral, psychological, and contextual factors affecting whether African American adolescents stay in high school. *Journal of Adolescent Research, 10 (1)*, 41-63. DOI: 10.1177/0743554895101004

Dorsen, J., Carlson, B., Goodyear, L. (2006). Connecting informal STEM experiences to career choices: Identifying the pathway. *ITEST Learning Research Center.* Education Development Center.

Matloff-Nieves, S. (2007). Growing our own: Former participants as staff in afterschool youth development programs. *After-school Matters*, Spring 2009. National Institute on Out of School Time.

Lemke, J.L. (2001). Articulating communities: sociocultural perspectives on science education. *Journal of Research in Science Teaching*, 38, 296-316.

Olitsky, S. (2007). Promoting student engagement in science: Interaction rituals and the pursuit of a community of practice. *Journal of Research in Science Teaching, 44*, 33-56.

Pitts, W. (2007). Being, becoming and belonging: Improving science fluency during laboratory activities in urban education. Unpublished doctoral dissertation, City University of New York, Graduate Center.

Rahm, J. (2002). Emergent learning opportunities in a inner-city youth gardening program. *Journal of Research in Science Teaching*, 39, 164-184.

Rahm, J. (2007). Urban youths' hybrid positioning in science practices at the margin: a look inside a school–museum–scientist partnership project and an after-school science program. *Cultural Studies of Science Education*, *3*, 97-121.

Roth, W-M. & Tobin, K. (eds). (2007). *Science, Learning, Identity: Sociocultural and cultural-historical perspectives*. Rotterdam: Sense Publishers.

Rumberger, R. (2004). Why students drop out of school. In G. Orfield (Ed.), *Dropouts in America: Confronting the graduation rate crisis*, (pp.131–155). Cambridge, MA: Harvard Education Press.

Sewell, W. H. (1999). The concept(s) of culture. In V. E. Bonell & L. Hunt (Eds.), *Beyond the Cultural Turn.* (pp. 35-61). Berkeley, CA: University of California Press.

Sickler, J., Johnson, E. (2009). *Science career ladder retrospective impact study.* New York, NY: Institute for Learning Innovation.

Stetsenko, A. (2010). Standing on the shoulders of giants: A Balancing Act of Dialectically Theorizing Conceptual Understanding on the Grounds of Vygotsky's Project. In W. M. Roth & K. Tobin (Eds.), *ReUniting psychological and sociological perspectives*, (pp. 69-88). Rotterdam: Springer Press.

Stetsenko A. (2008). From relational ontology to transformative activist stance on developmental and learning: expanding Vygotsky's (CHAT) project. *Cultural Studies of Science Education,* 3, 471-491.

Tobin, K., Kincheloe, J. (Ed.). (2006). *Doing Educational Research*. Rotterdam: Sense Publishers.