

Building Engagement With Technology-Enhanced Local Learning White Paper for the National Science Foundation Convening on Youth Motivation and STEM Workforce Development Experiences

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Abstract: Drawing on a multi-year research and development program, the authors report on the promise of integrating locally-focused student investigations with ubiquitous access to advanced technologies. By doing this, students are better able to see the relevance of STEM skills and knowledge as they work to improve their local communities. Specific program examples cited show the paradigm as it has been implemented with upper elementary and middle school students. Contrasting examples show challenges in implementation. A four-part framework of essential program elements is offered to guide further investigation.

Overview

While much technology use in schools is greeted with fanfare, transformative impact has been harder to document. In most cases, the technology is co-opted to serve the prevailing transmission-driven school paradigm. Additionally, there is evidence of a split between technology use in and out of school, with many students not seeing how the technology they use in school relates to learning or future career choices (Selwyn, Boraschi, and Ozkula 2009; Selwyn and Husen 2010). All too often, the end result is that some students end up with a great deal of technological expertise that they are not allowed to use in school, while others (often from rural and/or socio-economically challenged communities) don't have the same experiences. While reduced, the digital divide is still all too present in American society. We believe that well-designed formal and informal learning experiences can play a pivotal role in bridging both the socio-economic and relevance gaps.

Whether embedded in the regular school day or in out-of-school settings, STEM-rich experiences that have practical relevance can engage students as they build citizenship and workforce skills. As students see real-world applications of STEM disciplines, their horizons expand. The world becomes more understandable, and they come to see themselves as competent learners. Within that broad realm, we have found that locally-focused projects are particularly valuable as the foundation for students' learning experiences. In the sections below we detail our work with a variety of geospatial, augmented reality, and agent-based modeling tools to enhance community-based investigations. Most of this work is with upper-elementary and middle-school students, but we are confident that the general parameters extend more broadly.

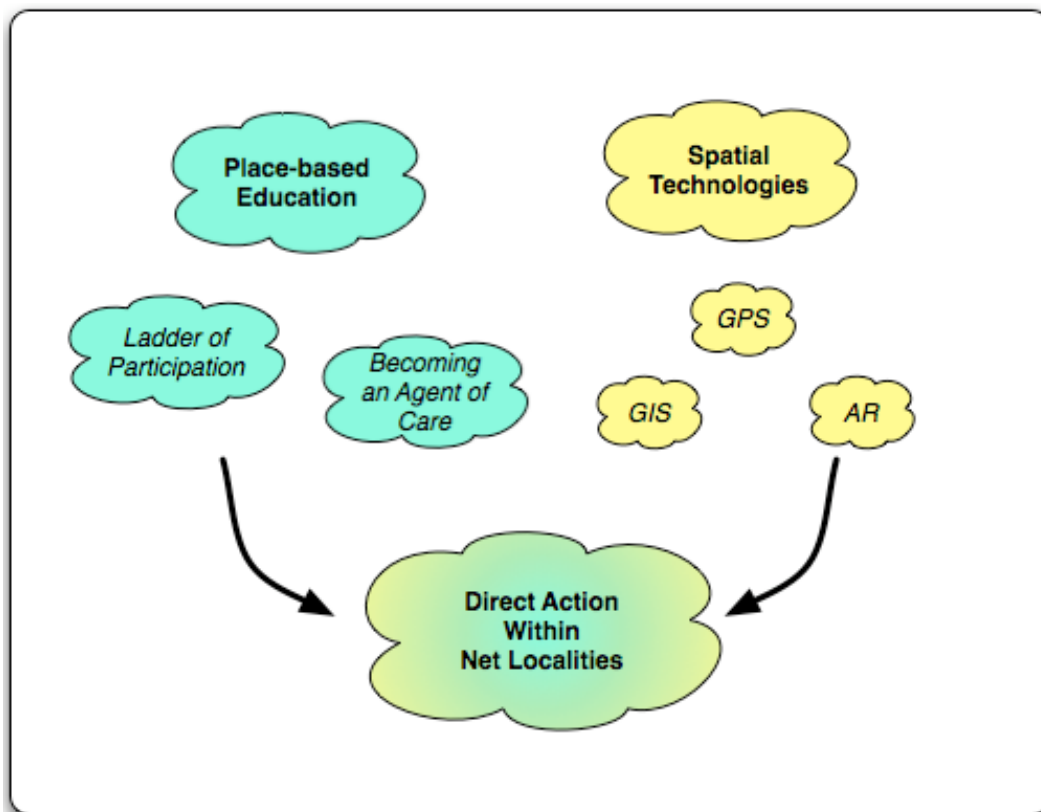
Theoretical Framework

This discussion builds on the general framework of place-based education (Sobel 2004; Smith and Sobel 2010) and on uses of advanced technologies, arguing that there is potentially a great benefit to be realized through their synthesis. As an umbrella concept, "place-based education encourages teachers and students to use the schoolyard, community, public lands, and other special places as resources, turning communities into classrooms" (Place-based Education Evaluation Collaborative

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2010). Beyond this broadly framed anchoring in the local, there are at least two foundational aspects that characterize high quality place-based programs. The first is increasing student ownership of the projects, as articulated by Hart (1997) in his ladder of participation. As Hart points out, having students “involved” can mean anything from token involvement up to full collaboration with adults in the community. Along with this focus on increasing student agency is the goal — at least for environmentally focused projects — of helping students become what Chawla (2009) calls “an agent of care for the natural world.” Together, these elements root students in their community and equip them to make a positive contribution.

In tandem with these elements of place-based learning are a range of spatially anchored technologies, including geographic information system (GIS), global positioning system (GPS), and augmented reality (AR) tools. Each of these offers opportunities for students to extend their thinking beyond direct experience with the local community. When they do this, they create what Gordon and de Souza e Silva (2011) refer to as net localities. As they describe it, “net locality implies a ubiquity of networked information – a cultural approach to the web of information as intimately aligned with the perceptual realities of everyday life. We don’t enter the web any more; it is all around us” (pgs. 2-3). Thus, there is a real need to help students live in both “real” and networked



spaces, drawing from both as they define their place in the world.

Fig 1. Integrating place-based education and spatial technologies

Cross-program research (Duffin, Murphy and Johnson 2008) has found that local projects in which students collect measurable impact data (e.g. measured pollution mitigation, not just advocacy)

lead to higher student interest and learning. While some might argue that project-based learning situated in real contexts takes too much time in an over-crowded curriculum, data such as this provides an effective counterpoint. Students with meaningful tasks will be motivated to engage with complex material more readily, and will be better able to integrate what they are learning into robust conceptual networks. As Gee (n.d.) notes, “a large body of facts which resist out of context memorization and rote learning comes free of charge if learners are immersed in activities and experiences which use these facts for plans, goals, and purposes within a coherent knowledge domain.” School learning on the other hand often remains detached from any real-world consideration, with students going through the motions and generating answers with no practical application. Schoenfeld (2010) cites as an example the classic school problem in which a given number of people need to ride a bus. Knowing that each bus can hold so many people, how many buses are needed? As a school math exercise, many students respond with a remainder or offer a solution involving fractional buses. Anyone solving it as a real problem wouldn’t generate these answers, since moving real people doesn’t allow for leaving some behind or having partial buses. When we move from the academic to the authentic, we can better support student learning.

Coupled with the benefits of authenticity, in many cases the immediate proximity of local contexts fosters greater student interest and enables students to take direct action in which they employ their STEM skills. Students are much more likely to care about the health of a local creek than about abstract considerations of water quality. Likewise, mountains thousands of miles away are less interesting than the mountains on the students’ horizon. Aside from the potential to spur interest, the local context favors taking constructive action. While many students are led to advocate and raise funds on behalf of saving a distant rainforest or protecting a charismatic but endangered species, they can actually get involved in a local native plant restoration project. From the standpoint of learning and capacity development, we believe — consistent with Hart’s ladder of participation — that direct action with constructive mentoring is far more educational than advocating that others in a distant land take action at the students’ behest.

To be clear, this focus on the local is not a call for parochial worldview. Rather, the local investigations help to build a framework that can be used to understand the distant. For example, one of the authors of this paper was a teacher whose fourth grade students were investigating biomes. Rather than doing a simple cataloging of different ecoregions, they began their work in a patch of woods across the street from the school, studying life in the temperate deciduous forest. Linking field study and classroom work, they used a variety of text and online resources to identify species and reconstruct the local food web. In parallel with this, they used databases to link abiotic and biotic features, over time learning how adaptations favor survival. Building on this strong foundation, they were able to use this interpretive framework to understand distant regions, culminating in multimedia presentations on life in different global biomes (Coulter 2000). Framed well, a “local to distant” scope helps students to become well-grounded global citizens.

Research Context

This paper builds on the findings of a joint 3-year effort by the Missouri Botanical Garden (MBG) and the Massachusetts Institute of Technology (MIT) to build students’ STEM engagement through technology-enhanced local learning. Supported by the National Science Foundation and private funders, MBG and MIT have developed a range of projects that leverage geospatial, augmented reality, and agent-based modeling tools. Most of these projects also embed service-learning opportunities that enable students to apply and extend their learning. Examples of recent projects include:

- Middle school students using preliminary data and ArcGIS to track an EF-4 level tornado that struck their neighborhood only a week before. Although students had personally seen homes and businesses that were leveled, it wasn't until they mapped the tornados to see the path of destruction that real inquiry began. Starting with this high-visibility event, they went on to map seasonal variation in the likelihood of tornado strikes across the country and to investigate real data in depth. Student-driven questions included thought provoking queries such as *"Texas has a lot of tornados, but they also have a lot of land. Is there another way to investigate frequency? How does Texas compare if we map tornados per square mile?"*
- 6th grade students using agent-based modeling via StarLogo TNG to learn about bioretention as a tool for managing storm water run-off. In the model, students make sense of their efforts to improve a local habitat by adding areas devoted to native plants. Areas planted with deeper-rooted, native plants are capable of absorbing more runoff, mitigating flow into drainage channels. By adding virtual native plants into the model and re-running scenarios, students are able to model the intended impacts of their efforts by compressing time and space. The students also gain valuable experience using modeling as a tool for scientific inquiry.
- 4th and 5th grade students learning about water quality in their neighborhood park through an augmented reality game. While the students had played in the park for years, they hadn't noticed the ecological impact of how people use the park or the impact of surrounding businesses. Challenged by an environmental mystery created with augmented reality software, students completed first hand investigations of the park while "meeting" virtual residents and professionals on handheld computers. Meeting back together at the end of the investigation, students shared the evidence they gathered to determine what was causing a real-life water quality concern.

Program evaluation data indicate that the joint focus on advanced technology applications and high-interest local issues can engage a broader range of students than more traditional methods. Programs such as these correlated with higher levels of student and teacher interest, and gave evidence of students actually using STEM concepts and technology skills in their work. The fusion of interesting local contexts and opportunities to apply what they are learning appears to be creating positive, self-sustaining energy within the program.

In contrast, other programs we supported failed to achieve this level of engagement, remaining in a passive academic mode for teachers and students. Even though the program ran in after-school and summer settings (and thus, participants were freed from burdensome standardization and accountability requirements), the tasks didn't break out of the traditional paradigm of school exercises. Thus, real contrasts emerged in our portfolio of schools between the active, investigatory programs and more passive ones. On the one hand, we had students using geographic information system (GIS) tools to investigate socio-economic inequalities in access to healthy food while others photocopied local history facts and mounted them on construction paper.

Findings and emerging conclusions

Given the stark contrast in program outcomes, it is clear that simply basing a project in the local community is not sufficient. Rather, it is an enabler of certain attributes that are desirable for promoting STEM involvement. Specifically, we have found the following to be important program elements:

- Strong adult leadership with appropriate STEM pedagogy
- Access to local human, physical, and cultural resources
- Technology resources that enable active investigation and sense-making
- Administrative and parental support for active learning

By far the strongest predictor of a successful program was the quality of adult leadership. The programs supported by the MBG-MIT partnership all employed teachers to lead after-school and summer programs in addition to their “regular” school duties. In the more successful programs, teachers embraced what Gee (n.d.) has described as post-progressive pedagogy, offering “a well-integrated combination of embodied immersion in rich experience... and scaffolding and guidance [for students].” The key is to move past dry “teaching by telling” on the one hand and just throwing kids into experiences on the other. Instead, he argues, learners need immersion in experiences and the support of more expert guidance. In this context, the expertise needs to be both in the relevant content domains and in learning. While one could quibble with Gee’s dismissal of progressive pedagogy as not providing adequate support, his vision of supported engagement is on target. More than simply doing activities, students in our more successful programs had a sense of purpose and direction to their work, with clear accountability to others who would benefit from their work. Programs generating less student enthusiasm were stuck in “school mode,” characterized by a level of passivity among teachers and students. Virtually every week needed to be scripted by the program staff, with little effort by the teachers to engage in active exploration.

Strong pedagogy on the part of the teacher-leaders is necessary, but much more is required for projects to succeed. Leaders also need to be able to marshal the physical and human resources that extend the range of possibilities. Thus, a stream investigation benefits from high-quality testing kits and mapping tools. Likewise, a local food project benefits from partnerships with community supported agriculture (CSA) groups. Giving student investigators access to high quality tools and connections to people working in the field makes the project more authentic as “real” tools are used and students can see adults in the community who value the work at hand. These adults can then become mentors and role models for students forming career aspirations. More generally, the addition of tools and people helps the project stop being a school exercise. Instead, students are now part of a valued community endeavor.

A third critical dimension we have found is effective use of technology to support student inquiry. While virtually anyone today can look up facts through search engines, technological enhancement to post-progressive pedagogy requires a higher level of commitment on the part of teachers and students. Our work has focused on constructive uses of geospatial, augmented reality, and agent-based modeling tools, but there are many other resources (such as probeware) that offer similar benefits if used well. The critical distinction is in how the technology supports student thinking. Technology limited to fact searching reinforces a learning model of knowledge accumulation. More engaging uses of technology can support complex thinking as students engage in geospatial analysis, build models, and see their community from a new perspective through augmented reality. A key test is whether students go beyond simply having more information and toward seeing the community differently as a result of technology integration. As noted earlier, a net locality has strong integration of real and representational environments.

Fourth, strong administrative and parental support is required. Community-based study requires presence in the community. If administrative restrictions keep students on the school grounds (or worse, in the classroom), projects cannot achieve the level of significance envisioned here. For out-of-school projects, parents may be called upon to provide transportation to local field sites and help with weekend monitoring. Both administrators and parents need to be comfortable with the minimal amount of risk involved in field study. A creek project, for example, requires proximity to water. Policies that prohibit students being near water are counterproductive. All of the adults involved need to be comfortable with the concept of “manageable risk” (Tulley 2011) and help students to act responsibly in their field study.

Done well, programs that embed these elements create a fusion of energy that helps research teams sustain themselves and provide an “identity home” that nurtures students’ STEM identities. More than just an enclave for techie nerds, these projects build links between students interested in technology (who gain experience in a range of STEM fields in which their skills can be applied), and students interested in impacting their community (who learn that STEM skills enable greater understanding of their community). Over time, students who start with dissimilar interests come to appreciate and share diverse interests as they create STEM-based inquiry teams.

Discussion

While technology-enriched place-based education won’t address every curricular need, we have found it a compelling way to frame a wide variety of investigations. Viewed more broadly, the underlying principles apply in a wide range of learning contexts. Giving students opportunities to apply their knowledge in authentic contexts and to see how their STEM skills and understanding make a difference are essential components of engaged learning. In turn, this enhanced engagement is required for 21st century citizenship.

For all of these reasons, the synergy between place-based education and technology holds promise as a strategy for addressing current limitations in traditional schooling. Implicit in the work described here is a real trust in teachers and students to make good choices. Both have to be seen as capable of exercising sound judgment, though mentoring is likely to be needed to guide optimal program design. Provision of “more able assistance” (Luckin 2010) through mentors can help in project design and execution, but there is no substitute for giving learners of all ages opportunities to exercise judgment so that they can better own the project at hand and build capacity to make better judgments in the future. Teacher-proofing and kid-proofing the curriculum is all too common today as pacing charts and mandated curriculum resources keep everyone following a script. Realizing the vision presented here will require a paradigm shift in how we see the roles of teachers and students.

References

- Chawla, L. (2009). Growing up green: Becoming an agent of care for the natural world. *Journal of developmental processes*, 4(1), 6-23.
- Coulter, B. (2000). What’s it like where you live? Meeting the standards through technology-enhanced inquiry.” *Science and Children*, 37(4), 46-50.
- Duffin, M., Murphy, M., & Johnson, B. (2008). Quantifying a relationship between place-based learning and environmental quality: Final report. Woodstock, VT: NPS Conservation Study Institute in cooperation with the Environmental Protection Agency and Shelburne Farms.

- Gee, J. (n.d.). Game-like learning: An example of situated learning and implications for opportunity to learn. Retrieved from <http://www.academiccolab.org/resources/documents/Game-Like%20Learning.rev.pdf> July 14, 2011.
- Gordon, E. And de Souza e Silva, A. (2011). *Net locality: Why location matters in a networked world*. West Sussex, UK: John Wiley & Sons.
- Hart, R. (1997). *Childrens' participation*. New York: Unicef.
- Luckin, R. (2010). *Redesigning learning contexts*. New York: Routledge. Schoenfeld
- Place-based Education Evaluation Collaborative (2010). *The benefits of place-based education: A report from the Place-based Education Evaluation Collaborative (second edition)*. Available online at <http://tinyurl.com/PEECBrochure>.
- Selwyn, N., Boraschi, D., and Ozkula, S. (2009). Drawing digital pictures: An investigation of primary pupils' representations of ICT and schools. *British Educational Research Journal*, 35(6), 909-928.
- Selwyn, N. and Husen, O. (2010). The educational benefits of technological competence. *Evaluation & Research in Education* 23(2), 137-141.
- Smith, G. And Sobel, D. (2010). *Place and community based education in schools*. New York: Routledge.
- Sobel, D. (2004). *Place-based Education: Connecting classrooms and communities*. Great Barrington, MA: Orion.
- Tulley, G. (2011). *Beware dangerism!* (Kindle Single) Amazon Digital Services.