Taking Action! Student Generation of Solutions to Local Environmental Problems
STEM for All Multiplex Synthesis: February 2022

Introduction

As educators, we believe we have a societal duty to empower pre-college students to ask questions, engage in investigation, and work cooperatively with others to generate solutions to present and future interdisciplinary problems. Science concepts and practices are instruments for inquiry about real-world questions. When learning about local interdisciplinary science challenges through the science and engineering practices, students experience the three dimensions (practices, disciplinary concepts, and crosscutting concepts) in, as it were, their native environment, which also includes the fourth dimension: the social setting. The authenticity and complexity of the setting stimulate and challenge teachers and students alike and can integrate all subjects in a natural way so that questions and investigations sprout in all directions (Mayhew and Edwards 1917).

The February 2022 Theme of the Month explores the multidimensional learning that can take place as students "learn STEM content through both science practice-rich activities (e.g., field-based data collection and analysis) and engineering practice-rich activities (e.g., the design of solutions for students' communities and localities) and which fosters students' 3D science learning (e.g., Songer & Ibarrola Recalde, 2021).

The Expert Panel

The webinar panelists explored several themes, drawing from their bodies of work. Dr. Nancy Butler Songer, the moderator for this webinar, is a Professor and Dean of the College of Education at the University of Utah. Dr. Songer was joined by Rebecca Clark Uchenna of the Maine Mathematics and Science Alliance; Kirby Whittington from the Life Right Here and Everywhere project at the University of Utah; and Beatriz Cañas, the Director of Equity, Diversity, Inclusion, and Accessibility at the Chicago Botanic Garden.

Setting the Stage for Student Investigation

Student-driven inquiry, whether within formal or informal settings, entails organization and particularly kinds of presentation and simplification to empower students to find their questions, gain skill in shaping productive inquiry, and to make use of the expertise, technology, and other resources that are available to them.

Rebecca Clark Uchenna described WeatherBlur, a long-running program of the Maine Mathematics and Science Alliance that involves 3-7th grade students and their teachers in year-long investigations in their community. Project staff, as well as experts from the community, support the students as they observe and explore the natural world in their area. Observations lead to questions, and the project staff and others, interacting on the project website, help them shape researchable questions, and design their extended investigations. The SMART framework supports this by requiring that their research be "Specific, Measurable, Attainable, Realistic, and Timely."

Kirby Whittington described "Life Right Here and Everywhere," a 6-week middle-school curriculum which is "designed to help foster learning about life science, but also engineering solutions to students' local problems." As with WeatherBlur, students begin by observation and exploration— learning their landscape, and on the lookout for questions about the biota that they may hardly have noticed before. So,

the first discovery the students make is the unsuspected diversity of life around them. As they learn more about their surroundings, the curriculum introduces the general problem of non-native species and engages students with designing solutions to the problem posed by a particular non-native species, such as the spotted lanternfly. Students are then encouraged to bring their proposed "eco-solution" to their community, to enlist others in the effort to control the lanternfly, a rapidly spreading threat across the Northeast of the US.

Beatriz Cañas described how the Chicago Botanic Garden makes it possible for students to engage with issues of environmental justice in their communities. The Botanic Garden provides a beautiful setting within which the students can begin their exploration of natural history, within the Garden, and in their own neighborhoods. The Botanic Garden also makes connections with community groups that provide their own perspectives on environmental issues that are important to them. As the students settle on the questions to investigate, they learn relevant techniques both for data collection and for designing solutions, which can then be shared with the community.

In all three cases, therefore, there is time spent on helping the students become more aware and knowledgeable about local data and the ecology of their local environment, as well as about issues of current concern, for which they can learn and apply science and engineering methods in designing and evaluating solutions. A comment by Rebecca Clark Uchenna expresses this shared pattern of development:

> *That's really what place-based education is all about. It's really, really student-driven, student-focused. The students come up with their questions. And then from there, with... support and help from [our] staff, they reach out to their local community members or scientific experts, if they have any in their backyard, to kind of help craft their questions into something that students can actually investigate.*

Tools for Data

For projects which involve students so heavily, tools for collecting, displaying, and making sense of data play an important role, both in doing the work, and scaffolding the acquisition of skills and methods. The panelists mentioned several digital tools that their participants are using for data collection and analysis. Increasingly, too, there are user-friendly mobile tools for field identification of animal or plant species. As these tools become more reliable and usable, they can overcome one of the major stumbling blocks encountered in student field work (Bopardikar et al. 2021).

But the choice of technologies is not only about the quality of the technology, but also equity must be considered in the design of such programs. If a tool is right for a project (or even necessary), then funding must be secured to ensure access for all participating students. If the Internet is necessary (for example, with the use of a web-based environment like WeatherBlur's, or a data tool like CODAP), then the reliability and capacity of Internet access is a necessary part of program planning. Kirby Whittington said:

> *...we do understand there are some barriers in terms of having just an electronic device, in general, to be able to collect this data. But that was something that we very much tried to make sure that there weren't certain barriers to students actually engaging material-wise to the curriculum that we have students do*.

Social Justice

Issues of equity and social justice are an integral part of such community-engaged, student-driven learning. and they go far beyond questions of access to tools and resources. As Dr. Songer said,

[there are] social justice issues in people's projects and work about using appropriate language and about DEI or EDI work and how we are promoting this kind of taking action projects across a variety of different populations and topics and viewpoints.

The students need to be helped to see the justice dimensions in all aspects of their inquiries. It's not only the issues that they may seek to address — water or air quality, species loss or invasions, transportation design for climate mitigation, or the urban heat island. Equity and justice should (and can) be part of deciding whom to speak with, whose knowledge and expertise to seek, whom to report to, and even how to collect and represent the data. Equity should also be in the design of project teams and the search for domain experts who will be advising the students in their investigations. Moreover, very well-intentioned programs can unintentionally seem to exploit the target community. So, time and attention must be given to developing authentic relationships and the mutual adoption of goals. Beatriz Cañas said:

...working on social justice issues, especially related to STEM, I think it's always really important to think of it holistically. So down to the people that you're hiring to teach these topics, making sure that the staff have formal training around sensitive conversations that they themselves understand the lived experiences of these students. It's even best if they have shared identities with the students or with the neighborhoods that you're trying to engage with. So I always really made sure that the people that were coming in could connect with the students in that way. And that also goes with like interacting with community partners, having knowledge of those communities, building relationships over time.

Finally, it is important to remember that when students (or other humans!) engage closely with environmental or social issues that affect the lives of real people, there can be a significant emotional cost — the problems can be overwhelming, the amount of knowledge that is needed can seem oceanic, the distress that they may learn about can be painful and disturbing. Students will often be aware, at some level, of the social injustice that underlies many of the problems they study. As Rebecca Uchenna said:

If you have a poor or unhealthy environment, then your life will be affected in some way...This is a big question, a big topic and kind of little bit hard for younger students to kind of wrap their heads around. But through local community action projects, really making that connection to - 'I want a healthy environment because it affects me, it affects my family, it affects my friends.' … Here in Maine, we have a big, obviously, lobster industry.... if we don't have a healthy ocean, we won't have any more fishing. And a lot of these students who participate in WeatherBlur have parents, families who rely upon this fishery as their livelihood. So I think, again, making those personal connections to these bigger complex topics is really, really important.

Scientist Participation

Naturally, the kinds of place-based investigations that we have been considering will often include scientists as collaborators or participants, whether the project is explicitly a "citizen science" project or not. While scientists have been natural allies and resources for science education, however, the actual enactment of school-scientist partnerships is not always straightforward. A basic consideration is what the functional role of the scientist is to be. It may be as an advisor to the project, providing specialist input in design questions, evaluation of technology, etc. It may be as co-designers of materials (curriculum or reference materials) or as resources for teacher education. Scientists can support students' motivation and engagement by sharing what they do, and what's exciting about it. Or they can take direct interest in the actual project work on the ground, or in the data that is being collected by the project. In all these cases, there will need to be careful conversations about roles and expectations, to take into consideration the different cultures and constraints of scientists, teachers, and students (Trautman et al 2012, Zoellick et al. 2012, Drayton and Falk 2006).

Recommendations for Researchers

Projects such as those addressed in this month's Theme touch on several areas of research, including:

- if a project is designed and developed by a university or other agency that is collaborating with the school, what is the unit of collaboration within the school districts — is it the teacher, the school, or the district? What do these different strategies require in terms of partnership formation, design for sustainability, or the possibilities of spread of participation within a district?
- What kind of learning burden does the program place on participating teachers, and how is that addressed in the design? How is teacher learning and participation supported by the schools, and what logistical or other school-cultural factors need to be altered or adapted to facilitate teachers' participation and growth in expertise?
- Do students acquire persistent expertise in the crafting of researchable questions, design of methods, or analysis and presentation of data as a result of their participation in these programs? What may be the contributions of various factors, such as the tools used, the mediation of teachers, the participation of scientists, or of the designers?
- What is the scientists' experience in these projects? For example, a study of one scientist-teacher collaboration identified a range of benefits, from a sense of satisfaction in rendering service, to the acquisition of useful research data, to a renewal of excitement about their own work through contact with enthusiastic teachers (Drayton and Falk 1997). How can an understanding of scientists' possible benefits shape project design?

Recommendations for Administrators and Policymakers

Science projects that are place-based with an attention both to environmental issues and social justice may require considerable flexibility to enable teachers and students to participate effectively, raising logistical issues around field work, teacher professional development, and event planning. Administrators can play a decisive role in the success of such programs, if they take an informed interest in the outcome, and help negotiate the practical constraints that are part of all school cultures.

Even if the project makes its primary point of contact with a single participating teacher, administrators and policymakers can play a valuable role in building or negotiating community partnerships, to support and sustain the innovation.

Administrators and policymakers can facilitate such community-based STEM learning by identifying and addressing issues of access to tools or resources that might result in restricting participation by some students or community partners. They can also play a key role in working throughout the project to identify possible strategies for wider participation across their district or system, and for sustainability in the future.

Recommendations for Teacher Leaders

Teacher leaders can become informed about projects such as those featured this month in the panel and playlist, that combine student STEM practice with community issues and raise the idea with their colleagues. They can identify and encourage teachers who show an interest in this direction for their work to take leadership in contacting community groups, environmental non-profits working in the area, or teachers elsewhere who have participated in such efforts. Aside from playing such a catalytic role, teacher leaders can also play an important role in capacity building, by identifying teacher professional development opportunities that can support colleagues with respect to content knowledge, gaining expertise with technology or other tools, and collaboration with citizen science projects in their area.

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