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Citizen Science for Maine's Classrooms: The Case for Improving STEM Learning

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Abstract

Education, business, and community leaders recognize the need for increased emphasis on science, technology, engineering, and mathematics (STEM) education to prepare students for future careers and citizenship. STEM education best practices increasingly call for engaging students in doing the work of science, and citizen science offers an exciting opportunity for this type of teaching and learning. Maine has a unique opportunity, because of the size of our state and the number of research and education organizations engaged in citizen science, to offer citizen science experiences to a statewide cohort of students. Through this work, Maine can serve as a model to school districts, states, and regions for impactful and authentic STEM learning that reaches all students.

In the face of increasingly complex environmental and policy challenges, society has placed increased emphasis on science education—or more broadly science, technology, engineering, and mathematics (STEM)—to support career readiness for students and to develop an engaged and prepared citizenry. The National Research Council 2008 report *Ready, Set, Science!* describes four reasons to teach science well (Michaels, Shouse, and Schweingruber 2008: 3):

1. Science is an enterprise that can be harnessed to improve quality of life on a global scale.
2. Science may provide a foundation for the development of language, logic, and problem-solving skills in the classroom.
3. A democracy demands that its citizens make personal, community-based, and national decisions that involve scientific information.
4. For some students, science will become a lifelong vocation or avocation.

The Maine Department of Labor report *Science, Technology, Engineering and Mathematics (STEM) Employment in Maine: A Labor Market and Workforce Assessment* projected greater job growth for STEM occupations than average job growth for all occupations across the state and noted that Maine workers in STEM occupations earned on average a 58 percent higher wage than workers in non-STEM occupations (MDOL 2008). A more recent estimate projects that between 2017 and 2027, there will be 6 percent growth in Maine's STEM job sector and 0 percent growth in non-STEM jobs, compared to 13 percent and 9 percent, respectively, nationally. Despite this demand, not enough students enter the workforce qualified for those careers (Change the Equation 2015). Preparing students for careers in Maine and beyond demands investing in improved STEM education for all students across the state. This work is critical for the future economic prosperity of Maine students and to the economic success of Maine as a whole (MDOL 2008).

We exist in an increasingly complex world with more access to information and data than ever before. So students need to be prepared to use available information to make personal, community-level, and policy-level decisions to address these challenges. Climate change presents a particularly clear example of a scientifically complex and politically mired issue. For example, the Gulf of Maine is warming faster than 99 percent of the world's oceans, a warming that has contributed to the loss of the Gulf's cod fishery (Pershing et al. 2015). The story of the decline in the cod fishery highlights the importance to Maine's economic future of today's students learning how to collect, evaluate, synthesize, think critically about, and reason with complex data. If citizens are skilled in such thinking, perhaps we will be able to avoid future losses of economically critical species, maintain the health of the ecosystems and natural resources that we depend on, and respond or adapt more rapidly to changes in those systems.

Maine is well positioned to improve STEM education and to be a leader and model for other states in how to achieve equitable and broader STEM literacy for all students. The Maine Department of Education's *Statewide Strategic Plan for Science, Technology,*

Engineering, and Mathematics (STEM) reiterates the assertion that access to quality STEM learning opportunities can improve student career choices and decision making as engaged citizens (MDOE 2010). The report outlines a vision where Maine students "have equitable access to effective STEM instruction; receive instruction in which STEM concepts are applied and integrated; and understand the relevance of STEM to their communities and to their own career aspirations" (MDOE 2010: 1).

Citizen science is a promising strategy to support this vision for learning. Because of the number of institutions engaged in citizen science efforts across the state, the scale of our student and teacher populations, and the willingness of Maine teachers to innovate and share their experiences with their peers, Maine schools can realize the potential that citizen science offers to engage all Maine students in deep STEM learning.

LEARNING SCIENCE BY DOING SCIENCE

Science is not just a set of facts to be memorized, but it is a way of thinking about and exploring the world. Efforts to improve science education have identified the need to engage learners in the processes and practices of science to move learners toward approaching questions and problems the way STEM professionals would. The NRC report *Ready, Set, Science!* represents this vision through its four strands of science learning (Michaels, Shouse, and Schweingruber 2008: 20):

1. Understanding scientific explanations.
2. Generating scientific evidence.
3. Reflecting on scientific knowledge.
4. Participating productively in science.

This thinking is reflected in the latest national standards in science, the Next Generation Science Standards (NGSS), which integrate crosscutting concepts, scientific and engineering practices, and disciplinary core ideas. The document that predated the NGSS, *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, articulates a path forward for science learning experiences that interweave these three dimensions for meaningful STEM learning. The framework articulates the following vision (National Research Council 2012: 9):

> The learning experiences provided for students should engage them with fundamental questions about the world and with how scientists have investigated and found answers to those questions. Throughout grades K–12, students should have the opportunity to carry out scientific investigations and engineering design projects related to the disciplinary core ideas.

By the end of the 12th grade, students should have gained sufficient knowledge of the practices, crosscutting concepts, and core ideas of science and engineering to engage in public discussions on science-related issues, to be critical consumers of scientific information related to their everyday lives, and to continue to learn about science throughout their lives.

Although Maine has not adopted the NGSS as state standards, much of the work happening in Maine science classrooms has been informed by the framework and the resulting standards. In our work with teachers, including informal surveys and in-person communications, most have stated that their curriculum is targeting NGSS learning standards. In addition, even the existing Maine Learning Results, developed in 2007, represent some of this same thinking through its unifying themes and skills of scientific inquiry and technological design process.

Curriculum providers, school leaders, and teachers all recognize that this type of learning requires new classroom experiences for students. Citizen science represents one promising method to foster and support these types of experiences. Citizen science is characterized by public engagement in scientific projects (McKinley et al. 2015). The public may engage with the project in a range of ways from contributing data to inform professional scientists' investigations to developing investigations alongside the professional scientists (Shirk et al. 2012). The project may be designed to engage and support novice participants or to engage more experienced volunteers. The participant experience may include connections and interactions with practicing scientists. Through these experiences, students conduct authentic investigations and use the associated science and mathematics practices. Environmental science, natural resource management, and conservation have already proven to be promising contexts for engaging the public in citizen science (McKinley et al. 2015; Shirk et al. 2012). A focus on environmental and natural resource–related questions connects participants to critical and complex issues that are locally relevant. This work has the potential to increase interest in, and understanding

of, science (Bonney et al. 2014; Crowley et. al 2015; Hiller and Kitsantas 2014; Trautman et al. 2013; Zoellick et al. 2012) making it a promising strategy to support STEM learning.

The range of citizen science experiences has the potential to be a rich opportunity for student learning that cuts across content areas, particularly emphasizing the skills involved in working with and analyzing data. Kastens (2014) describes a hypothesized learning progression where students move from informal, unstructured observations of the world, to working with small datasets that they collect themselves, to using large, professionally collected datasets to answer well-defined questions, to analyzing and working with large datasets in the context of ill-defined problems. Learning experiences developed around citizen science participation allow students to move across multiple stages of this progression. When students contribute to citizen science projects, they are being supported to move from informal observations of the world to collecting relevant and meaningful data. In that context, they can use their data to answer questions appropriate to their level of expertise (examples in our work include looking at impacts of invasive species on biodiversity on the school campus or monitoring how a species' population may be changing over time). That experience prepares them for working with a larger dataset, one to which they have contributed. The questions students explore with the larger dataset may parallel or diverge from the questions scientists are answering with the same data, but knowing that they are contributing to and using the same data as professional scientists may be a motivating force for the students (Zoellick et al. 2012).

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Creating a context for authentic science investigations does not ensure the learning outcomes described. Projects designers must consider not just how the students will be doing science, but how they will reflect on and come to understand the nature of scientific inquiry through that experience. Bringing citizen science experiences into classrooms demands effective and thoughtful curriculum development; rich and prolonged teacher professional development; supportive school leadership; in-class, online, and in-field support from volunteers, program providers, and experts; and funds to support field trips and equipment costs. Teacher, curriculum, and district leaders are critical partners in this work.

ACHIEVING THE VISION FOR ALL MAINE STUDENTS

Focusing on Middle School

Middle school grades offer a promising space to focus our work. Tai et al. (2006) found that science learning experiences before high school may be most significant to influence students' science career aspirations. While it is important to support more science learning in the elementary grades, a convergence of middle school learning standards in math and science encourage a rich, authentic investigation experience where students can engage in the full suite of scientific practices.

In the 2015–2016 school year, Maine had 40,509 students enrolled in grades six through eight (approximately 13,500 per grade).[1] While distributed across a large geographic region, we can reach all of those students at least once in their middle school careers with a citizen science experience. Through our citizen science program Vital Signs, we reach an estimated 2,700 students each school year, and through our LabVenture! program, we reach 70 percent of the state's fifth and sixth graders each year. Our work suggests that the scale of Maine's student population makes it feasible to reach students across the entire state.

A focus on middle school also supports the interdisciplinary potential of citizen science investigations. Middle school teachers are more often organized and supported to work across content areas, in contrast to the high school level where teachers are organized in content area departments. A broad middle school focus, along with a range of potential citizen science programs to engage with, allows schools and districts to home in on the grade-level where implementation makes the most sense. This work needs to start with a statewide group of scientists and citizen science project partners working alongside educators and district leaders from early-adopter districts who are willing to lead the way and model the possibilities for other districts.

Supporting Teacher Learning Communities

Professional development for teachers is an essential step for classroom implementation, and learning experiences need to be prolonged and supported over a number of years. We have found that what may start as a few small modifications to their curriculum becomes, over time, a completely new way of doing things. We encourage teachers to start with small steps and evolve their practice each year to achieve a larger transformation of science learning in their classroom (Morrisseau and Voyer 2014).

Through our teacher professional development work, we connect participants with peers and teacher-leaders who can give them a vision of what student learning can look like through citizen science. Over the course of the last eight years, we have worked with nearly 400 educators from across Maine, with more than a third participating in multiple professional development events. To reach more teachers and support them more effectively over time, we now emphasize building professional communities, regional groups of teachers who are ready and willing to support one another and share the challenges and solutions that they encounter. These teacher communities are a promising avenue to reach all Maine's middle school science teachers, to support them over time, to help them bring deep science learning through citizen science to their classrooms, and to do so without exhausting our program resources. Programs will have to meet teacher and district curriculum needs and be adaptable to the local context.

Creating Synergy across Maine's Citizen Science Efforts

A number of institutions are already working to bring citizen science into Maine classrooms. Moving forward, we should aim for a broader synergy across our efforts. Currently, Maine teachers face multiple opportunities that often compete for their professional development, planning, and classroom time. Program providers should work together to ensure that our professional development and curriculum can work to increase teachers' comfort no matter which programs they integrate into their classroom. We can actively identify those places of convergence for participants, as well as places where they might seamlessly flow from one experience to another. It takes significantly more time, and possibly other resources, to engage in a citizen science–based, authentic investigation, so we also need to make the case to school and district leaders that these experiences foster powerful learning. The field of citizen science is still trying to illuminate the best practices for supporting student learning. Perhaps through an annual conference or workshop for Maine practitioners and a broader effort to synthesize our efforts, we will help fill in the gaps and develop a model for statewide citizen science learning.

Despite 20 years of trying to improve STEM education to support future career success and to foster critical thinking, much work remains. Maine has all the necessary ingredients to implement citizen science as an innovative strategy to improve STEM education at a state level. Where other regions may make a commitment to reaching all students in a city or a county, we can reach students from Kittery to Madawaska, from Lubec to Jackman. Engaged and committed research and education institutions, district and teacher-leaders, and teacher learning communities all have a critical role to play in this work. Bringing our work together, building on one another's efforts, generating implementation models, and describing best practices are the first steps to ensuring each Maine student has an opportunity to learn science through citizen science.

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ENDNOTE

1. Student population data is from http://dw.education.maine.gov/DirectoryManager/Web/maine_report/SnapshotGeneral.aspx

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