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Will the Adoption of Science Standards Push Maine Schools Away from Authentic Science?

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by Bill Zoellick and Jennifer Page

Abstract

Maine is considering revision of rules that provide guidance to school districts about the science knowledge students are expected to have as they graduate from high school. Some science educators suggest adoption of the Next Generation Science Standards (NGSS) as a substantial component of the rules. In this paper, we argue that the NGSS are overly prescriptive and narrow and that a NGSS-based standard would push science instruction toward *school science* where outcomes are known in advance and away from *authentic science* where students explore questions that are useful to the community because answers are not yet known. Our experience has been that authentic science learning is more likely to re-engage students who have decided that science learning is for others, not for them. We seek to stimulate a deep, careful consideration of the consequences of moving toward standards based on the NGSS.

STANDARDS AND AUTHENTIC SCIENCE

Maine is considering replacing its decade-old Maine Learning Results for Science and Technology with rules based upon the Next Generation Science Standards (NGSS). Viewed at a high level, the NGSS are built around the important idea that science instruction should not just be about specific chunks of current scientific knowledge, but should instead introduce students to knowledge through the practice of science with attention to crosscutting concepts (e.g., cause and effect, patterns) that are at the heart of scientific inquiry. At this high level, teaching aligned to NGSS is likely to improve science learning. But the NGSS are not just a set of big ideas about science teaching. They are a set of standards and, as such, if they are adopted as the rules identifying the science knowledge that Maine students will be expected to demonstrate, there will be no such thing as *NGSS-aligned*. Either students will meet the standards or they will not.

Over the past year, we have gained experience in working with schools that have already adopted the NGSS locally. In the course of that work, we have found that the NGSS make it difficult to provide authentic science learning. We do not believe that anyone wants that outcome, but we also recognize that not many people have worked closely enough with the NGSS as binding standards to understand how their adoption as the official regulatory guidance for science teaching in Maine will make it more difficult to support multiple, truly alternative pathways toward proficiency-based graduation.

We begin this paper by explaining what we mean by *authentic science* learning and what makes it different from conventional *school science*. We then provide examples of how the NGSS performance expectations conflict with authentic science learning. We conclude by arguing that NGSS, when adopted as standards rather than as a set of useful big ideas, is biased toward meeting the needs of a minority of Maine's students and has the potential to exacerbate the tendency for many students to see science as something that is for other students, but not for them. We offer these views and arguments with the hope that we can stimulate deeper consideration of the strengths and weaknesses of the NGSS before we make them the basis for the rules that drive science education in Maine.

WHAT MAKES AUTHENTIC SCIENCE LEARNING AUTHENTIC?

In traditional school science, the data that students collect and the work that they do have no consequences beyond the classroom. At the end of the year, their measurements and analyses are discarded or perhaps saved in a portfolio. The next year, a new group of students does the same experiments over again.

In contrast, the scientific work that students do matters in authentic science learning. For example, during the 2017–2018 school year, students from Sumner Memorial High School in Sullivan, Maine, are collaborating with shellfish committees and a Maine Department of Marine Resources (DMR) scientist to develop a better understanding of soft-shell clam settlement and predation by green crabs in local clam flats. The shellfish committees and the DMR would be unable to undertake investigations at this level of detail without the help of teachers and students. As another example, students at the Edna Drinkwater School in Northport and Vinalhaven School (both in Maine) are evaluating aquaculture methods for multiple marine species. These students are designing their own experiments. Their kelp lines are subsampled for a University of Maine study on value-added siting for sea vegetable farms in coastal Maine. The kelp lines and the data exist because of the students' work.

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These kinds of investigations change the relationship between the school and the community from places where students are "learning to leave" (Corbett 2007) to places where students are directly engaged in the work of the community. Maine is currently at the forefront in developing these kinds of authentic, community-centered science education programs, along with developing an understanding of what is needed to support and expand this kind of learning in schools.

HOW AUTHENTIC SCIENCE DIFFERS FROM SCHOOL SCIENCE

School science is usually broken into units and instruction proceeds from unit to unit. For example, students might study erosion and deposition for a number of weeks and then move on to plate tectonics. Investigations in school science often fit within a unit. An investigation may take an entire class or might extend over a number of classes, but in comparison with authentic scientific work, school science investigations do not last long. This is possible in part because what the students will learn and how they will learn it are planned out. Teachers do not expect to be surprised at the outcomes of investigations in school science.

Authentic science learning is different. For example, part of the Sumner High School students' project focuses on overwintering of green crabs. No one knows what proportion of green crabs leave the clam flats for deeper water. Developing an understanding of the seasonal movement of green crabs will require more than a few class sessions or a few weeks. It will involve deciding how and where to trap the crabs, looking at the resulting data, coming up with conjectures, and testing those conjectures. The results will lead to new questions that may require collaboration with people in other places. Developing a working understanding of how and where crabs overwinter may stretch over a few years, so this year's students will need to document their conjectures and findings so that next year's students can pick up the inquiry.

In working through all of this, the students will have the opportunity to learn things about science that students conducting school science only read about. They will learn that conjectures rarely come out as planned and that this is how science makes progress. They will come to understand that when scientists are not able to answer a question directly, it is not because they are hiding something or don't know anything, but because good science is usually tentative and often uncertain. They will learn why this matters.

It should be clear from this example that, in some ways, authentic science goes deep into a problem while school science focuses on breadth, surveying many topics that are loosely connected, if connected at all. But authentic science is not just about depth; breadth emerges from pursuit of a question as it raises new questions and from following the data and questions wherever they may lead. Science, particularly science aimed at learning about complicated ecological systems, becomes increasingly interdisciplinary as it attempts to deepen understanding of how things work. In authentic science, breadth and depth are interconnected, rather than in opposition to each other.

UNINTENDED BARRIERS

We rarely meet a district or school administrator who does not get excited about the idea of seeing more authentic science education in schools. As required by Maine law, schools are now moving toward high school graduation requirements that are based on students' ability to demonstrate proficiency, rather than a focus on passing grades. There is a sense among teachers and administrators that the shift to proficiency-based graduation will support more engagement in authentic science.

State regulations about science and technology standards shape the definitions of science proficiency that schools use to decide when students are ready for graduation. The rules at the state level can either expand or constrain the options the school districts consider. As of this writing, the regulations governing science instruction are encoded in a version of the Maine Learning Results that was last revised in 2007. In what follows, we will refer to these 2007 rules simply as the MLR.

Figure 1 contains the MLR for knowledge about ecosystems, which is the domain of science in which the Sumner High School students are working as they explore questions related to clam populations. Figure 1 illustrates that the MLR are largely *descriptive* rather than *prescriptive*. They are descriptive because they describe what students should know. They are not prescriptive because they do not prescribe exactly how students should demonstrate this knowledge.

The Maine Department of Education is now considering replacing this version of the MLR with a revised version based on the NGSS. Figure 2 presents the NGSS performance expectations related to ecosystems.

The first thing that one might notice in comparing these two figures is that there are more performance expectations than MLR standards for ecosystems. Looking more closely, one realizes that the NGSS performance expectations prescribe assessment of very specific combinations of performances with content, whereas the MLR describe the desired competencies more generally, with fewer references to specific science content or methods to demonstrate proficiency. The specificity is

Figure 1: Maine Learning Results for Ecosystems

Students describe and analyze the interactions, cycles, and factors that affect short-term and long-term ecosystem stability and change.

a. Explain why ecosystems can be reasonably stable over hundreds or thousands of years, even though populations may fluctuate.

b. Describe dynamic equilibrium in ecosystems and factors that can, in the long run, lead to change in the normal pattern of cyclic fluctuations and apply that knowledge to actual situations.

c. Explain the concept of carrying capacity and list factors that determine the amount of life that any environment can support.

d. Describe the critical role of photosynthesis and how energy and the chemical elements that make up molecules are transformed in ecosystems and obey basic conservation laws.

Figure 2: NGSS Performance Expectations for Ecosystems

HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

HS-LS2-3. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.

HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.

HS-LS2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

HS-LS2-6. Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

HS-LS2-8. Evaluate evidence for the role of group behavior on individual and species' chances to survive and reproduce.

what makes the NGSS performance expectations attractive to science teachers charged with creating common assessments of proficiency. The NGSS performance expectations say exactly what the student needs to do, while the MLR leave things more open ended.

But the specificity of the NGSS performance expectations creates difficulty for schools interested in engaging students in authentic science and with local problems. Returning to the Sumner High School example, it is not difficult to shape the students' study of clam population dynamics to ensure that they will be able to demonstrate the four competencies enumerated in the MLR. By contrast, the NGSS performance expectations focus on specific, predetermined content rather than on larger understandings that will emerge in the course of the students' authentic work. In following the data and the models that they build, students may not necessarily need to "construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions." Whenever students set aside authentic work to focus on unrelated learning goals, it is just school science—things that students have to do just to graduate.

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Other NGSS performance expectations are also too prescriptive and specific. Here are a couple of examples from other domains.

- **HS-PS2-4.** Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
- **HS-ESS1-2.** Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.

The NGSS contains 71 of these performance expectations at the high school level, with the expectation that students will demonstrate proficiency in all of them. We are concerned that adopting such highly prescriptive standards to serve as Maine's definition of science competency will eliminate time and space for authentic science learning in our schools. The problem is not just the number of performance expectations, but also the degree to which they prescribe the knowledge that students are expected to carry with them out of high school. The only way to guarantee that these particular bits of knowledge will be covered is to contrive a science education program aimed at doing just that. Where is the authentic inquiry in such a program?

WHY THIS MATTERS

The NGSS website speaks of "preparation for careers in science, technology, engineering and mathematics, which are wellsprings of innovation in our economy." It asserts that "to keep their options open and maximize their opportunities, all students should follow a rigorous program in both science and mathematics" (https://www.nextgenscience.org/need-standards).

There are students who are willing to take that advice and dive into the STEM (science, technology, engineering, and math) pipeline. These students take Advanced Placement courses in science and math and thrive in science as it is traditionally taught in schools. Yet, we strongly believe that authentic, community-focused science learning is important for these students too. Such authentic science experiences will expand their understanding that science is tentative and messy and often proceeds slowly. Students should not have to wait until they are pursuing a master's degree to engage in authentic science. But our primary concern is that most students are not like the ones queuing up for the STEM pipeline. Many of these other students will go on to college. Some will even pursue technical careers in computing, medicine, or other fields, but even as they pursue such careers, many of them will still feel that science is something other people do.

We see such alienation from science as a problem. We also suspect that the kinds of highly prescriptive, detailed standards that the NGSS developed make this problem worse, not better. Students might justifiably conclude that someone who thinks that Newton's Law of Gravitation and Coulomb's Law are essential knowledge is seeing the world differently from how they do.

In more than a decade of work with authentic science learning, we have seen many examples of how practical work focused on problems with immediate, local significance opens a door to science for students who had decided that science was not for them. Often the opening starts with a just small sense of competence, but with care and support, that sense of competence can grow. And once re-engaged, some of these students will decide to pursue technical careers. Our experiences lead us to believe that the way to re-engage students with science is to give them interesting, important scientific work to do.

Maine's commitment to multiple pathways toward graduation in its proficiency-based graduation law would seem to ensure that schools should be able to offer authentic science learning along with the more conventional, prescriptive approach to science embedded in the NGSS. However, increasingly prescriptive standards narrow the number of paths available toward meeting them. If Maine revises its specifications for science learning so that they are substantially like the NGSS performance expectations, there may not be room for authentic science learning as one of the multiple pathways.

Talk about standards may seem like something that should be left to experts. The same is true for science. Consequently, there is a great temptation to think that science education standards are something for other people to examine closely, rather than something to think about oneself, but we believe that this is not the case. Moving away from the current MLR to a new version based on the NGSS will have a chilling effect on the vibrant growth of authentic science learning in Maine. Everyone needs to consider this question carefully.

REFERENCES

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