Dear Ms. Templeton:

It is our understanding that the Maine Department of Education is seeking views from educators to inform rulemaking regarding the Maine Learning Results for Science and Technology (MLR). It is also our understanding that the Next Generation Science Standards (NGSS) are under consideration as a model for the revised MLR.

We are educators from three non-profit organizations that work with science teachers to involve students in exploring questions where the answers are not already known and where the students’ work is truly useful, often to the communities where the students live. Because the students’ work has consequences in the world outside of school, the students take it seriously. The students learn that when working with real problems, gaining insight into one question often leads to new questions. We call learning where students use scientific practices and thinking to improve understanding of complex, real world problems “authentic science learning.” This is different than typical “school science” where students perform an experiment, either get the “right” result or not, finish their assignments, and move on to the next lesson.

Over the course of our work we have had substantial experience with schools and districts that use the NGSS in different ways to inform their decisions about science high school graduation standards. We have found that the NGSS has had many positive effects on schools. We have also found that it can diminish opportunities for authentic science learning and can lead, instead, to more school science.

In what follows we share both what we have found to be positive about the NGSS and what has been more problematic. We conclude by offering suggestions about how to hold on to the beneficial parts while avoiding the troublesome ones. It is our hope that these comments will contribute to nuanced, productive thinking about how the NGSS might contribute to strengthening the MLR for Science and Technology while also considering how some elements of the NGSS could impede growth of ambitious approaches to science instruction that are emerging in Maine.

How the NGSS Have Improved Science Teaching in Maine

The NGSS carry forward the three-dimensional conception of science teaching that was developed in A Framework for K-12 Science Education (hereafter, “Framework”) where effective instruction is conceived as a weaving together of scientific and engineering practices, crosscutting concepts, and disciplinary core ideas (DCIs). The benefits that we have seen develop from the substantial attention given to the NGSS in Maine schools over the past few
years are tied to this focus on weaving the three dimensions together. It is noteworthy that the current MLR, last revised in 2007, contain learning requirements that are very similar to the NGSS crosscutting concepts (MLR Standard A), practices (Standard B), and DCIs (Standards D and E). Further, the 2007 MLR remind educators that, “It is essential that classroom instruction integrate the processes and ideas of Standards A, B, and C with the knowledge of Standards D and E, rather than teach them separately.” However, our experience in observing and participating in classrooms prior to the emergence of the Framework and the NGSS was that, despite this admonition, most teachers tended to focus primarily on the content in Standards D and E without giving careful thought to how to give similar prominence to practices and crosscutting concepts.

That situation has changed since the introduction of the NGSS. Teachers and students now have access to textbooks and online curriculum materials that weave the three dimensions together, many teachers have participated in workshops and other professional development focused on the NGSS, and science graduation standards in many school districts now emphasize proficiency in the NGSS practices together with content knowledge.

The net effect of these changes has been that we now more often see instruction that encourages students to attend to practices as well as to content. We have seen less attention to crosscutting concepts, but we also see evidence that this is changing. It appears that teachers first had to figure out how to routinely integrate scientific practices into instruction and, now having done that, are beginning to draw students’ attention to patterns, cause and effect, energy flows, and so on. We also note the recent emergence of more professional development focused on crosscutting concepts. We believe that, overall, the quality of science teaching in Maine is now better than what we observed in classrooms as recently as 7 or 8 years ago. We credit the Framework and the NGSS with teachers’ increased commitment and ability to provide three-dimensional science instruction.

Districts, schools, and teachers have also, in parallel with increased attention to the NGSS, begun to pay more attention to authentic science learning over the past five years or so. From conversations with teachers and administrators, we trace this change to a belief that the proficiency that students gain in scientific practices such as asking questions, using data, and constructing explanations is often more durable than are the particular bits of scientific knowledge that students acquire. This shift in focus from content to practices is also due in part to the NGSS.

What is Authentic Science Learning and Why Does it Matter?

A scientific investigation that teachers and students are undertaking this year with assistance from Schoodic Institute serves as an example of what we mean by authentic science learning. The students are working with the Maine Department of Marine Resources (DMR), the local shellfish warden, and shellfish committees from two towns to gain better understanding of how to reduce soft-shell clam predation by green crabs. The interactions that the students are trying to tease apart are complex. The DMR and the town shellfish committees wanted to develop a better understanding of these issues but were limited by limited by manpower: they simply did
not have enough people to do the surveys, analyze and graph the data, and develop conjectures about how this complex system works.

At the same time, the local high school was looking for ways to involve students in meaningful scientific work that would involve posing researchable questions, collecting and analyzing data, building models of systems, developing new questions, and communicating their work to others who were genuinely interested in what the students were finding out.

The Schoodic Institute helped the high school, DMR, and clam fishing community connect with each other. The teachers, students, DMR scientist, shellfish warden, and fishermen are now turning an abandoned lobster pound into a research site and beginning work on what they anticipate will be a multiyear project in which data collection, analysis, modeling, and reasoning by students will play a central role. The program involves students from across the high school population, including students who are at risk of not completing high school and students who expect to pursue science studies in college. All of these students are involved in the full range of scientific practices required by this investigation.

In working through all of this, these 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 just don’t know anything, but because good science is usually tentative and often uncertain. They will learn why this matters.

One of the important features of authentic science learning is that in addition to providing challenging problems and real-world scientific experiences for college-bound students, it re-engages students who have decided that they do not like science and that science is for other students, not for them. Our research into this re-engagement suggests that it emerges from combination of factors that include a sense that the work is important and tied to outcomes beyond school and increased self-efficacy as the students engage in the work with adults and other students, learning that they can contribute personally to the outcomes.

Finally, we note that authentic science learning is not unique to our three organizations. Interest in engaging students in authentic science learning through Citizen Science and place-based and problem-based learning has grown substantially over the past decade. The growth has been particularly strong in Maine. For example, last month a National Academies of Science committee that is preparing a report about learning through Citizen science invited a small number of people to make presentations. For those of us from Maine it was something of a family get-together. The number of people that were there from Maine was wholly out of proportion to the population of our state or the number of students in our schools.

How the MLR Revision Could Put this Work at Risk

Figure 1 contains the current (2007) MLR for knowledge about ecosystems, which is the domain of science that is most relevant to the soft-shell clam population and predation study. These MLR are largely descriptive rather than prescriptive. They are descriptive because they describe
what students should know. The are not *prescriptive* because they do not prescribe exactly how
students should demonstrate this knowledge.

<table>
<thead>
<tr>
<th>Students describe and analyze the interactions, cycles, and factors that affect short-term and long-term ecosystem stability and change.</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Explain why ecosystems can be reasonably stable over hundreds or thousands of years, even though populations may fluctuate.</td>
</tr>
<tr>
<td>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.</td>
</tr>
<tr>
<td>c. Explain the concept of carrying capacity and list factors that determine the amount of life that any environment can support.</td>
</tr>
<tr>
<td>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.</td>
</tr>
</tbody>
</table>

**Figure 1. MLR for ecosystems.**

The work that the students are doing on the clam flats is nearly ideal with regard to these learning results. The students will have to grapple with the issues addressed in these four standards and will need to consider them in different time scales, thinking both about seasonal change and change over longer time spans. From an educational design standpoint, there is no tension between these standards and the authenticity of the learning.

Figure 2 presents the NGSS Performance Expectations (PEs) related to ecosystems. In comparing these PEs to the current MLR, the first thing one might notice is that there are more PEs. Looking more closely, one will also notice that the PEs are more detailed than the current MLR. In their effort to weave together a particular practice or practices with a particular crosscutting concept for each DCI, the PEs become specific and prescriptive. It is this movement from *description* of what the students should be able to do to *prescription* of what they must do, in detail, that can come into conflict with authentic science learning.

Authentic science learning and school science learning both require up-front design work; neither “just happens.” In school science, the desired outcomes are known in advance as are the methods for reaching those outcomes. This foreknowledge of methods and outcomes is what enables teachers and curriculum developers to contrive sequences of lessons that will lead toward each of the prescribed performances in Figure 2.

Authentic science does not work that way. Neither outcomes nor methods can be fully specified in advance. Instead, the work is driven by pursuit of the initial question and the new questions that emerge as understanding grows. Importantly, this is why authentic science is something that working scientists and students like to do and want to do. As Richard Feynman put it, “The
prize is the pleasure of finding the thing out, the kick in the discovery, the observation that other
people use it - those are the real things¹.

| **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. |

Figure 2. NGSS PEs for ecosystems.

The design of an authentic science learning project can and, in fact, must include specification of and attention to learning results at the level of granularity of the current MLR, as in Figure 1. As the students focus on following the lines of inquiry that emerge in the course of their work, the teacher uses the ideas incorporated in the learning results to stimulate and deepen students’ thinking.

But if the learning results shift from the descriptions in Figure 1 to the predetermined combinations of practices, crosscutting concepts, and DCIs in Figure 2, there is no guarantee that students will need to do these specific things in authentic pursuit of the problem. The only way to provide such a guarantee is by setting aside authentic pursuit of the question, at least for awhile, to do some school science that has been carefully contrived to lead to these particular PEs. If a student should ask, “But how does this tie into the model of predation that we have developed?” the answer would sometimes have to be, “Well, it doesn’t really. But you need to meet this standard for graduation.”

An important point to keep in mind is that this conflict with authentic science learning is not an inevitable outcome of the three-dimensional science learning that the Framework and the NGSS have helped stimulate in Maine science classrooms. The kind of authentic science learning that we have described here is wholly consistent with the focus on weaving together practices, crosscutting concepts, and DCIs. We would even argue that it can often bring about and sustain this weaving together more consistently and deeply that school science can. The issue is not that the learning results in Figure 2 are three-dimensional, but that they are so specific, combining practices, crosscutting concepts, and DCIs in such particular ways.

Closing Thoughts and Suggestions

First, as indicated above, we have found that authentic science learning is a valuable approach to teaching science to all students. We are not suggesting that it is the ONLY way to teach science. There are times when one really does want to focus on particular learning objectives and when school science will be the most efficient way to achieve that.

Our concern, instead, is that an overly specific, prescriptive approach to articulating learning results or “performance expectations” can move teachers away from using authentic science learning. We have already seen evidence of that in school districts that have adopted the NGSS PEs as graduation standards.

Our preferred approach to revising the 2007 MLR for Science and Technology would be to:

- Revise standards A and B so that they are even more consistent with the NGSS crosscutting concepts and practices.
- Review standard C in the light of the Framework and recent research on the Nature of Science.
- Retain the high level, descriptive character of Standards D and E.
- Strengthen the language and other supports for a three-dimensional approach to science instruction.

As we noted at the beginning of these comments, we believe that the movement to threedimensional science instruction is already well underway thanks to the availability of new curriculum materials and professional development since the publication of the NGSS.

An alternative approach, which might be coupled with the preferred approach, would be to present the NGSS PEs as examples of the kinds of proficiencies that students should be able to demonstrate, rather than specifying them as the particular performances that must be demonstrated.

There is a deeper question about how one conceives of science teaching that underlies the consideration of different approaches to specifying learning results that we have explored in these comments. In our view, prescriptive learning results that are at the level of specificity of the NGSS PEs reflect a decision to place greater emphasis on design decisions made by the expert authors of the NGSS and less emphasis on design decisions that teachers can make as they respond to students’ interests and needs and to local learning opportunities. Our preference is to provide teachers with greater flexibility so that they are able to draw upon their
own knowledge of local resources, their community, and their students to create science learning that is responsive to local context.

Our close observation of science teaching and learning over the past decade has been encouraging in that we have seen greater emphasis on science teaching in general, including instruction at the K-5 levels, and more three-dimensional instruction and less emphasis on teaching sciences as facts to learn. We credit the Framework and the NGSS for much of this progress. The comments we offer here are intended to assist in continuing and accelerating that improvement.

Bill Zoellick  
Education Research Director  
Schoodic Institute at Acadia National Park  
bzoellick@schoodicinstitute.org

Dr. Jennifer Page  
Director of Education  
Hurricane Island Foundation  
jenn@hurricaneisland.net

Yvonne Thomas  
Education Director  
Island Institute  
ythomas@islan
dinstitute.org