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STEM Education Policy in Maine and the Nation

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by Thomas E. Keller

Thomas Keller provides an overview of K-12 STEM (science, technology, engineering, and math) education policy in Maine and the nation, and makes recommendations for several agencies in the state. He argues that although standards and assessment are important, there need to be corresponding changes instructional materials methods and in school culture. Although we do not yet have a fully integrated STEM curriculum, Keller suggests that "we are overdue for interdisciplinary work where possible."

INTRODUCTION

Recent policy reports have made urgent calls for improving U.S. STEM (science, technology, engineering and mathematics) education in response to both poor test performance by U.S. youth and worsening economic conditions in this country (Committee on Prospering in the Global Economy 2007; Carnegie Corporation 2009; PCAST 2010). These documents are filled with comparative statistics that show the relative decline of U.S. students' test performance and national competitiveness and the increase of both in other nations.

The broad-brush analyses in these reports call for reflection on the status, goals, and actions that have brought the nation and its K-12 students to this low point and consideration of the status of STEM education as the perceived solution to the problems our nation is facing. This article is written for two purposes: first, to offer a perspective on the STEM education policy at the national and state levels, and second, to apply that perspective by making recommendations to be taken by various agencies in Maine.

THE STATUS OF STEM EDUCATION IN K-12

In many respects, STEM education is in its infancy. Indeed, STEM might reasonably be described as still in its neonatal state. Full models of STEM education, that is, ones that integrate the content and processes of science, technology, engineering, and mathematics into one highly coherent STEM curriculum, at any grade level are rare, and across the K-12 span are largely non-existent. The Board of Science Education of the National Academies has recently begun a study on "iSTEM" (www7.nationalacademies.org/bose/iSTEM_homepage.html), but the final study report is still many months away and seems likely to point to the promise rather than the actuality of integrated STEM education in schools.

The promise of integrated approaches to STEM that ensure continuity across the educational spectrum is becoming more tangible, due to recent efforts both at the state and national levels. The recent development of the national Common Core State Standards for Mathematics and English Language Arts (ELA) (www.corestandards.org), and the soon-to-be-developed Next Generation Science Standards (NGSS) (www.nextgenscience.org) provide unprecedented opportunities to create a more coherent and coordinated educational system nationwide. The ELA standards already make a link to science by including a section on science literacy, emphasizing the skills of critical reading and writing of non-narrative texts that are so central to today's information age. It is expected that the NGSS will increase the coherence by creating specific standards that are parallel or even overlapping with the mathematics ones. For example, both emphasize the importance of learners developing a set of domain-specific practices.

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The use of the term "practices" was deliberate, at least in the science education field, as a way to signal that scientists use these skills as they conduct their investigations and work (thus, practice) and that students must practice the skills to become proficient. Practices cited in the standards include developing and using models and planning and carrying out investigations (for science and engineering), and using appropriate tools strategically and attending to precision (for mathematics). One example of the parallelism is the clear overlap between the mathematical practice of "constructing viable arguments and critiquing the reasoning of others" with the scientific and engineering practice of "engaging in argument from evidence." The concept of practices integrates content and processes by emphasizing the criticality of content knowledge along with the ability to apply and use this content in meaningful ways. Because of this, the new focus on practices may help teachers to teach knowledge within authentic contexts of use, rather than as disembodied abstractions to be memorized. The full set of science standards is being built from foundational work put forth in *A Framework for K-12 Science Education* (NRC 2011a), which outlines a vision for science education along with three dimensions for it (a limited set of core ideas, scientific and engineering practices, and crosscutting concepts). These standards are still in a developmental stage and Maine is one of 26 lead states participating in their creation under the guidance of Achieve, Inc. This is an important effort and is the first step toward a coherent system.

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Simultaneous with the development of national standards, there are significant changes in the landscape of assessment that also offer significant opportunities for better learning. For example, "Race to the Top" funding is supporting two assessment consortia to create assessments that, among other goals, support and inform instruction. These developments have the potential to redefine assessments, but we need to keep expectations realistic and be ready to build on what will surely be beginnings rather than complete systems. With the availability of waivers for adequate yearly progress as currently written in the No Child Left Behind legislation, drafts of a revised Elementary and Secondary Education Act that point to the limitations of current assessments, and the expectations that the Race to the Top assessment consortia will generate superior assessments, the pressure felt by states to identify a failing school is prematurely lessening. Unfortunately, this may end up addressing the symptom without addressing the disease. The public should not entirely eliminate accountability measures that have done an outstanding job of pinpointing lack of educational equity; rather, we should demand that those measures be designed to more comprehensively show what students can know and do.

With any luck, the new standards and the new assessments will align in calling for instruction that emphasizes productive practices, but even this may be insufficient to guarantee success in our schools. Students will perform no better, even on better tests built on better standards, without corresponding changes in curriculum materials, instructional methods, and school culture. Complex systemic problems always require systemic solutions, and it will be the responsibility of states and districts to support the coherent vision at the local level.

As recently as the early 2000s, Maine was leading the nation in these content areas and assessment as a result of work on a comprehensive local assessment system that was designed to include a state-testing component with a curriculum-embedded one. Teacher-based teams in science, mathematics, English, language arts, and social studies generated standards-based assessments, and thousands of hours of professional development were undertaken across the state. As a result of this effort, the assessment literacy of teachers and administrators (and state department of education staff and higher education faculty) was increased statewide, and instruction and assessments built to common standards was becoming common.

Currently Maine uses the New England Common Assessment Program for testing in mathematics and reading in grades 3-8, and uses the SAT as the major portion of its high school assessment. There is no longer any curriculum-embedded component to measure attainment of standards, so all scores depend on high-stakes test results from state assessments. In science, the state creates and implements its own test for grades 5, 8, and 11. Professional development in assessment as a statewide activity for teachers and administrators is not conducted as it once was, yet the needs for understanding the level of performance of each student is just as great.

Another relevant development is the changing role of engineering and technology, the "E" and "T" in STEM. In spite of a flurry of interest at the national level, these are subjects that continue to have little traction in most K-12 schools. Technology has always suffered from an identity crisis: Does "technology" mean the use of laptops and other technology-based instructional tools, or is it the set of courses taught in some middle and high schools around topics such as small engines and machine tools, or is it that which is taught in career and technical education centers, or even some of combination of these? There are other obstacles to broader uptake of these subjects at the K-12 levels. For example, science and mathematics teachers are often lacking the professional development, confidence, resources, or time to embed key concepts and principles from their subjects in a design-focused lesson structure. And, pockets of "T" may be taking place outside comprehensive schools. An informal review of the Maine Department of Education's Career and Technical Education (CTE) web site shows that much technology education is underway in this area at CTE schools. However, even in CTE schools there seems to be little or no integration of STEM subjects. There is reference to a technology and mathematics program in CTE schools, but little mention of STEM education, per se. Going forward, technology needs to be given greater credence in comprehensive school programs, but only if well integrated with science, engineering, and mathematics (and ELA).

Engineering educators have done much work nationally, supported largely by the National Academy of Engineering (NAE) and the International Technology and Engineering Education Association, to advance more widespread teaching of engineering education. This is evidenced by the implementation of two curriculum projects: Engineering Is Elementary (www.mos.org/eie) and Project Lead the Way (www.pltw.org/). Two recent reports (Katehi, Pearson and Feder 2009; NAE 2010) conclude that, although much work in curriculum and instruction has been accomplished, the field is not quite ready for a full set of K-12 standards. There is, however, promising research indicating that instruction in engineering process and design lead to greater student achievement in mathematics and science, and both reports recommend that engineering be incorporated as a pedagogical approach to teaching science and math. This research also led to the inclusion of engineering design as both a practice and a core idea in *A Framework for K-12 Science Education* (NRC 2011a). In other words, engineering has made entry into K-12 science standards that may become common across the country. The embracing of engineering, especially the design process, was facilitated by common scientific and engineering practices and the value for K-12 students to experience both science and engineering for career exploration, use in everyday life, and personal interest.

SUGGESTED ACTION STEPS

If research and practice have yet to create a system of integrated STEM education (as opposed to the separate content areas of science, technology, engineering and mathematics), and our students continue to perform poorly on separate current measures S,T,E,M, what are meaningful short- and long-term goals for educators and the general public?

This takes us back to the national (and I propose state) goals of STEM education, which the NRC report *Successful K-12 STEM Education* (NRC 2011b) identifies as

- Expanding the number of students who ultimately pursue advanced degrees and career in STEM fields and broaden the participation of women and minorities in these fields.
- Expanding the STEM-capable workforce and broaden the participation of women and minorities in that workforce.
- Increasing STEM literacy for all students, including those who do not pursue STEM-related careers or additional study in the STEM disciplines.

According to *A Framework for K-12 Science Education* (NRC 2011a), these goals are likely to be achieved, at least in science, by engaging students in studying a set of core ideas through science and engineering practices over multiple school years. A related strand of work on 21st century skills (also known as "deeper learning" or soft skills) indicates that such skills overlap with science education in five areas—adaptability, complex communication/social skills, non-routine problem solving, self-management/self-development, and systems thinking (NRC 2010, 2011c). All of this work points to the conclusion that learning just the facts of science, mathematics, engineering, or technology is insufficient to achieve the three goals cited earlier. What is needed is a definition of STEM that emphasizes interconnections of ideas and practices and support for key players in the state education system.

The changes that are needed are as follows. First, we will need to align goals (and standards) with practice. This is stated in various ways in educational circles though usually the issue is approached from an assessment perspective. Phrases such as "what you test is what you get," "measure what is important," and "teach to the test" each signal the crucial role that assessment plays. If our goals in science education are the three cited earlier (STEM-focused, STEM-capable, and STEM-literate), we cannot develop these capacities by viewing these subjects as discrete bodies of knowledge to be memorized rotely, and we cannot assess them such that instruction is driven to this end. Assessment is just one area of misalignment between goals and practices, but it is a particularly important one. Maine has the opportunity to drive the actions of one of the two Race to the Top assessment consortia by being a "governing state." The state should do so by advocating for robust, technology-based platforms that allow for high-powered simulations that provide more realistic and authentic assessment (and learning) in science along with math and ELA. Learning about assessment for formative and summative purposes and for alignment with standards and instruction has multiple entry points for professional development for teachers and administrators. Finally, a state-level data system must be built from local school-level data systems, which is founded on a system of common aligned standards, curriculum, instruction, and assessment to yield meaningful results.

Second, we need to take advantage of school as a group experience. Scientists and engineers operate in teams or at least in a social environment. They must work together and communicate clearly and effectively. Looking across current STEM policies, social engagement is a strong theme. For example, the Common Core State Standards for Mathematics refers to the importance of being able to construct viable arguments and critique the reasoning of others. *A Framework for K-12 Science Education* (NRC 2011a) cites engaging in argument from evidence and obtaining, evaluating and communicating information. *Engineering in K-12 Education* (NAE 2009) urges research on how design ideas and practices develop in students over time, and work on 21st century skills identifies the need for complex communication/social skills. Clearly success in the 21st century requires social skills and these necessitate explicit instruction and classroom time. Too many schools in Maine separate students and treat learning as an isolated individual endeavor.

Third, we need more educators who act as leaders. Though it is evident that teachers are most important for the improvement of improving student achievement, research has shown that school leadership and school climate are vital to establishing the conditions for success in schools (Bryk et al. 2010). Maine must have effective, learning-focused principals, curriculum coordinators, lead teachers, or some structure that provides consistent supportive educational leadership in schools, and we need a system that produces, develops, and sustains these talented individuals. Greater coordination across advanced learning opportunities (be they at in-state higher education institutions or cohorts of Maine educators enrolled in out-of-state institutions) would lead to better efficiency and the chance to give focused attention to Maine's issues. For example, regular colloquia on research findings and their relationship to practical needs should be instituted in both face-to-face and distance-learning formats.

Fourth, we need to cross content lines. Clearly there are basics in each subject area (e.g., multiplication in math) that must be learned in order to apply them across subject areas (e.g., determination of momentum in physics). Knowledge of and facility with the multiplication tables are necessary for chemistry and physics; knowledge of and facility with reading a multitude of genres of text are vital for approaching an article on biotechnology. Unfortunately, students are frequently expected to make these leaps on their own and just as frequently they do not. Flexible application of core ideas across a variety of contexts and topics is strongly promoted (or even mandated) in the practices within the common core mathematics standards; the scientific literacy sections of the common core ELA standards; and the scientific and engineering practices, crosscutting concepts and core ideas within *A Framework for K-12 Science Education* (NRC 2011a). Although we as a state and country are not yet positioned for a fully integrated STEM curriculum, we are overdue for interdisciplinary work where possible. There are schools and classrooms in Maine that serve as experiments and models. Work at Falmouth High School, Durham Middle School, and across South Portland demonstrates how subject disciplines can enhance each other. Indeed at the University of Maine, interdisciplinary work through the Sustainability Solutions Initiative cuts across the fields of social sciences, natural sciences, mathematics, economics, communication, and engineering.

Fifth, we need to train teachers and administrators better both initially and continually. According to data collected by the U.S. Department of Education (title2.ed.gov/Title2STRC/Pages/SupervisedExperience.aspx) Maine currently has 15 institutions (eight private and seven public) that prepare teachers. The U.S. Department of Education also collects data on the average number of clock hours required before student teaching. While the data gathered for this statistic could be interpreted in various ways, and the value of the statistic itself could be questioned, these clock hours for private institutions range from 0 to 600, and for publics from 35 to 120. This variability seems unreasonably large considering that all of these are preparing students for the same K-12 classrooms. More coordination among these programs would identify common goals and lead to sharing of best practices. In the interests of efficiency and coherence, it may also be valuable to focus our teacher training and reduce the need for seven public institutions that train teachers in small and separate programs.

Maine does have, or rather had until 2008, a state-funded system of professional development, termed the "Per Pupil Professional Development Funds," which were combined with local funds to create local and regional systems for professional development. Maine still has active teacher and administrator professional societies such as the Maine Science Teachers Association, the Association of Teachers of Mathematics in Maine, and the Maine Curriculum Leaders Association. Led by volunteers with some assistance from Maine Department of Education (MDOE) staff, these organizations are providing important professional development opportunities. At the same time, dependence on voluntary leadership leads to variability. Bringing these associations (and other groups) into a standing advisory council for the MDOE would provide coordination of schedules and focus areas, along with some economies of scale. They also could advise the University of Maine System on its K-12 educational endeavors such as pre-service teacher placement, needs of pre-service teachers, and needed types of professional development. Continuing to have subject-area specialists in the MDOE to serve as the connection between state policy, higher education, and classrooms is necessary to support good teaching and learning in these areas.

Sixth, we need to better mine the research and continually evaluate our actions. Maine has undertaken several unique educational efforts, but these are largely unreported in national peer-reviewed journals and seldom evaluated. Three major projects with connection to STEM are the laptop initiative that put computers in the hands of every middle school student in Maine, the requirement for all high school juniors to take the SAT, and the comprehensive local assessment system. What lessons and best practices have been learned from these? How has this knowledge been transferred to others? How well have they achieved their goals (e.g., for more Maine students to attend post-secondary training as a result of free SAT scores)? When Maine takes the lead with an innovative initiative, we need to invest in related research and evaluation or we have no idea whether we were successful.

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Seventh, knowing that each year's cohort of students is one that we cannot afford to teach poorly, we need to tie together the pockets of excellence we have in Maine—the science-rich businesses and nonprofits, institutions of higher education, distance learning, informal science and environmental education providers, state government, and schools—for the purpose of engaging and keeping youth in STEM pathways. Maine has several economic and education foci that are unique and/or underdeveloped. Certainly we have an active energy research and development community of practice with such groups as Central Maine Power, the Island Institute, Bangor Hydro Electric, the Maine Mathematics and Science Alliance, the Maine Energy Education Project, Efficiency Maine, and the Gulf of Maine Research Institute creating a Maine energy-literacy plan. We have world-class marine resources at the Bigelow Laboratory for Ocean Sciences, University of Maine's Darling Marine Center, Mount Desert Island Biological Laboratory, and Gulf of Maine Research Institute, which house cutting-edge scientific research and provides educational experiences for Maine students. Within the medical field, we have examples such as the Jackson Laboratory, the University of Southern Maine, and the Foundation for Blood Research engaged in life-saving research and educational opportunities for Maine students. In engineering, we have the University of Southern Maine's Manufacturing Applications Center and External Programs, University of Maine's College of Engineering, and Boston's Museum of Science all supporting the interests of Maine students in engineering. Connecting the researchers with the educators at these institutions would bring fruitful rewards to both. Many times, however, we do not capitalize on the opportunity of the proximity of learning and research. Even worse, students and their parents either must have an earlier connection to a program or painstaking search out each opportunity. Building these into educational and research opportunities ("practicing science") and making it easy to locate information on programming is an obvious next step to tying these pockets together.

Maine educational leaders must be bold and cannot let the good enough stand in the way of the excellent. Maine can lead the nation in STEM education.

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