SCIENCE EDUCATION

Opportunities and Challenges in Next Generation Standards

Goals for literacy, math, and science education may increase citizens' capacity to argue from evidence.

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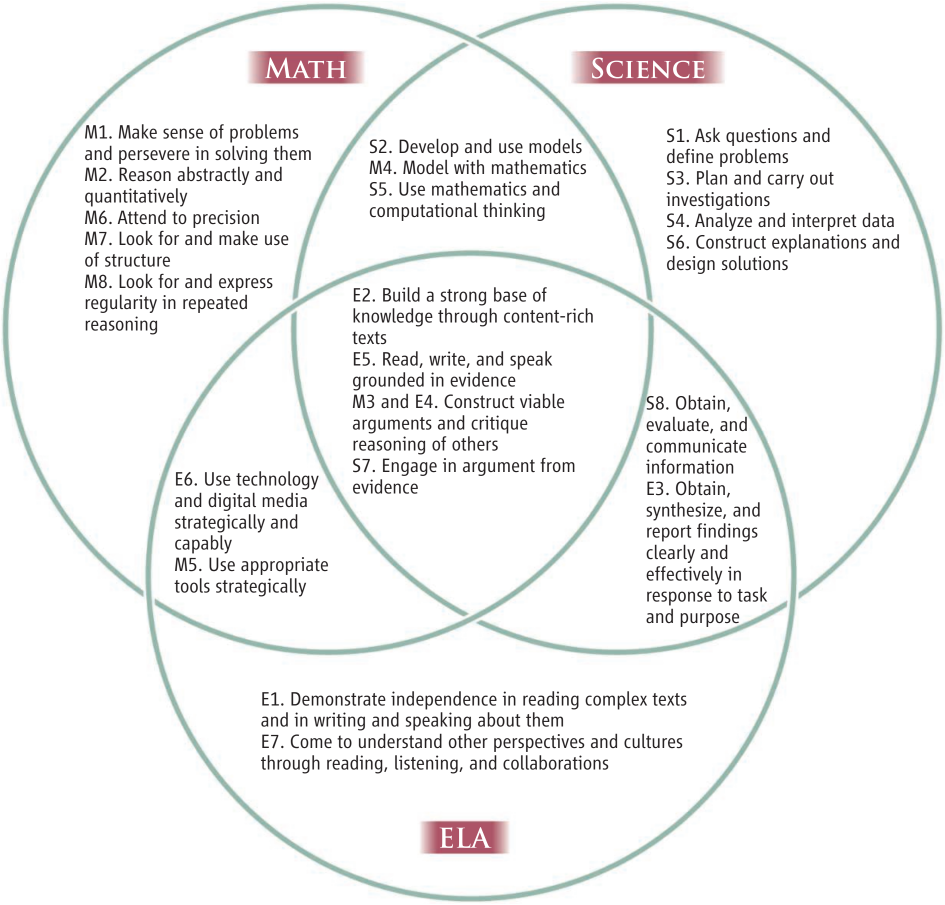
Imagine that politicians and the people they represent understood how human activity impacts Earth, including climate. And imagine that they had learned how to evaluate claims, argue from evidence, and understand models. These understandings and practices are prominent in the U.S. National Research Council (NRC) framework to guide the next iteration of standards for U.S. elementary and secondary school students (*1*). We discuss how aspects such as authorship, coordination among subject areas, and broader goals of college and career readiness give reason to believe that this effort will be more successful than previous attempts to use standards to improve science education (*2*).

Concurrent development in English Language Arts (ELA) ("literacy") and Mathematics, under the Common Core State Standards (CCSS) (*3*, *4*), has provided the opportunity to build on the strengths of these literacy and math documents from a science education perspective. Closely following the CCSS, the Next Generation Science Standards (NGSS) are being developed by Achieve, a nonprofit organization, working directly with 26 lead states (*5*). This structure acknowledges that the standards will be adopted and implemented at the state level.

Past educational standards were developed by professional organizations on behalf of scientists and educators and in different subject areas independently, yielding more material than any K–12 school system (kindergarten to high school) could teach well (*6*, *7*). Now there is a call for "fewer, clearer, and higher" standards (*8*).



Relations and convergences in literacy (*3*), math (*4*), and science and engineering (*1*) practices. Adapted from (*12*).

Building on Literacy and Math

The CCSS focus not only on what it will take to become a successful student in higher education but also a successful employee. Broadening the scope in this way, skills and abilities that support civic participation are explicit in the standards. Reading standards give earlier and more extensive treatment of informational text than in the past. This is echoed in the writing standards; "The ability to write logical arguments based on substantive claims, sound reasoning, and relevant evidence is a cornerstone" (*9*). Writing standards include in-depth research with an emphasis on analysis and presentation. Standards for speaking and listening include "Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data" (*3*).

We see a similar emphasis on reasoning and problem-solving in the math standards. Comparisons with high-performing countries find that spending more time on fewer topics gets better results. Thus, the math standards emphasize focus and coherence rather than covering topics in a curriculum that is a "mile wide and an inch deep" (*10*). Greater depth in each topic comes from students' development of mathematical expertise defined by eight standards for mathematical practice.

The math standards take an overdue step toward greater synergy with science by introducing modeling in secondary grades. The math standards define modeling as "the process of choosing and using appropriate mathematics and statistics to analyze empirical situations, to understand them better, and to improve decisions" (*4*). The elaboration of the basic modeling cycle resonates with the

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writing standards and with the science practices, e.g., "(5) validating the conclusions by comparing them with the situation, and then either improving the model or, if it is acceptable, (6) reporting on the conclusions and the reasoning behind them. Choices, assumptions, and approximations are present throughout this cycle" (*4*).

Literacy and math standards include practices that are challenging to teach in science without support from teachers of other subjects. Standards for Speaking and Listening include, "Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric" (*3*). Standards for Mathematical Practice include, "Construct viable arguments and critique the reasoning of others" (*4*).

Operationalizing Inquiry

In this promising context, science standards have been drafted, working from the NRC framework, that operationalized "inquiry" with eight practices of science and engineering: (i) asking questions and defining problems; (ii) developing and using models; (iii) planning and carrying out investigations; (iv) analyzing and interpreting data; (v) using mathematics and computational thinking; (vi) constructing explanations and designing solutions; (vii) engaging in argument from evidence; and (viii) obtaining, evaluating, and communicating information (*2*).

The framework attempted to narrow the number of core disciplinary ideas, although reviewers of draft science standards have said that the volume of content undermines the sense making required by the practices (*11*). The framework retained the idea of crosscutting concepts (e.g., structure and function, stability and change of systems), and argued that practices, core disciplinary ideas, and crosscutting concepts should not be taught or assessed separately from each other. Each draft science performance expectation incorporates one or more disciplinary idea, practice, and/or crosscutting concept. These performance expectations also cross-reference the literacy and math standards; the convergence is shown in the chart (*12*).

Science educators have decried the common practice of reading textbooks instead of doing investigations; the former is still alive and well (*13*). Literacy educators are concerned about increased emphasis on informational text in the CCSS (*14*). It is time to embrace the coherence and learning that can be achieved by making meaningful connections between and among direct experience with science and engineering practices and reading, writing, speaking, and listening (*15*).

What's Next?

Forty-five states have adopted the CCSS. If a substantial number of states adopt the NGSS, it increases the likelihood that developers and publishers of instructional and assessment materials will focus on creating a common set of tools, at least at elementary and middle grades. If colleges and universities accept high school courses that are based on the standards and the College Board continues to revise the Advanced Placement syllabi, high schools are more likely to follow them.

In addition to sufficient time and resources for educators and parents to learn how to support these more ambitious expectations, there are several challenges that scientists, educators, and policy-makers should consider. Advocates for high-quality science education for all students need to participate in conversations at the local and state level where educational policy is enacted. Scientists from higher education, research organizations, and corporations influence science education and can align their contributions with educational goals in the standards.

Historically, the United States has provided limited opportunity to learn science to most of its students and advanced training to a privileged few, focusing on the pipeline for future scientists and innovators without concomitant attention to a science literacy for citizenship. The system needs to be transformed to affirm high standards of accomplishment for all students and to provide resources for all students to reach them (*8*).

Although the literacy and math standards were widely adopted, and 26 states have served as partners in developing NGSS, momentum may be slowing; some states may reject the NGSS because of the inclusion of evolution and climate change (*16*). The National Center for Science Education, a defender of teaching evolution for more than three decades, broadened its mission to include the defense of teaching climate science.

Science education benefits from the learning sciences; scientists interested in the most effective teaching of science need to learn from education research. Formal schooling has been criticized as ineffective at motivating and inspiring students (*17*) and inadequate at recognizing the relation between interest and accomplishment (*18*). The NGSS can provide a platform for formal education to become more motivating. Many people are inspired by science in informal settings; parallel attention to the NGSS can contribute to "a wide-ranging and thriving ecosystem of opportunities that respond to the needs of children as well as communities" (*19*). Education and public outreach activities associated with research grants, whether in or out of school, should provide both preparation and inspiration. Local school districts, after-school providers, and informal science institutions need to create a coherent strategy for the regional science learning ecosystem.

This new round of standards development is an opportunity to improve science education that comes around once for each generation. We need to inform ourselves, figure out whether and how we want to get involved, and be intentional about our participation.

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