to help us understand the affordances and limits of these venues.

In sum, rigorous research on effective PD for science teachers is gradually accumulating, but we need a stronger theoretical base that reflects the complex ecology in which teachers work and learn. We also need better measures and interventions that are more highly specified. Though some might hope for a silver bullet, education reform that leads to fundamental change, such as that envisioned in the NGSS, requires time [it takes several years for teachers to change their practice (*6*, *27*, *28*)]. Reform efforts also require investments in infrastructure (leadership, teacher networks, planning time), the organizational coherence that encourages teachers to take risks and learn new content, parents to support the new standards, and students to demonstrate the perseverance and curiosity needed to achieve scientific literacy.

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PERSPECTIVE

A Business View on U.S. Education

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Business leaders depend on an education system capable of providing a workforce able to compete in a global marketplace. As a partner in education reform, the business community advocates for an increased focus on helping schools connect students more effectively to the world of work through hands-on problem-solving activities and practical experiences.

Government leaders recognize that being poorly educated is tied to unemployment, poverty, crime rates, and spiraling social services costs. Parents recognize that a quality education is key to their children's future. Teachers and educators view their students' success as key to their life's work. Business leaders seek a workforce that can compete in a global marketplace at a time when many jobs cannot be filled for a lack of qualified workers (*1*). Thirty years ago, the U.S. National Commission on Excellence in Education stated that "Our society and its educational institutions seem to have lost sight of the basic purposes of schooling and of the high expectations and disciplined effort needed to attain them" (*2*). Although modest progress has been made since then, the world has been changing faster than its education systems. We believe business leaders would argue that many reform efforts have not yet focused on the right issues.

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In the past 2 years, the Boeing Company has hired 33,000 new employees, and we observe two important phenomena. First, these new employees, from those lacking a high school diploma to those with a college degree, are generally quite good at using digital tools. Second, many seem to have rarely been put in situations where they have had to use their knowledge and skills to create a product of value. Those we hire have lots of ideas and can be savvy about many aspects of information technology. But those who haven't had to relate to a real-world experience of building something, or worked in a situation where failure is a real possibility, will generally need to spend considerable time on remedial training activities. For example, Boeing must now spend 13 weeks training employees for the same manufacturing jobs that used to require half the time; but even then, the employee often remains weak in the skills needed to manipulate materials effectively.

We believe the above observation is common among business leaders, spanning many business sectors. Although more is required from an education than preparing students for the world of work, such findings have important implications for education reform. Today, when students are not in the classroom, they may spend up to 12 or more hours per day using some form of electronic media, whether sending text messages by cell phone, watching TV, or engrossed in using a computer, with yet unclear impacts on learning and problem solving (*3*). While greater use of technology in and out of the classroom holds promise and should be explored, we consider it unlikely that computers and simulations will fully substitute for real experiences in which students manipulate materials and engage in problem-solving in groups.

The classroom therefore needs to be a place where students spend a substantial amount of time applying what they learn to solving relevant problems that are appropriate to their age. As stated by the Ministry of Education of Singapore, teaching should "encourage a spirit of innovation and enterprise in students, and nurture intellectual curiosity, passion, and courage to try new and untested routes (*4*)."

We suggest that businesses focus on helping schools connect students more effectively to the world of work. In the United States, new synergies with industry arise from the recently adopted Common Core standards in English Language Arts and Mathematics, plus the forthcoming Next Generation Science Standards (NGSS), which stress in-class discourse, explanation, argumentation, reading and writing informational text, and active problem-solving (*5*, *6*) [see page 276 in (*7*)].

The NGSS aim to incorporate real experiences into the classroom. But, as highlighted elsewhere in this issue [see page 320 in (*8*)], if we end up using inexpensive standardized assessments that mainly test for factual recall, the standards movement will simply prolong our failure.

The Education Task Force of the Illinois Business Roundtable has concluded that "the business community, in partnership with political and education leaders, must play a significant leadership role in education reform (*9*)." Recognizing that "education improvement is a marathon and not a hundred-yard dash" and that "education reform needs to be a collaborative, not adversarial, effort," we have helped to create the Career Pathways Program, where businesses are working with the Illinois State Board of Education to bring practical, experience-based curricula into the classroom that can help ensure that students are either job ready or college ready when they graduate from high school (*10*).

Nationally, academic and business leaders have come together in efforts to create effective learning environments outside of the classroom experience. For example, FIRST robotics competitions were founded on the premise that students can succeed when they compete, not just in a simulated game environment, but in the real world where there are winners and losers (*11*). These types of activities need to become part of formal schooling, not merely optional add-ons.

In summary, what can business do? First, be a strong advocate for exposing students to more hands-on problem-solving activities in the classroom. Second, help to provide scarce resources by increasing sponsorship of programs that engage students in such activities. Third, create more internship opportunities that allow students to be exposed to real-world work environments and directly learn what jobs are about. Fourth, support initiatives to question, and limit, the television, computers, and electronic games that can divert students' time and attention away from other world experiences needed for future success. We believe that professional success today and in the future is more likely for those who have practical experience, work well with others, build strong relationships, and are able to think and do, not just look up things on the Internet.

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REVIEW

Outside the Pipeline: Reimagining Science Education for Nonscientists

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Educational policy increasingly emphasizes knowledge and skills for the preprofessional "science pipeline" rather than helping students use science in daily life. We synthesize research on public engagement with science to develop a research-based plan for cultivating competent outsiders: nonscientists who can access and make sense of science relevant to their lives. Schools should help students access and interpret the science they need in response to specific practical problems, judge the credibility of scientific claims based on both evidence and institutional cues, and cultivate deep amateur involvement in science.

For half a century, the world's wealthiest countries have asked their education systems to teach science to all students, including those who will not go on to scientific careers (*1*). Under slogans such as "science literacy" and "science for all," schools have attempted to prepare all students to make sense of science in daily life. With the exception of modest and isolated gains in conceptual knowledge (*2*), it is not clear that these campaigns have enhanced people's ability to function in a world where conflicting health advice clutters the Internet, research is filtered through political screens, and the media strips context from scientific claims.

These results should provoke renewed interest in the relationship between science education and public engagement with science and the pursuit of more fruitful forms of science literacy. Instead, many scientists and policy-makers are turning their attention away from the role of science in daily life and advocating a greater focus on the so-called "pipeline": preprofessional education that delivers science-ready students to colleges and universities (*3*). Even crusaders for science literacy take for granted that scientific training—of the same sort that prepares students for scientific practice—will help nonscientists navigate fields as diverse as personal health, politics, the economy, leisure, and employment (*1*, *4*, *5*). There is little empirical evidence to support this assumption. On the other hand, a growing number of studies show untrained citizens engaging with science in adaptive ways (*6*). These citizens, whom Feinstein refers to as "competent outsiders" (*7*), identify relevant pieces of science and understand their local or personal implications without relying on school-based knowledge of particular scientific methods or concepts (*6*, *8*).

How can education help more people act like competent outsiders? We synthesize evidence to develop a research-based plan for cultivating competent outsiders: nonscientists who can access and interpret the science most relevant to their lives. We reconsider established goals of science education in light of three central findings about public engagement with science and discuss implications for research and practice.

How People Interact with Science

Research shows that different groups interpret science differently (*6*, *9*–*12*). An Alzheimer's advocacy group, biotech investment firm, and religious coalition may all be interested in stem cell research, but different motivations underlie their interest and shape their engagement. Social, cultural, and demographic differences influence how people engage with science, both in school (*13*) and out (*6*, *11*). For example, communications researchers have identified six demographically distinct groups of Americans who respond to news about climate change in predictable, group-specific ways (*11*). Local knowledge and experience, such as the history of tension between rural residents and a nuclear power plant (*14*), can play an important role. There are many different "publics" for science, each with different concerns and resources for making sense of the world.

To complicate matters, science is not a single, uniform thing. Science education places particular value on experimentation, but some fields rely on observational data or simulations, whereas others are devoted to theoretical inquiry. Even closely related fields can diverge on important matters, such as the validity of research methods or the nature of acceptable evidence (*15*). Nonscientists typically interact with specific manifestations of science rather than "science" as a whole (*6*, *12*, *16*). Although scientists may agree on abstract principles (such as hypothesis-testing) and

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