Reimagining Science Education

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On July 14, 2011 Google announced the winners of their international science competition. Three young women were chosen. In each project, we see not only the student's clear aspirations to use science to solve problems of consequence, but also how they used resources from their entire community, beyond simply their schooling, to engage with these challenges.

Lauren Hodges, who won in the 13-14 age group, studied the effect of different marinades on the level of potentially harmful carcinogens in grilled chicken. Her interest in this topic was triggered when she read about a lawsuit brought by the Physicians Committee for Responsible Medicine (PCRM) against seven fast food companies for not informing customers of the potential risk when consuming grilled chicken.

Naomi Shah, the winner among 15-16 year olds, conducted research to determine whether improving indoor air quality can reduce people's reliance on asthma medications. Naomi's interest in science was sparked at an early age through camps at the Oregon Museum of Science and Industry and LEGO Robotics competitions. She turned to science and engineering to come up with new ways to improve living conditions and eliminate unnecessary expenditures for health care.

Shree Bose, the 17-year-old Grand Prize winner, discovered a way to improve ovarian cancer treatment for patients when they have built up a resistance to certain chemotherapy drugs. Shree was inspired to research cancer after her grandfather died from the illness two years ago.

In reading their bios, it is apparent that these young women had their curiosity about science instilled at an early age. They have taken advanced science courses, attended enriching science camps, participated in numerous science competitions, been supported by family members and other caring adults who have nurtured their success, and have been rewarded and recognized for their accomplishments. As they prepare for college, and ultimately entering the workforce sometime within the next decade, they have exceedingly high expectations for themselves; they know what they will major in as undergraduates, and they talk about pursuing PhD research programs. They each fell in love with science at an early age and discovered that it is a way of looking at the world that equips them to solve problems and address challenges that have a direct human impact. Most important, they have succeeded at marrying their convictions and enthusiasms with opportunities to advance. As one of my colleagues noted: "It's funny how girls have that uncanny ability to find problems worth solving."

Contrast the essential ingredients of these stories with what we know about science education in our nation's schools, how it is delivered by teachers and texts, and how it is received by students. Recent national studies call our attention to the fact that at the elementary level science is barely being taught. More than 8 hours of instructional time is devoted each week to the teaching of English Language Arts (ELA) and over 5 hours per week to math; science is taught for less than 3 hours per week. The situation is worse in schools that have been identified as in need of improvement, where science is entirely eclipsed by the subjects that students will be tested on, and these are the very same schools that are likely to have higher levels of poor children and children of color. There is now a growing body of evidence that indicates grade-level, high stakes testing is heavily biasing the curriculum toward the teaching of tested subjects and away from less frequently tested subjects like science. Further, when science is given time during the school week, students are much more likely to be memorizing information presented in textbooks and answering questions at the end of the chapter than engaging in the kind of real-world problem-solving exemplified by the Google science girls.

Looking at this dynamic, we need to be wary of what might seem to be the obvious solution: making sure science is tested the way math and ELA are. Adding more science tests will not remedy this problem anymore than the testing in math and ELA have helped in those areas. Testing does not typically motivate engagement, passion, creativity, and innovative thinking. A quick look at the countries whose children outperform the U.S. on the Organisation for Economic Co-operation and Development (OECD) Programme for International Student Assessment (PISA) shows that none of them do anywhere near the amount of testing that is done in the United States. Some of the top-performing countries do national testing, but at the gateways only—e.g., upon exiting elementary or entering high school. None have grade-by-grade national tests.

It is time to acknowledge that as a consequence of the focus and implementation of No Child Left Behind there has been a decline in science teaching and learning of a sort that we have not seen in the modern era. We do not need any more commissions or studies to tell us what is strikingly evident—children of the NCLB era, who entered Kindergarten in 2003 and had little or no science education for the next seven years, are not going to do well in science in middle school or beyond. We are losing an entire generation to science illiteracy.

Yet science literacy is essential in the 21st century. President Obama has highlighted the need for improved national science education, stating "All American citizens need high quality STEM education that inspires them to know more about the world around them, engages them in exploring challenging questions, and involves them in high quality intellectual work." According to a report from the Center on Education and the Workforce, there will be eight million job openings in STEM-related fields by 2018, yet the U.S. continues to lag behind in student achievement in these areas. In 2009, PISA, measuring the skills and competencies of 15-year olds, found that U.S. students ranked 17th of 34 developed countries in science and 25th of 34 in math. The same study revealed that the U.S. has among the most unequal performance in the world, with achievement levels highly dependent on socio-economic status. Low-income and minority communities are especially hard-hit by lack of access to high-quality science resources. The results from the 2009 National Assessment of Educational Progress (NAEP) drive home the severity of the problem—only 18% of New York City's 4th graders and 13% of 8th graders performed at or above the proficient level in science.

The situation is most dire among low-income and minority students. This is evident in a notable absence of underrepresented groups such as women and people of color among the professional ranks in science and engineering fields. As of 2010, racial and ethnic minorities represent only a small proportion of those employed in science and engineering occupations in the United States. Collectively, blacks, Hispanics, and other ethnic groups (the latter category includes American Indians/Alaska Natives) constitute 24% of the total U.S. population, 13% of college graduates, and only 10% of college-educated individuals employed in science and engineering occupations. This gap is increasingly urgent in the current economic crisis, where science-related fields, including education and health services, are among the only industries showing job growth.

It is highly probable that over the next six years as "Generation NCLB" goes through high school we can expect banner headlines about continuing declines in science learning including a drop in the number of students taking advanced level courses in subjects such as biology, chemistry, and physics. That realization will be a precursor to the hue and cry from colleges, four years later, about the need for more remedial science and the falling number of American students majoring in sciences of all types. In a country that is obsessed with talk about systemic solutions, sustainability, and scaling, it is curious that no one seems to have realized where our narrow focus on math and ELA, and our heavy-handed emphasis on grade-level high stakes testing, would take us. On the other hand, we do seem to have successfully scaled a system nationwide that has led to a sustained level of decline in science learning at a time when we need just the opposite.

While the endpoint of our current trajectory is clear, the future could be—and must be—different. We know what can work to motivate children in schools. Perhaps the greatest asset in redirecting our course is children's innate curiosity about the world around them. As Naomi Shah notes in her bio, her first word was "why." Indeed, children are born curious and come equipped with a desire to learn that rivals even the most determined scientist. Early in school, however, this spark—what psychologists have dubbed intrinsic motivation—is all too frequently extinguished by the extrinsic goals and expectations of school. Fortunately, there is research-based evidence that says it is possible to rekindle this natural motivation to learn by designing environments that are supportive, that engage learners in meaningful activities, that lessen a student's anxiety and fear, and that provide a level of challenge matched to students' skills.

A National Research Council report, *Engaging Schools,* chaired by Deborah Stipek, Dean of Stanford's Graduate School of Education, determined that students can be emotionally engaged in learning if simple principles are followed: if subject matter is connected to students' personal lives and interests; if students have opportunities to be actively involved in solving or designing solutions to novel and multidimensional problems, doing experiments, debating the implications of findings, and working collaboratively; if students have multiple opportunities to earn a good grade (by rewriting papers or retaking tests); if attention is drawn to the knowledge and skills that students are developing, not to grades or scores; and if all learning and skill development is celebrated, whatever the level. Think about the Google science girls and how their experiences and opportunities exemplify these very principles.

As the Carnegie Corporation notes in their report, *Excellence and Equity in Mathematics and Science to Transform Education,* there is widespread agreement among policymakers, educators, and other stakeholders that all students, no matter where they live, what educational path they pursue, or what career they choose, need to be STEM-capable to drive future innovation and to contribute to the rapidly changing global economy. To meet this charge, schools have been challenged to dramatically redefine mathematics and science education to support multiple strands of inquiry and exploration across the curriculum so that students: experience excitement, motivation, and interest with respect to the natural and built world; develop and use scientific explanations, concepts, and models; generate scientific evidence to understand issues; reflect on science as a way of knowing; participate in science practices (e.g., presenting their findings); and identify themselves as science learners capable of doing science.

The Carnegie Corporation's Institute for Advanced Study Commission on Mathematics and Science Education argues that for such a transformation to occur we must move away from the current system of "telling" students about science to one that helps students gain critical problem-solving and inquiry skills in the context of relevant, real-world, interdisciplinary problems. While it's clear from the Commission's research that young people care deeply about contemporary STEM-related problems and are motivated to solve them (e.g., health and global warming), we need to develop learning practices that can stimulate students' passions for science and methodologies that teachers can use that motivate students and support deeper learning.

The newly released *Framework for Science Education*, published by the National Research Council and supported by Carnegie, seeks to deeply connect scientific practices with the learning of content in ways that will nurture students' passions for science. The Framework lays the foundation upon which a new generation of science standards will be developed. Recognizing that science is the key to solving the world's most pressing challenges, the Framework seeks to ensure "that by the end of 12th grade all students have some appreciation for the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology." The framework charts a new and important pathway for science learning by recognizing that content learning must be intimately coupled with the practices of science, and build students' understandings and appreciation of the scientific enterprise over multiple years.

Interestingly, much of what is being suggested in many of these reports is already being successfully deployed in science centers and other informal learning environments, and we need to find ways to connect the world of formal and informal science learning. Several decades of school reform initiatives have taught us that schools cannot and should not go it alone. At a time when schools face shrinking resources and growing demands, reversing declines in science learning will require leadership from civic institutions that partner with families, communities, and schools. We know the critical role that informal science learning experiences play in igniting students' passions and in fostering deeper learning of science content. Whether it's PBS shows like *Sid the Science Kid* or *Dinosaur Train* or the technological literacy initiative at the Museum of Science in Boston, the National Research Council report on *Learning Science in Informal Environment* found that informal science learning promotes diversity and broadens participation and that non-school environments have a significant impact on science learning outcomes among historically underrepresented groups. Significantly, the recently released PCAST (President's Council of Advisors on Science and Technology) report on *K-12 STEM Education for America's Future*, calls for better integration of informal and formal science education. The PCAST report not only calls for better coordination of STEM education activities, but also suggests that every middle school and high school should have a partner in a STEM field, such as a research organization, college, university, museum, zoo, aquarium, or company, that can bring STEM subjects to life for students.

Science centers in particular—of which there are 347 in the United States—are well positioned to play a leadership role, offering rich and engaging education programming and inspirational exhibits that are linked to classroom curriculum. Science centers offer a diverse ecology of engagement strategies, from kinetic to contemplative, from experiential to instructional. The thread through all of these strategies is unpressured exploration and invention, the characteristics that define engaged and passionate learning and lead to creative thought and innovation. The diversity of this ecology offers an unparalleled laboratory setting to explore and support the impact of different strategies on different learners, and positions science centers to serve as potent innovation partners for science learning in the formal education sector.

It is increasingly evident that organized educational activities outside the classroom are necessary to strengthen core-learning skills, spark new interests, and promote greater enthusiasm for science among today's youth. Further, informal science learning organizations are especially well suited to serve as capacity building and implementation partners in the reform work of K-12 education. As we seek to create a science infrastructure in this country that aspires to meet the President's goal of high-quality, inspiring STEM education for all, we must ensure that there is broad-based coordination and input on the part of elected officials, local school districts, administrators, teachers, and science centers, and others in the informal STEM sector. Strategies that take into account the broader STEM learning ecology have the greatest potential for success.

If we are to develop more passionate, engaged, and highly qualified STEM learners among today's youth, the implementation of policies and programs that support deep partnerships across formal and informal education sectors is key. We need to change the traditional pattern of funding that goes exclusively to either formal or informal and find ways to leverage funding that can bring the two sectors together. Some examples might include:

1. Allowing nonprofit, informal education institutions (such as science centers and museums) with a proven track record of providing quality teacher professional development programs to directly compete for Title II teacher quality funds;

2. Leveraging the federal government's $1.1 billion annual investment in "21st century community learning centers" to encourage the states to seek non-profit partnerships that promote innovation in STEM learning;

3. Supporting science center and museum eligibility in the President's initiative to recruit, prepare, and support 100,000 new math and science teachers through newly established alternative certification programs for both pre-service and in-service teachers;

4. Supporting the importance of informal education in advancing educational innovation by endorsing the sector's eligibility in all federal agency STEM reform initiatives; and

5. Encouraging the National Science Foundation and/or the U.S. Department of Education to establish national research and development centers built around major STEM learning challenges (e.g., underrepresented populations, effective teacher professional development, learning technologies, etc.) and to ensure that informal learning institutions are eligible to compete; the existing infrastructure of the Regional Education Laboratories could be utilized for this purpose.

By design, informal learning environments such as science centers are inherently "low-stakes," making them ideal environments in which to develop, test, and iterate new models of teaching and learning. At the New York Hall of Science (NYSCI) we have committed ourselves to serving as an innovation partner for the formal education sector by launching several initiatives that stimulate children's innate curiosity and tendency to be critical thinkers.

The Center for Play, Science and Technology Learning (SciPlay) enhances students' understanding of and engagement in science by harnessing the potential of play. SciPlay's intent is to encourage more students to enter and remain in the STEM career pipeline by blurring the boundaries between play and learning—between tinkering and thinking—resulting in a positive impact on students' attitudes and achievement in science. SciPlay identifies informal learning experiences that are broadly accessible and builds easy-to-implement extensions of these experiences for the classroom. For example, a simple playground slide can be enhanced with motion sensors, and students given a goal and rules for scoring such that the fun of repeatedly sliding to win the game at the same time motivates a series of experiments exploring frictional force. The model also incorporates a small-scale computer application (a "digital app") that simulates the game experienced in the informal setting, allowing students to explore quantitative data logged automatically during earlier game play and also supporting them in generating new data. The digital app supports students doing inquiry in the classroom in a way that continues to be fun and engaging, all the while helping students formalize the science concepts.

NYSCI's Design Lab is a venue where informal science educators and classroom teachers collaborate on developing new lesson plans and resources that engage K-12 students in the problem-solving process that is central to engineering and technology. With Design Lab, NYSCI is making a significant investment in the transformation of STEM learning locally, regionally, and nationally, offering K-12 teachers a collaborative space where they can create, test and assess design-based approaches to teaching and learning STEM. Through the design process, one learns how to identify a problem or need, how to consider design options and constraints, and how to plan, model, test, and iterate solutions to vexing problems, making higher-order thinking skills tangible and visible. Design-based activities are intrinsically motivating to teachers and students because they engage the desire to learn how things work so that we can make new things that work better. Engaging in activities, such as designing a model boat that can float carrying a given weight, creating experiments with hand-built rockets to determine the most effective structure, or exploring possibilities for alternative energy sources, all help learners develop deep conceptual understanding of the knowledge and principles of a domain and support the development of self-guided inquiry skills that are often difficult to teach.

Such initiatives respond directly to the recommendations of the new science Framework and reflect the findings of many recent commissions looking at the future of science education. Just as important, they are aligned to the empirical evidence we see in the experience of the Google science girls. Successful engagement in science learning builds on children's natural curiosities and positions science as a tool that can be used to address the world's most pressing challenges.