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EDUCATION WEEK

# SPOTLIGHT

## On STEM

Editor's Note: Schools and policymakers emphasize STEM as a way to prepare students for 21st century challenges, leaving teachers with their own challenge: how do you successfully engage students in these subjects? This Spotlight offers tips on how to create effective science and math learning opportunities for students.

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Sara D. Davis for Education Week

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# Latest Wave of STEM Schools Taps New Talent

By Erik W. Robelen
*Raleigh, N.C.*

Few Americans may know about the Grand Challenges for Engineering—from making solar energy affordable to ensuring access to clean water—but the students at a new school on the campus of North Carolina State University are getting to know them firsthand.

The set of 21st-century challenges, devised by the National Academy of Engineering, serves as a frame and inspiration for the curriculum at this school, one of a relatively small but rapidly growing number of STEM-focused schools cropping up across the country.

At a time of heightened national attention to improving education in the fields of science, technology, engineering, and mathematics, the development of such schools has gained mo-

**Zipporiah Bush, left, and Sadie Lisk photograph clay creations during a science and engineering class at a STEM-focused high school on the campus of North Carolina State University. It's one of a new crop of schools reaching out to populations that are underrepresented in the STEM fields.**

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mentum as a strategy to boost knowledge and interest in the subjects.

While STEM schools historically have tended to target the top math and science students in a state or district, the new wave appears to have a broader reach, with many of the schools aimed especially at serving groups underrepresented in the STEM fields, such as African-American, Hispanic, female, and low-income students.

Just this academic year, new STEM schools have opened in a number of states, including Arizona, New York, North Carolina, and Tennessee.

The school at N.C. State, a partnership between the university, the 147,000-student Wake County district, and the nonprofit North Carolina New Schools Project, stresses project-based learning and the integration of topics across content areas.

In its first year, the school identified five of the 14 Grand Challenges for Engineering as the connective curricular tissue.

"By doing a thematic approach, I think you can hook the kids," said Principal Rob Matheson. "The kids can get into solving challenges. ... They're really global issues, like access to clean water."

At a ribbon-cutting ceremony last month, Lt. Gov. Walter H. Dalton, a Democrat, made clear that the school has ambitions beyond its walls. "You're going to be an anchor school," he said. "You're going to be a model for others."

## 'A Term of Art'

Creating STEM-focused schools is not a new idea. Some of the oldest campuses with a math and science emphasis date back decades, such as Stuyvesant High School and the Bronx High School of Science in New York City. The Illinois Mathematics and Science Academy is celebrating its 25th anniversary.

Experts say these highly selective schools play an important role in nurturing top talent, but that a vital national challenge—and an economic imperative—is casting a far wider net to develop talent that might otherwise not be tapped.

"There is a large interest and achievement gap ... in STEM," said the President's Council of Advisors on Science and Technology in a report last year that called for 1,000 new STEM-focused schools over a decade. "The underrepresentation of minority groups and women in STEM denies science and engineering the rich diversity of perspectives and inspiration that drive those fields."

There is not necessarily an agreed-upon definition for a STEM school.

"'STEM school' is a new term of art," said Karl T. Rectanus, the leader of the NC STEM Community Collaborative, a public-private partnership in Raleigh that promotes effective STEM education.

"There are schools that define it very differently," said Barbara Means, a researcher at SRI International who studies STEM schools.

Some, she said, simply bring a more intensive approach to a traditional curriculum, beefing up the offerings and requirements in science, math, and related subjects. Others emphasize project-based learning and integrating ideas across disciplines. Still others may focus on a particular occupational theme, such as biotechnology.

Ms. Means and others warn, however, that some schools may add the label without making real changes.

"A commonality is there needs to be more STEM learning opportunities than in a conventional school," Ms. Means said. "There needs to be a richer set of resources and a requirement that goes beyond the minimum in math and science."

Although there's no official count of STEM schools, an SRI report identified 315 such public high schools as of the 2007-08 academic year.

Some states, including North Carolina, are making the growth of STEM schools a key part of their strategy to improve math and science education and better prepare students for the workforce.

In its successful bid for a federal Race to the Top grant, the state outlined plans to establish four STEM "anchor schools" to provide exemplary curriculum, serve as sites for leadership academies and teacher professional development, and be "test beds for innovation."

June Atkinson, the state superintendent, tied the effort to economic development and ensuring the state can compete globally.

"Many of the careers our students will have will need a good foundation in math and science and technology," she said.

The STEM school at N.C. State University has just 55 students, all 9th graders, but will add another grade each year. It's also an early-college high school, with a five-year program allowing students to earn both a high school diploma and two years of college credit.

To apply to the Wake-N.C. State University STEM Early College High School, students must write two essays—one describing a STEM-related experience—and supply three recommendations, said Principal Matheson. Grades and standardized-test scores are also reviewed. Any Wake County student may apply, he said, but the goal is not to recruit top math and science students.

"Our target groups are underserved, underrepresented [populations]," said Mr. Matheson.

About 70 percent of students are minorities (mostly African-American), half are girls, and 43 percent will be the first in their family to attend college, he said. Forty-five percent are eligible for a free or reduced-price lunch.

Students attend a daily seminar, plus three, 90-minute courses: a hybrid earth sciences and

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engineering class; Integrated Mathematics 1; and Humanities 1, a hybrid of English and world geography.

## Clean Water

Mr. Matheson stressed that the school's theme of the Grand Challenges for Engineering isn't simply about learning in the STEM disciplines. Students explore other aspects, such as the economic, political, and ethical dimensions.

The teachers say they are enthusiastic about the emphasis on STEM and the Grand Challenges.

"There are ways for every discipline to fit into the STEM focus," said Tammy L. King, who co-teaches Humanities 1.

In August, the students in that class were reading Lord of the Flies. As a class project, students were tasked with writing survival guides that deal with strategies for coping with life when stranded on such an island, such as how to govern themselves, how to build shelters, and how to ensure access to food and clean water.

In the school's science/engineering class, students were learning about fresh water issues, such as how to treat drinking water. On a recent day, they also were constructing topographical maps of an island.

"We're all thinking about that 'access to clean water' Grand Challenge and trying to make everything mesh," said Evelyn Baldwin, the co-teacher of the science/engineering class.

Another STEM high school just opened on the campus of the University of North Carolina at Greensboro. An additional 19 schools, with support from the North Carolina New Schools Project, are this year taking on a new STEM focus.

Ohio—with financial help from Battelle and the Seattle-based Bill & Melinda Gates Foundation—has supported the development of 10 STEM schools, part of the Ohio STEM Learning Network. (Editorial Projects in Education, which publishes *Education Week,* also receives support from the Gates Foundation.)

"The idea was to create a STEM high school in each region [of Ohio]," said Eric D. Fingerhut, a vice president at Battelle, a research and development organization based in Columbus, Ohio, that manages the network. "Each school would serve a dual function: educating students in their own right, but then serving as a platform or hub that is generating the type of energy around improved STEM education that can spin out into the public schools ... and be a catalyst for innovation."

Admission is nonselective at the schools, with an emphasis on serving underrepresented and high-need populations.

## 'Favorite Things'

Texas has a growing alliance of like-minded schools, the Texas Science, Technology, Engineering, and Mathematics network, or T-STEM. It now counts 59 member schools, including nine new ones this fall.

The effort is a collaboration among philanthropies and state entities, including the Texas Education Agency, the governor's office, as well as the public-private Texas High School Project.

Among the key features of T-STEM schools are small size, project-based learning, an integrated curriculum, and serving underrepresented students.

A recent SRI study found that in the 2008-09 year, T-STEM schools' students scored "slightly higher" than matched comparison school peers on the state's 9th grade math exam, as well as 10th grade math and science tests.

"We actually have relatively little evidence around the effectiveness of STEM schools" overall, said Ms. Means, the SRI researcher. She described the Texas data as "showing some beginning positive effects in terms of test scores."

Ms. Means is leading a new research project, with funding from the National Science Foundation, to explore the feasibility of conducting a long-term, national study of "inclusive" STEM schools that target underrepresented populations. A key question, she said, is whether students at those schools retain interest in STEM fields and pursue college work and careers in them.

At the Wake-N.C. State STEM school, it's too soon to tell what the 9th graders will end up doing, but some already have their eye on STEM careers. One said he wants to be an aerospace engineer, another a computer engineer.

"I'm really into science and math and technology," said a third, 9th grader Vernon Ingram.

"One of my favorite things is engineering," said freshman Richard Putney. "I probably want to be in robotics or an audio engineer."

*Coverage of mathematics, science, and technology education is supported by a grant from the GE Foundation, at www.ge.com/foundation.*

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# Woodrow Wilson STEM Fellowship Strives to Change Teacher Training

## Fellowship Striving to Change Teacher Prep

By Erik W. Robelen

Candice B. Kissinger spent some 35 years as a research scientist in the pharmaceutical industry. Jeremy M. Sebens, with a degree in aerospace engineering, worked in the oil industry and for a company building radio-controlled model airplanes. Hwa Y. Tsu majored in engineering and has done graduate-level biomedical research.

All three are now part of Indiana's teaching workforce through an intensive fellowship program that prepares individuals with STEM expertise—whether career-changers or those fresh out of college—for jobs in secondary schools serving disadvantaged populations.

At the same time, the program, first announced in 2007, strives to promote changes in university-based teacher preparation, including extensive clinical experiences in public school classrooms, analogous to the training doctors receive.

Indiana was the first state to get started in the fellowship program, established by the Woodrow Wilson National Fellowship Foundation, in Princeton, N.J. The state's third cohort of teacher-candidates was announced at a May event that featured Gov. Mitch Daniels.

The first sets of fellows for Michigan and Ohio were named this spring. The eventual goal, according to the foundation, is to have similar initiatives in eight to 10 states.

Each participant earns a teaching certificate and a master's degree and receives a $30,000 scholarship. In return, fellows commit to teaching for three years in a school serving a significant population of students at risk of academic failure.

### Classroom Practice

Many fellows say the best part of the experience is the time in middle and high school classrooms. They typically work in schools several days a week for a full academic year as part of their preparation, observing and providing classroom support and eventually taking on lead-teaching duties in consultation with the classroom teacher.

"You could take the theory you're learning and apply it the very next day and come back and say, 'Hey this worked great,' or 'It didn't work at all,' " said Mr. Sebens, who was hired to teach engineering this fall at H.L. Harshman Magnet Middle School in Indianapolis.

"The part that prepared me the most was just the actual experience of being in the classroom and being mentored by classroom teachers," said Mr. Tsu, who just completed his first year as a full-time teacher of physics and physical science at North Central High School in the Washington Township district, in Indianapolis.

"I have seen how the classroom gets set up, how they deal with establishing culture, establishing expectations," he said, "rather than student-teaching, where I drop in for six weeks and then I drop out." The fellowships come amid persistent calls to improve education in the STEM subjects—science, technology, engineering, and math—including from President Barack Obama, who often describes it as an economic imperative. He has called for recruiting 100,000 excellent STEM teachers over the next decade and, in a 2010 speech, touted the Woodrow Wilson program.

In a report issued last fall, the President's Council of Advisors on Science and Technology issued a report on the need to improve STEM education, and suggested that the "most important factor" was teachers with deep content knowledge in those subjects and mastery of the pedagogical skills required to teach them well. But the report concluded that "too few of these teachers" are in the classroom. *(See Education Week September 22, 2010.)*

### 'Anybody Can Throw Bricks'

The Woodrow Wilson program is among a growing number of ventures to tackle this challenge. Others include the Math For America fellowship program; UTeach, a STEM-preparation model first developed at the University of Texas at Austin; the Knowles Science Teaching Foundation's fellowship program; and the federal Robert Noyce Teacher Scholarship program, which has provided some aid to Math For America and UTeach.

The Woodrow Wilson program has quickly ramped up and now involves 17 universities across Indiana, Michigan, and Ohio. To date, 349 fellows have been admitted, including 211 named this spring.

Each state's work is supported with a blend of public and private dollars. In Indiana, major private support comes from a $10 million commitment from the Lilly Endowment in Indianapolis. In Michigan, the W.K. Kellogg Foundation has committed $18 million. A variety of foundations are supporting the Ohio fellowships.

Each university gets $500,000 to help with planning and design but must match that amount.

Arthur E. Levine, the president of the Woodrow Wilson foundation, said his organization worked hard to get broad-based support for the programs, not just from universities and school districts but from top state leaders, including governors and key lawmakers.

Ultimately, he hopes to have a powerful set of state-based examples around the country.

"We thought the greatest leverage we could have was on states," he said. "We don't want to be in 50 states, but in eight to 10 states in various regions of the country, and we would like those states to be models."

The focus on STEM teachers was a big draw in Indiana for Gov. Daniels, a Republican, said Tony Bennett, the state education secretary.

"The governor really was very attracted to this because of his passion and his desire to see quality science and math teachers," Mr. Bennett said. "Having his voice in support for an education initiative like this is always a very strong pillar."

It may come as little surprise that a central goal of the fellowships is, as Mr. Levine puts it, to "transform teacher education." After all, the former president of Teachers College, Columbia University, has been an outspoken critic of traditional teacher preparation. He was the author of a 2006 report that said the majority of teacher-candidates go through low-quality programs that fail to prepare them adequately. *(See Education Week September 20, 2006.)*

"Anybody can throw bricks," Mr. Levine said. "The question is: Can you improve it?"

The program is not intended to impose a cookie-cutter design, say Woodrow Wilson foundation officials. Each university and its partners are encouraged to devise an approach that best fits their needs.

Still, there are central elements the foundation expects.

For one, the programs must be "truly clinically based," said Constance K. Bond, a vice president of the foundation, who suggests that such an approach is rare in university teacher preparation.

"What we're looking for is having our teacher-candidates learning on the job," she said. "We want them embedded in the school. ... We want the clinical to drive the master's program."

In addition, the foundation expects the design and implementation of programs to involve a genuine partnership between a university's education school and its college of arts and sciences (plus the engineering school, where applicable), as well as with local school districts. Another core element is ongoing mentorship from experienced teachers that continues for three years after fellows earn teaching certificates.

Ms. Bond, who works closely with the local programs, acknowledged that it's tough to get universities to make big changes in teacher preparation. "All have made progress, ... but to different effects and to a different extent," she said. "It's very heavy lifting; I don't think any of us are surprised by that."

Ms. Bond cites the University of Indianapolis as one of the most promising examples.

"They really have taken this and every opportunity it provides and run with it," she said.

Jennifer A. Drake, the director of the University of Indianapolis' fellowship program, described her university's program as a "radical" departure.

"We didn't use previous courses," she said. "We didn't use our previous model. We started over completely and said: 'If the clinical component is central, how do we then think about how to deliver the content that we know we need to deliver?'"

As part of earning a master's degree, the teacher-candidates are in schools three full days a week in the fall, she said, and five in the spring. And the university has worked hard to marry the coursework with the clinical experience, she said, a process that involves continual refinement.

That coursework covers math and science pedagogy, incorporation of literacy strategies into STEM teaching, and adolescent psychology and development, among other topics. For the pedagogy component, Ms. Drake said, faculty members in such content areas as math, chemistry, and biology work closely with fellows to develop "authentic, real-world projects."

### Room for Improvement

Mr. Tsu, who last year earned his teaching license through the University of Indianapolis program, said the fellowship program has prepared him well, especially with so much classroom time.

"When I started as a full-time teacher, it almost felt like I had a year of experience," he said. "It was a brand-new program, so there were some things that worked, some that didn't, but overall, it was a lot better experience than maybe a traditional pedagogy, theory, read-the-book type thing."

The 16,000-student Wayne Township district, a partner in the University of Indianapolis, has hired seven fellows.

"We were able to hand-select the very best fellows we had for vacancies," said Jeffrey K. Butts, the district superintendent.

Participants in several of the Indiana programs said the fellowship is not for the faint of heart.

"It was a lot of work," said Mr. Tsu. "My first year, I probably pulled six or seven all-nighters."

"It is very intensive, and you are working very, very hard," said Ms. Kissinger, the former research scientist, who is a fellow at Purdue University. "This is not something you would want to do casually."

To be sure, the fellows see areas for improvement in the programs. Ms. Kissinger, for instance, described her coursework as a "mixed bag," but said the university has proved responsive to feedback. Overall, she's been pleased with her experience.

"One year, and you're going to be ready to go," she said. "I think they've fulfilled their promise."

Ms. Kissinger also said, though, that she and some other fellows in the Purdue program, specifically designed for rural schools, have had trouble getting jobs in such schools. She ultimately was hired to teach 8th grade science this coming school year in the city of Lafayette, Ind.

One fellow who expressed decidedly mixed feelings about his experience was Jared R. Allen, a former research scientist who was in the first cohort at Indiana University-Purdue University, Indianapolis.

"If I were to put it on a scale of 1 to 10 of preparation, I would give it about a 6 or 5," he said, pointing especially to the coursework as often lacking relevance.

But Mr. Sebens, in that same university's second cohort, said he's seen a lot of changes in the fellowship and rated his experience as "very good to excellent."

Several outside observers say they're encouraged by the Woodrow Wilson initiative.

"The program has really terrific strengths," said Francis Q. Eberle, the executive director of the National Science Teachers Association, based in Arlington, Va. For example, he praised the extended mentorship for teaching fellows and the emphasis on placing them in high-need schools.

David Harris, the chief executive officer of the Mind Trust, an Indianapolis-based nonprofit that supports entrepreneurial ventures in education, said he especially appreciates the effort to change university programs.

"The vast majority of our teachers are going to be prepared through teacher colleges for the foreseeable future," he said. "Any effort to revamp and re-energize schools of education is very worthwhile, ... but it's a difficult task."

### Backsliding Ahead?

A crucial question, observers say, is whether the changes in teacher preparation at participating universities will have staying power.

Ms. Bond of the Woodrow Wilson foundation said she's very mindful of that concern, especially once the formal partnership with the Woodrow Wilson Foundation comes to a close and if outside funding dries up. "We worry about plateaus and how easy it is to slip back into old, comfortable ways," she said.

In any case, a lot of enthusiastic fellows with strong STEM knowledge—and in some cases, years of professional experience—are already making their way into teaching careers, such as Mr. Sebens.

"There's not a whole lot of 7th grade engineering classes in the country," he said. "It's pretty much my dream job."

*Coverage of mathematics, science and technology education is supported by a grant from the GE Foundation, at www.ge.com/foundation.*

## WHO'S TAPPED

The Woodrow Wilson Teaching Fellowships program, which recruits and prepares teachers in the STEM fields, drew more than 1,500 applicants this year. Of the 211 selected:

**99%**
Majored in a STEM discipline

**26%**
Earned an advanced degree

**43%**
30 years or older

**51%**
Female

**49%**
Male

SOURCE: Woodrow Wilson National Fellowship Foundation

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# New Science Framework Paves Way for Standards

By Erik W. Robelen

With the goal of sparking big changes in K-12 science education across the country, an expert panel convened by the National Research Council today issued a framework to guide the development of new national standards in the subject.

Top priorities include promoting a greater emphasis on depth over breadth in understanding science and getting young people to continually engage in the practices of both scientific inquiry and engineering design as part of the learning process. Another goal is to promote what the panel calls greater "coherence" in the teaching of science as students progress through school, with the core scientific concepts revisited at multiple grade levels to build on prior learning and help facilitate a deeper understanding.

Now that the framework is complete, Achieve, a nonprofit organization based in Washington, will work with states and outside experts to craft a set of what's being billed as "next generation" science standards for elementary and secondary education, expected out by fall 2012. Organizers say they hope that states from coast to coast will ultimately choose to adopt the standards to replace existing ones.

The effort comes amid strong and growing concerns about the need to improve student achievement in the STEM fields—science, technology, engineering, and mathematics—and as the 45 states that adopted common-core standards in math and English/language arts attempt to implement them.

"Many of those states are feeling, if we're doing common things in math and English/language arts, why not in other areas?" said Helen R. Quinn, who chaired the NRC panel and is a professor emeritus of physics at the Stanford Linear Accelerator Center at Stanford University.

"The goal is better science education, and I would say, certainly at the early grades, more science, too," said Ms. Quinn, who laments that the subject "has almost disappeared" at the K-3 level.

The framework is built around three major dimensions: scientific and engineering practices; cross-cutting concepts that unify the study of science and engineering; and core ideas in four disciplinary areas—physical sciences, life sciences, earth and space sciences, and engineering, technology, and the applications of science.

Funding to develop both the framework and the new standards comes from the Carnegie Corporation of New York. (The foundation also underwrites coverage of district and high school reform in *Education Week*.)

The congressionally chartered NRC issued a draft last summer, but made significant revisions in response to public feedback, though Ms. Quinn emphasized that the final product still keeps to the core agenda for revamping science education.

The National Science Teachers Association, based in Arlington, Va., issued a statement praising the framework as holding the potential to bring about "transformational changes" in science education, especially with the focus on better engaging students and bringing close attention to the practices of science.

That said, Francis Q. Eberle, the group's executive director, cautioned that there's plenty of work ahead to see if the framework really can spur widespread change.

"That's the big question," he said in an interview. "It really will depend on the ways in which it gets implemented. There are many steps: articulation into standards, then what happens for teachers, teacher preparation, for curriculum, for assessments. We're at the beginning of a journey here."

The NRC panel itself was mindful of those challenges.

"The committee emphasizes that greater improvements in K-12 science and engineering education will be made when all components of the system ... are aligned with the framework's vision," the document says.

### Advances in Learning

An 18-member committee that included experts in education and science from a variety of disciplines designed the framework. It lays out the broad ideas and practices that students should learn and that are intended to serve as the foundation for the new standards.

The new science framework comes more than a decade after the NRC first issued a set of national science education standards in 1996. Separately, in 1993, the American Association for the Advancement of Science published its Benchmarks for Science Literacy. Both documents, which experts say have a lot in common, are seen as having had considerable influence on state science standards. At the same time, the documents have encountered criticism, including the complaint that they contain too many learning objectives for students.

In a foreword to the new document, leaders at the National Academies explained the rationale for undertaking the work.

"This project capitalizes on a major opportunity that exists at this moment," with most states having recently adopted common standards in math and English/language arts, write Ralph J. Cicerone, the president of the National Academy of Sciences, and Charles M. Vest, the president of the National Academy of Engineering.

They also note that "not only has science progressed" since the national documents on science content were produced in the 1990s, but "the education community has learned important lessons from 10 years of implementing standards-based education." Furthermore, they point to a "new and growing body of research" on science learning itself.

"We've learned an awful lot about how children learn and ways to develop environments to support science learning, and this is our chance to reflect [that]," said Brian J. Reiser, a member of the NRC committee and a professor of learning sciences at Northwestern University, in Evanston, Ill. "The research points us to what is possible and helps us articulate this vision for what really effective science education should be."

In setting the stage for the framework, the committee points to its concerns about the current state of science education in the United States.

"It is not organized systematically across multiple years of school, emphasizes discrete facts with a focus on breadth over depth, and does not provide students with engaging opportunities to experience how science is actually done," the document says. "The framework is designed to directly address and overcome these weaknesses."

Mr. Reiser drew special attention to the committee's attempt to bring better coherence across elementary and secondary education in learning science by promoting the idea that key concepts—such as energy or forces and motion in the area of physical sciences—should be revisited at various grade spans, whether K-2, 3-5, and so on.

"Each of our core ideas appears in each of these grade bands," he said. "We're trying to articulate a way that children can develop more and more sophisticated ideas building on these prior ideas."

Mr. Reiser added: "This is not a dramatically new idea, but unfortunately, there are lots of obstacles in our education system that ... work against coherence."

The framework also contains a strong emphasis on engineering and technology.

"Engineering and technology are featured alongside the natural sciences ... for two critical reasons: to reflect the importance of understanding the human-built world, and to recognize the value of better integrating the teaching and learning of science, engineering, and technology," the NRC document says.

It later elaborates on that matter, saying that engineering and technology were included in the framework to "provide a context in which students can test their own developing scientific knowledge and apply it to practical problems." The panel adds that, at least at the K-8 level, those topics typically do not appear elsewhere in the curriculum.

## 'A Lot of Transparency'

Work is now starting to get under way by Achieve, a group governors and business leaders created in 1996, to translate the conceptual framework into a set of standards.

The organization has already assembled a team of 36 writers with expertise across science and education to craft the standards, said Stephen L. Pruitt, the vice president for content, research, and development at Achieve. Mr. Pruitt, who will take the lead in overseeing the process, said the list of writers would be made public in coming weeks.

Although Mr. Pruitt emphasized that all states will have a chance to weigh in on the standards at various points, a group of approximately six to eight states will serve as "lead state partners" in their development. Achieve is inviting states to apply to participate in that capacity, he said, and the organization will rely on a group of outside experts to help make a final decision, with the goal of having a diverse group of states both geographically and in how they currently organize their science standards.

"It is going to be truly a state-led effort," said Mr. Pruitt, a former state official in the Georgia education department—including as a science supervisor—with a dozen years of experience teaching high school science.

In addition, a broad-based "stakeholder group" will provide feedback throughout the process, he said.

"We've got about 700 names on that list so far, from K-12 educators to prominent scientists, industry leaders, a group that we wanted to be very representative of the country," Mr. Pruitt said. "This is an effort that is going to require a lot of transparency and a lot of people being engaged in the process throughout."

There will be some notable differences between the effort to develop science standards and the recent work on common standards in math and English, he said. Achieve also played a key role in crafting the common core.

For one, unlike with the math and English standards, participating states will not be required to make a prior commitment to adopt the science standards. Also, Mr. Pruitt said no plan exists to his knowledge for the federal government to create any particular incentives for states to adopt the standards, as is the case with the math and English standards.

Mr. Pruitt himself was a member of the NRC framework panel, though he had to step down from that position when he joined Achieve's staff last summer.

Even as the framework emphasizes the importance of scientific practice, he said, that in no way should be interpreted as backing away from the notion that students should have a clear understanding of critical scientific concepts.

"I want to be real clear that there is going to be plenty of content, but also [a focus on] how scientists use it," he said. "So we want it to be more than just students memorizing facts, but we recognize that science is a body of knowledge."

The framework document itself explains the governing philosophy behind its approach to science content.

"The continuing expansion of scientific knowledge makes it impossible to teach all the ideas related to a given discipline in exhaustive detail during the K-12 years," it says.

"But given the cornucopia of information available today virtually at a touch—people live, after all, in an information age—an important role of science education is not to teach 'all the facts' but rather to prepare students with sufficient core knowledge so that they can later acquire additional information on their own."

Stepping back, the report's authors say that the ultimate goal of the framework is to ensure that by the end of 12th grade, all students have "some appreciation of the beauty and wonder of science," have sufficient knowledge of science and engineering to engage meaningfully in public discussions, are careful consumers of scientific and technological information, and have the skills to enter careers in science, engineering, and technology if they wish.

Students should "see how science and engineering are instrumental in addressing major challenges that confront society today, such as generating sufficient energy, preventing and treating diseases, maintaining supplies of clean water and food, and solving the problems of global environmental change," the committee says.

In addition, the panel expressed its hope that the vision of change in science education laid out in the document will "motivate and inspire" more people, and a better representation of the nation's diverse population, to pursue careers in science and engineering.

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# National Park Service Expanding Education Mission

## Agency plans to reach a fourth of U.S. students

By Nora Fleming
*Sausalito, Calif.*

Dense fog is slow to abate on this recent morning, as more than 200 6th graders scatter into small groups on the site of an old military camp in California's Marin Headlands outside San Francisco. They are a mix of moods—eager, hesitant, hyperactive, and sleepy—as they begin their first full day at NatureBridge, a residential environmental field-science program in partnership with the National Park Service.

The program, in its 40th year, has served close to 1 million children from all over the country at four national parks on the West Coast: Yosemite, Olympic, Golden Gate, and the Santa Monica Mountains. This coming spring, the program will expand to the East Coast, with the help of a $4 million grant from Google Inc., to set up camp in the Prince William National Park, about 40 minutes outside the nation's capital.

NatureBridge's continued efforts to engage children in science at some of the country's most beautiful sites comes alongside a national push to improve the quality of STEM—or science, technology, engineering, and mathematics—instruction, in light of U.S. students' lackluster test performance compared with many of their international peers'. In the most recent round of the federal Race to the Top competition, for instance, the seven finalist states are required to highlight how the plans submitted in their original proposals will improve and enhance the quality of STEM education in their schools.

The increased attention to STEM has focused in part on how to improve student interest in learning about these subjects and pursuing careers in the fields later on. Hands-on learning experiences, like those NatureBridge and the National Park Service use, are seen by some as one solution. Yet in a time of tight resources and high-stakes testing in education, such programs also face a challenge in vying for funding and proving their legitimacy.

"To improve environmental literacy and attract more kids to explore STEM careers, we as a society need to shift attitudes and expand the knowledge of young people through broader and more engaging programs that teach kids about key issues," said NatureBridge Executive Vice President Jason Morris. "This work is never going to be scaled by NatureBridge alone offering environmental education programs in all places. But we can demonstrate the viability of these types of programs and ensure we maintain cutting-edge and relevant programs that embrace and evolve with the changes in the field."

> "We're not just a place to take a field trip to."
>
> PETE DEMYANOV
> Instructor, NatureBridge

### Unaware of Learning

A group of 16 of the 6th graders breaks off with NatureBridge instructor Pete Demyanovich, who will guide them through the week. Each campus, while geographically distinct, follows NatureBridge's core education framework for inquiry-based science: developing students' sense of environmental awareness, connections to the natural world, and stewardship for the places they live in.

But each session, for each school, is different, tailored to the age, the grade, and the goals of the particular school.

For Terman Middle School, a public school in Palo Alto, Calif., the goal this week is not merely to improve students' understanding of earth science, but also to develop and build a more cohesive 6th grade in the 660-student school. Prior to arrival at NatureBridge, teachers spent hours setting up small groups that transverse social circles, socioeconomic classes, and ethnic boundaries. Throughout the day, activities focus on connecting these students with one another, many who had not met prior to this week.

After a few rounds of icebreakers and a lesson on plate tectonics, Mr. Demyanovich's group creates interactive skits to illustrate the scientific principles just learned. Later, the students figure out how to cross an imaginary pool of lava in a team-building activity. At lunchtime, they sit in a circle to make sandwiches, ensuring "no trace" of trash, or even crumbs, is left behind. In the afternoon, group members pair off to collect water samples and organisms from a nearby pond for a lab activity later in the day.

According to Mr. Demyanovich, a former classroom teacher, one of the features that sets the program apart from classroom learning is that the children are engaged and learning science without being aware they're learning. Even the "quiet kids" come out of their shells and participate, he said, the classroom hierarchies and politics erased.

Hands-on science education is fundamental to improving "geo-literacy," or understanding the connections between actions and impact in the ecosystem, said Daniel Edelson, the vice president of education for the National Geographic Society, which has helped support NatureBridge through evaluation, advice, and funding through its foundation. Students have to learn through real experiences, he said, not just textbook learning.

"In creating schools that are optimized for academic learning, we've created environments that interfere with learning about the natural world," said Mr. Edelson, who was also a member of the education advisory council that helped NatureBridge devise its core education framework. "We need to create opportunities for students to learn about the environment through firsthand experiences. This means getting them out of school buildings in order to observe and experience the natural world."

### Making Connections

As interest in STEM education rises nationally, there seems to be a particular focus on science. Efforts are under way to develop common standards in the subject. (All but four states have already adopted the common-core state standards in mathematics.) But there's not only heightening attention to science learning itself, but to instruction that builds students' understanding of the connections between science and the environment.

The U.S. Department of Education this fall announced it would recognize exemplary schools that actively promote environmentally friendly practices and encourage students' environmental literacy through the new Green Ribbon Schools program. A group of environmental education experts also plans to release a framework next year to guide assessments of students' environmental literacy, and by 2015, the Program for International Student Assessment, or PISA, will even include an optional exam on the subject.

The National Park Service and its partner providers may be leaders in promoting that literacy. A memorandum of understanding is currently in the works between the Education Department and the U.S. Department of the Interior, which manages the National Park Service, to collaborate on education goals around teacher development and STEM, among other subjects, using outdoor classrooms and spaces.

That comes on the heels of the Park Service's release of a five-year strategic plan, which will guide the agency to its 100-year anniversary in 2016 and into the next century. The plan relies on no additional public funding, but instead, focuses on improving services and program quality and refocusing target audiences.

## Expanding Access

A major component of the plan is to expand education programs for a quarter of America's schoolchildren through real and virtual field trips, teacher professional development, and more partnerships with organizations like NatureBridge to provide programs at their 394 parks or similar sites. Park Service leaders hope to supply free transportation to nearly 100,000 students annually and leverage digital learning and social media as a way to reach more children.

That means children in New York City, for example, could use Skype to virtually explore the kelp forests in Southern California's Channel Islands or see the ins and outs of a historic Nebraska homestead, said Julia Washburn, the Park Service's associate director for interpretation and education. Lesson plans for teachers to use in conjunction with parks and historic sites, large and small, are also being expanded for the Park Service's website. The aim is to provide access to the parks for students who may not be able to participate in programs like NatureBridge because of limited access to locations or funding.

"The benefits of multiday, residential, outdoor education programs are very well documented and well embraced, but they are expensive to provide and require a lot of resources," Ms. Washburn said. "This means they are typically a deeper experience for fewer kids. Shorter single-day, field-trip experiences are less expensive, and can serve more students, but their impact, while still beneficial, isn't as great."

Late in the afternoon, students take their pond samples to the microscope lab to look for and identify insects, which they sketch in their NatureBridge field journals. For a number of students, it's their first time using microscopes. A typical science class back at school, a few casually mention, is reading assigned paragraphs out of a textbook.

Despite the growing attention to STEM, in many places, the quality of science instruction has been found lacking.

A recent report from WestEd, a San Francisco-based research organization, found that 40 percent of California elementary teachers surveyed said they devote 60 minutes a week or less to science. The quality of science instruction in most schools was subpar, the report found, mainly because of poor instructional materials, ill-equipped teachers, and a lack of assessments—factors attributed in part to budgetary pressures and deemed to be common nationwide.

Given today's fiscal realities, justifying the importance of programs like NatureBridge could get more difficult. The Park Service, for one, faced its first federal cuts in years and may have to reduce programs in the future. NatureBridge, which operates as a nonprofit, currently provides funding to more than a third of participants. Many schools do their own fundraising to pay for the program, including Terman Middle, which raised $6,000 through the local PTA to pay for the students' attendance.

Although participation hasn't declined, demand for assistance has heightened, according to NatureBridge. Private grants, thus far, have enabled the program to meet the need. The program has also continued to make a greater effort to reach out to students from underprivileged and diverse backgrounds to expose them to national parks and field science.

For students who live in highly urban areas, and whose families are not able or inclined to visit these types of spaces, it can be challenging to make hands-on environmental science experiences relevant, educators say.

"The question is: How do you take an education experience that may seem far removed and help make connections with everyday life? How can we better ensure the environment is not separated from day-to-day life and make an impact on environmental literacy and stewardship in the short and long term?" said Nicole Ardoin, an assistant professor of environmental education and social ecology at Stanford University.

A team of Stanford researchers led by Ms. Ardoin hopes to uncover those answers. Last month, the Moore Foundation, based in Palo Alto, awarded grants to both NatureBridge and her team to perform a comprehensive multiyear evaluation of NatureBridge's field-science efforts and to develop measurements to assess environmental literacy and stewardship outcomes of programs like it. They hope the research will reveal some of the nonacademic impacts of those types of experiences, she said, as well as build on ongoing evaluations of the program by Stanford and others that assess the impacts of inquiry-based science and long-term effects on teachers and students.

## Taking It With You

For some, the NatureBridge experience resonates long after the program. Alumni Virginia Delgado participated in the program as a 6th grader, later served as a high school counselor, and now, as a college student, is pursuing a degree in environmental studies with plans to work one day in environmental law. She said she hopes to work to ensure that all children, regardless of background, have access to experiences like NatureBridge.

Or take Chris Raisbeck, who attended the Yosemite program as a high school student, brought his students to the campuses as a teacher, and now serves as NatureBridge's field-science operations manager. He said the program he first visited more than 30 years ago has maintained the core education mission that drew him to it as a 16-year-old and persuaded him to come back to work for it as an adult.

For these Terman Middle School students, right now they're only thinking about the moment. The sun comes out less than an hour before dusk. The adjacent beach, enshrouded in fog for most of the day, is suddenly visible. Last night, students ventured to the shore to watch a special type of plankton glow in the dark. Tomorrow, Mr. Demyanovich's group heads on a hike to scope out local bird life and make connections to the insects they found today.

"It's really important this experience is not a bubble," Mr. Demyanovich said. "We focus on thematic teaching, teaching that unites the day. We are all educators [at NatureBridge] and are upping the bar to be thought of as a school. We're not just a place to take a field trip to."

*Coverage of science, technology, engineering, and mathematics education is supported by a grant from the GE Foundation, at www.ge.com/foundation.*

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# Awareness Grows of Importance of Learning Science Beyond School

## Opportunities are plentiful, from after-school programs to computer simulations to visiting a zoo

By Erik W. Robelen

When a fresh round of national and international data on student achievement in science came out recently, the results—widely seen as disappointing—prompted familiar hand-wringing from political leaders and education experts about the steps needed to improve science instruction in the public schools.

What's often missing from the national dialogue on the issue is a concerted focus not simply on what happens in the classroom, but also on the opportunities to learn about science—and to inspire a passion for the subject—that come outside the school day and the formal curriculum.

But many leaders in the field often referred to as "informal science education" say that is beginning to change. There are signs that this sector is garnering wider attention and starting to be included in broader discussions on how to improve science learning among young people.

David A. Ucko, a former senior official at the National Science Foundation, said the field now has greater external recognition of its impact on public awareness, understanding, and engagement with science and related subjects.

"There is definitely momentum building," agreed John H. Falk, a professor of free-choice learning at Oregon State University, in Corvallis. "The good news is that the field is of late being invited to some tables and being taken seriously as important, but it's still roughly an order of magnitude less than formal education."

One boost to the cause was the 2009 release of a major National Research Council report, "Learning Science in Informal Environments." With the prestige of the National Academies behind it, the NRC document served as a clarion call.

"Efforts to enhance scientific capacity typically target schools and focus on such strategies as improving science curriculum and teacher training and strengthening the science pipeline," the report said. "What is often overlooked or underestimated is the potential for science learning in nonschool settings, where people actually spend the majority of their time.

"Beyond the schoolhouse door," it said, "opportunities for science learning abound."

Indeed, they do. Visits to science-rich cultural institutions, such as zoos, aquariums, science centers, and natural-history museums immediately come to mind. But it's really a host of opportunities: astronomy and robotics clubs, after-school programs and science competitions, collecting rocks or taking a walk in the woods, watching television programs such as "MythBusters," or turning to the Internet to learn more about cancer or global warming. The list goes on and on.

President Barack Obama, who has aggressively used his bully pulpit to promote education in the STEM fields of science, technology, engineering, and mathematics, seems to share an appreciation for learning outside the classroom. He hosted an Astronomy Night on the White House lawn in 2009 and, last fall, the first White House science fair, celebrating winners of STEM-focused student competitions.

"In many ways, our future depends on what happens in those contests," Mr. Obama said at the October event. "It's in these pursuits that talents are discovered and passions are lit, and the future scientists, engineers, inventors, and entrepreneurs are born."

### No Tests or Grades

In an increasingly data-obsessed education landscape, one challenge is meeting the demand for concrete evidence on how individuals benefit from informal learning opportunities.

The NRC report found "abundant evidence" that people of all ages learn science across a wide range of venues and activities. But that report, and interviews with experts in the field, suggest there's still a long way to go in better evaluating and understanding the impact.

Advocates for informal learning emphasize that it's vital not simply to align measures for out-of-school learning with the focus on standardized achievement tests so prevalent in public education. Instead, the idea is to gauge scientific skills and understanding in ways that are more appropriate to the various settings and activities, as well as to look at interest in science topics and a person's self-identification as someone knowledgeable about science.

"If we allow the things that are easy to measure in school districts as the only definitions of learning we're going to consider, we are leaving off the table an awful lot of things," said Kevin J. Crowley, the director of the University of Pittsburgh's Center for Learning in Out-of-School Environments and an associate professor of education and psychology. "We need to have compelling, theory-based, reliable measures, and we're just beginning to chip away at that right now."

The NRC report said one important feature of informal learning settings is the absence of tests, grades, and other familiar approaches used by schools to document the effect of education.

"Assessments should not be limited to factual recall or other narrow cognitive measures of learning," it said, but instead "should address the range of intellectual, attitudinal, behavioral, social, and participatory capabilities that informal environments effectively promote."

In fact, tools are now emerging that show the potential to link individuals' learning across a lifetime of different experiences. *(See Education Week, April 6, 2011.)*

One domain that is seeing a strong push to promote learning and engagement in science is the after-school setting. In fact, 2011 was billed as the "Year of Science in After-School" by several leading groups, including the Afterschool Alliance, the National After-School Association, and the National Summer Learning Association.

"We're all speaking with one voice to say this is important," said Anita Krishnamurthi, the director of STEM policy for the Afterschool Alliance, an advocacy group based in Washington.

Meanwhile, initiatives have recently emerged in California and Missouri to establish sustainable statewide systems that support and promote high-quality after-school programming in the STEM fields. The initiative in Missouri, Project Liftoff, is working to spark similar undertakings in other Midwestern states as well. Among the efforts planned are identifying a menu of first-rate curricular materials in the STEM fields, better preparing after-school program staff members to provide engaging STEM activities, and supporting the evaluation and improvement of such after-school offerings.

The project is getting financial backing from the Noyce Foundation, which also underwrote this special report, and the Charles S. Mott Foundation, which helps underwrite economic-stimulus coverage in *Education Week*.

Some advocates have eyed policy changes at the federal level to gain better leverage for informal science learning. A prime target is the main federal source of after-school aid, the $1.2 billion 21st Century Community Learning Centers program.

Last year, a White House advisory panel on science and technology—as part of a larger report on improving STEM education—urged the government to create a set-aside in the program for those fields. It suggested that the funding could be pooled with other federal aid to create a new, coordinated initiative across agencies to support high-quality out-of-school activities that "inspire" students in the STEM subjects. Such activities could include after-school and summer school programs, as well as contests, the report said.

The news and entertainment media have long served as powerful vehicles for educating the public about science, from newspapers and magazines to TV and radio programs, documentaries, and IMAX films. Even science-fiction movies have helped inspire young people to learn about science. The National Science Foundation is a key supporter, having issued an assortment of grants over the years for educational programming, including the science desk at NPR, television programs like DragonFly TV, and giant-screen movies like "Tornado Alley," which premiered in March.

Private foundations have also played a role. In February, for instance, the Howard Hughes Medical Institute, based in Chevy Chase, Md., announced the launch of a $60 million documentary-film initiative to bring compelling science features to television.

Further, new technologies hold tremendous promise to advance science learning and interest, with the advent of increasingly sophisticated computer games and simulations, among other developments.

## 'Urban Advantage'

Ensuring access across the U.S. population, especially among low-income and minority families, is seen as an important goal for many informal initiatives and institutions, from after-school programs to science centers and museums, such as Explora, in Albuquerque, N.M. Explora offers free memberships for low-income families and hosts Family Science Nights in partnership with the city school district as a way to better acquaint such families with its offerings.

The Family Science Night idea also illustrates another theme: the value of fostering direct connections between schools and informal learning environments. Around the country, there's no shortage of such collaborations.

Explora, like many other science centers, also offers professional-development programs for teachers. And it offers a menu of more than 200 hourlong experiential programs for students, called "explorations," pegged to the state's academic standards.

In New York City, Urban Advantage, a program led by the American Museum of Natural History, has brought together the city school system and an assortment of science-rich institutions, including the New York Hall of Science, the Queens and Brooklyn botanical gardens, and the Bronx Zoo, to provide rich opportunities to improve middle school students' understanding of scientific inquiry.

The value of such collaborations between schools and informal institutions was brought into clearer focus by a 2010 report from the Center for Advancement of Informal Science Education, a partnership of several organizations that was founded with NSF support.

The report said formal-informal collaborations can enhance students' and teachers' conceptual understanding of science, improve student achievement, strengthen students' disposition toward the field, and help teachers integrate inquiry and new materials into the classroom.

"Despite scores of such examples, these collaborations have generally failed to institutionalize: In many communities, they come and go with changes in funding and leadership," it said. "The walls between formal and informal learning professional fields are only beginning to crumble. There is too little transfer of practice, learning, and community."

Even as informal science education is gaining more prominence, people who know the field say insufficient money remains a big barrier to expanding its role.

## 'A Modest Change'

In a recent essay, Mr. Falk from Oregon State University, along with Lynn D. Dierking, also a professor of free-choice learning at that university, noted that far more funding goes to public schooling in science than informal learning opportunities.

"Even a modest change in this ratio could make a huge difference" to Americans' science literacy, they wrote in the December issue of American Scientist magazine, though they emphasized that they were not suggesting lessening support to schools.

Martin Storksdieck, the director of the Board on Science Education at the National Academies, suggests that advocates still have a lot of work to do in convincing policymakers and the public that informal science learning merits increased investment.

He points to a telling illustration. The federal economic-stimulus legislation enacted in 2009 included on a short list of institutions barred from receiving funds not only casinos, golf courses, and swimming pools, but also zoos and aquariums. (The Senate-passed bill sought to add museums, theaters, and several other categories to the list, but that language was removed.)

"At the end of the day, we haven't made the value proposition in the political arena or to consumers as much as we should," Mr. Storksdieck said, "of just how fundamentally beneficial these learning spaces are, and how much we as a society and as individuals benefit when we take part in what they have to offer us."

*This story was underwritten by a grant from the Noyce Foundation, at www.noycefdn.org.*

*Published January 11, 2012*

# Out-of-School Time Drawing Girls Into STEM Learning

## Underprivileged also targeted

By Nora Fleming
*Oakland, Calif.*

A group of high school girls listen eagerly for their mission: Use the tools on hand to design a self-propelled boat that can cross water with 50 passengers on board. The passengers: pennies. The tools: pipe cleaners, popsicle sticks, and balloons. The water: an inflatable kiddie pool.

It's another engineering "design challenge" at Techbridge, an after-school program for girls that encourages interest in STEM—science, technology, engineering, and mathematics—subjects. Close to 30 girls are here this day at Arroyo High School, one of 21 Techbridge sites in California's Bay Area that serve more than 600 elementary and secondary girls in total, close to 90 percent of them minority students.

While Techbridge still operates a number of after-school programs like Arroyo's, its other related STEM initiatives, scaled by large national funders like the National Science Foundation, Google, and the Noyce Foundation have enabled the organization to reach more than 10,000 girls in the out-of-school-time space to date.

Those efforts coincide with the national momentum to teach STEM curricula outside traditional school walls, targeting minority, underprivileged, and female students not well represented in the STEM professions. Such environments could be a catalyst, some believe, that shifts students' attitudes about STEM through innovative teaching methods not bound by the protocol of the school day.

According to Techbridge Executive Director Linda Kekelis, whether or not a student chooses to pursue a STEM career has more to do with conditioning than predisposition. With the right curriculum and right environment, she said, it's possible to change a student's mind.

"Girls and boys, it's not that they are so different. Their experiences, however, can be very different, which leads to different interests and career trajectories," she said. "Techbridge is providing the expectations and the experiences to level the playing field for girls, particularly in STEM."

### Limited Progress

More than a decade ago, the scarcity of women and minorities in STEM fields inspired the creation of Techbridge, which began as a small after-school program in the Bay Area supported by an NSF grant.

While the organization's initial goals have remained the same, the statistics nationally haven't changed much, according to a U.S. Department of Commerce report released last year. Women hold less than 25 percent of STEM jobs, says the report, even though they make up about half the nation's workforce. The numbers of minorities and those from underprivileged backgrounds are similarly low.

But now, more heads are turning toward using out-of-school experiences as a means to up the numbers.

Last year was deemed the "Year of Science in Afterschool," an initiative to promote out of school STEM efforts spearheaded by Noyce Foundation in partnership with other out-of-school-time advocacy organizations. (*Education Week* has been a recipient of Noyce funding.) Leaders in the out-of-school and expanded-learning arenas have also actively promoted the incorporation of STEM into the curriculum for their programs and for the schools they work with. And the U.S. Department of Education is looking into providing technical assistance for STEM professional development through the 21st Century Community Learning Centers program, which finances some 9,000 after-school sites nationwide.

The California STEM Learning Network, a new outgrowth from a Bill & Melinda Gates Foundation initiative, seeks to improve the quality of the state's STEM education and encourage more students, particularly the underserved, to pursue STEM careers through after-school and out-of-school programs. (The Gates Foundation also provides support for coverage of business and innovation in *Education Week.)*

Those programs are a perfect opportunity to provide engaging learning opportunities for underprivileged students that traditional classroom environments cannot, said Chris Roe, the chief executive officer of the state STEM network. Additionally, given that the state funds 4,000 of these after-school programs, the initiative's efforts can be implemented at minimal cost, he added.

The state network hopes to reach 1 million children and will work with more than 1,000 programs this year. A national STEM network is also in the works.

"We know from the research that student engagement and making STEM relevant to students is critical," Mr. Roe said. "Today, there is a large disjunction for students who don't see a lot of relevance in what they are learning in the school day and their lives. By exposing students to STEM in out-of-school time, they are learning, for example, how engineering can be exciting."

Techbridge has also sought to stimulate student excitement, especially for students who were turned off or misinformed about STEM. To design its curriculum, Techbridge asked girls, as well as teachers and parents, what would appeal to them. They then took their core ideas—like taking things apart and wondering how they work or understanding how STEM could "make the world a better place"—and incorporated them into lessons.

Role models, student leadership, and teamwork are also critical, Techbridge has found, to encourage girls. Program participants meet female professionals who work in STEM fields and take field trips to see them in action at companies like Apple, Facebook, or eBay.

While Techbridge's target population and goals may be specific, some of its central ideas can be replicated in other, more general after-school programs, said Carol Tang, the director of the Coalition for Science After School, a national organization based at the University of California, Berkeley. Out-of-school-time programs need not become solely STEM-targeted, she added, but could infuse high-quality STEM curriculum into the core components of their existing program at a low cost.

"Because there is such a great diversity of after-school programs, we need to identify a diversity of successful examples so that the majority of after-school programs can find models to fit their own audiences and infrastructure," Ms. Tang said.

Techbridge has shown components of its program can be used elsewhere. Parts of the curriculum are now taught in more than 100 other after-school programs and its STEM "program in a box" for Girl Scout troops is used by councils around the country that serve 4,000 girls.

### Beefing Up Teaching

Part of promoting student interest in STEM and delivering high-quality programs could be linked to the instruction itself.

A 2009 report from the Carnegie Corporation of New York found that math and science education needs to be transformed, primarily through school redesign, with better use of time and more effective teachers.

Now, aspiring teachers and undergraduates from California State University, East Bay, are teaching STEM in middle school after-school programs, including Techbridge sites, and a larger initiative, the California Teacher Pathway, is on 10 California State University campuses, and includes teaching STEM in after-school programs at a number of the sites.

The goal is for preservice teachers not only to gain confidence teaching through the after-school setting, but also to become familiar with hands-on teaching methods that are characteristic of high-quality after-school programs and conducive to learning STEM, said Joan Bissell, the director of teacher education and public school programs for the CSU chancellor's office. The teacher-candidates will also get a better "appreciation" for the children they are working with, the majority of whom are underprivileged, she said.

"After-school programs tend to very significantly deepen the learning opportunities children and teacher-candidates have," said Ms. Bissell, who serves as the university lead on the project. "The experience can be transformational for the teacher-in-training, as, in essence, they learn the craft of teaching in environments rich with opportunities for children's inquiry and projects that enable the candidates to observe the different ways a child can learn."

### Ice Cream and Science

The different ways of learning found in out-of-school programs like Techbridge's can seem, on the surface, to be simple, but they are much more strategic. At Lincoln Elementary in Oakland's Chinatown neighborhood, for one, students are unaware they're still learning.

The final bell sends many students flooding through halls, eager to head home to start a week's worth of vacation. But in Mr. Fong's 5th grade classroom, it's far from empty and silent.

About 25 5th grade girls shake plastic bags full of sugar, cream, milk, and vanilla extract inside larger bags filled with ice cubes and rock salt. Girls knead and pummel their bags into their desks and bounce up and down with bags in hand, impatiently waiting for extra cold ice to freeze the liquids into solids and create ice cream.

In the quest for the creamiest and best-tasting vanilla ice cream, groups of four decide what ratios to use of milk and cream to add up to one cup of liquid. When they enjoy the treat later on, they'll learn the science behind why the salt and ice produce the dessert.

It's the environment found at Lincoln this day, all girls, working collaboratively in hands-on, "fun" educational activities, that makes the Techbridge program so effective, according to some. At the least, the environment improves girls' self-confidence and esteem, instructors say, but for others, it builds a real passion for STEM, which has inspired a number to pursue STEM majors and careers, according to Techbridge research.

David Drew, a professor of education at Claremont Graduate University, outside Los Angeles, says it will be challenging to change the statistics and push more underrepresented populations into STEM careers, but it's possible. It starts with a shift in attitudes, he said, by students, parents, teachers, and leaders.

"There is a vast amount of untapped, wasted talent in this country: Too few girls, too few students of color, and too few students from poverty are going into STEM," said Mr. Drew, who has written extensively on STEM education. "Things will change only when we realize that students in these groups have just as much intelligence and aptitude as any other group."

*Coverage of leadership, expanded learning time, and arts learning is supported in part by a grant from The Wallace Foundation, at www.wallacefoundation.org.*

> "Girls and boys, it's not that they are so different. Their experiences, however, can be very different, which leads to different interests and career trajectories. Techbridge is providing the expectations and the experiences to level the playing field for girls, particularly in STEM."
>
> LINDA KEKELIS
> Executive Director, Techbridge

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# Building STEAM: Blending the Arts With STEM Subjects

## Goals are creativity and engagement

By Erik W. Robelen

The acronym STEM—shorthand for science, technology, engineering, and mathematics—has quickly taken hold in education policy circles, but some experts in the arts community and beyond suggest it may be missing another initial to make the combination more powerful. The idea? Move from STEM to STEAM, with an A for the arts.

Although it seems a stretch to imagine STEM will be replaced in education parlance, momentum appears to be mounting to explore ways that the intersection of the arts with the STEM fields can enhance student engagement and learning, and even help unlock creative thinking and innovation.

In fact, federal agencies, including the U.S. Department of Education and the National Science Foundation, are helping to fuel work in those areas.

The NSF has provided research grants and underwritten a number of conferences and workshops around the nation this year, including a forum hosted by the prestigious Rhode Island School of Design, titled "Bridging STEM to STEAM: Developing New Frameworks for Art-Science-Design Pedagogy."

Picking up on the Rhode Island institution's push for STEAM, in late September, a lawmaker from that state, U.S. Rep. James Langevin, a Democrat, introduced a House resolution to highlight how "the innovative practices of art and design play an essential role in improving STEM education and advancing STEM research."

On-the-ground examples of bringing the arts and STEM learning together abound, from Philadelphia and Boston to San Diego.

For instance, the Philadelphia Arts in Education Partnership, with support from a $1.1 million Education Department grant, is working with city schools to help elementary students better understand abstract concepts in science and mathematics, such as fractions and geometric shapes, through art-making projects.

High school students in several U.S. cities, meanwhile, compete for an annual ArtScience Prize. First launched in Boston in 2008, the contest fuses concepts in the arts and design with the sciences. The theme of last school year's curriculum and contest was the Future of Water. This year, it's Virtual Worlds, and next, the emerging field of synthetic biology.

One advocate of the STEM to STEAM push is Harvey Seifter, the director of the Art of Science Learning, a project financed by an NSF grant that organized three conferences last spring in Washington, Chicago, and San Diego that brought together scientists, artists, and researchers, as well as educators, business leaders, and policymakers to explore how the arts can be engaged to strengthen STEM learning and skills and produce a more creative American workforce.

"For me, it is about connecting—or reconnecting—the arts and sciences in ways that learning can happen at the intersection of the two," said Mr. Seifter, an expert in arts-based learning who also consults with Fortune 500 companies on business creativity. "We believe there is a powerful opportunity here to use the arts and arts-based learning to spark transformational change in science education."

One core idea Mr. Seifter and other STEAM advocates emphasize is that the arts hold great potential to foster creativity and new ways of thinking that can help unleash STEM innovation.

"There is creativity in STEM itself, super genius in it, ... but in arts education, it really is the raison d'etre to be out of the box, to accept the chaos," said John Maeda, the president of the Rhode Island School of Design, in Providence.

Artists and designers, he said, are "risk takers, they can think around corners."

Mr. Maeda invokes STEAM as a pathway to enhance U.S. economic competitiveness, citing as an example the late Apple co-founder, Steve Jobs, a leading force behind the iPod, iPhone, and other electronic devices.

### In da Vinci's Footsteps

"What STEAM means, it should feel like Steve Jobs, what he did for America," Mr. Maeda said. "It is an innovation strategy for America."

To be sure, the idea of integrating the arts with learning in other fields, including the stem disciplines, is not new. In fact, some observers have noted an increase of late in activity more broadly

> "For me, it is about connecting—or reconnecting—the arts and sciences in ways that learning can happen at the intersection of the two.
>
> HARVEY SEIFTER
> Director, Arts of Science Learning

to promote arts integration across the curriculum, at a time when the arts struggle to keep a foothold in classrooms amid school budget cuts and the pressure for academic gains in subjects like reading and math. *(See Education Week Nov. 17, 2010.)*

But some experts perceive a special connection between the arts and the STEM fields. Mr. Seifter, for instance, points to a 2008 study led by Robert Root-Bernstein of Michigan State University, which found that Nobel laureates in the sciences were 22 times more likely than scientists in general to be involved in the performing arts. Others note that Albert Einstein was an accomplished violinist. And then there's the Renaissance figure who some view as the personification of STEAM: Leonardo da Vinci, the Italian painter and sculptor who also made a name for himself as a scientist, engineer, and inventor.

Whether integrating the arts with STEM education enhances student learning is not exactly a settled matter, as even advocates like Mr. Seifter acknowledge.

"There is no question, to me, the critical missing piece is the data," said Mr. Seifter. He adds that even as he's witnessed the power of the intersection, he sees a critical need for a "solid body of empirical knowledge about what the arts bring to the STEM equation."

Indeed, research examining the effect of arts integration on student achievement across disciplines appears to show mixed results.

Leaving the research question aside, however, some experts stop short of embracing a change from STEM to STEAM.

Alan J. Friedman, a former head of the New York Hall of Science, said it's crucial for students not to lose sight of the differences, for example, between art and science.

"One crucial point at which they part ways is the act of deciding, 'Is it good art? Is it good science?' " said Mr. Friedman, a member of the National Assessment Governing Board who holds a doctorate in physics. "Science and art have a lot to learn from each other, a lot of inspiration to share, a lot of commonality. They also have some very essential differences that are at the core of what they are, which is why I have trouble with STEAM."

Susan R. Singer, a biology professor at Carleton College in Northfield, Minn., echoes the point.

"Not to devalue the symmetry, but they are very different ways of knowing the world," said Ms. Singer, who previously served on the National Research Council's Board on Science Education. "I would stop short of STEAM, but celebrate the ways that they work together."

What the intersection of the arts with STEM learning looks like in practice varies widely.

## 'Fraction Mural'

The Philadelphia Arts in Education Partnership is focused on math and science instruction in the elementary grades, with support coming from its four-year grant from the Education Department's Arts in Education Model Development and Dissemination program. For example, through art-making projects, students at one school manipulated the abstract concepts underlying fractions for a more concrete understanding of how they work. The students even created a "fraction mural" displayed at the school.

"We match arts skills and processes to a specific learning goal in math and science," said Raye Cohen, the education director at the Philadelphia arts group.

She said that work with the visual arts is especially promising. "Visual arts just seems to really be able to home in on the concept, taking it from the abstract to the concrete, so students are really able to understand it," she said.

Ms. Cohen says the project involves an "intense research component" and will look at a variety of effects, including student test scores, suspensions, and unexcused absences, as well as parent engagement in homework and changes in teaching practices.

In California, a $1.1 million grant last year by the state's Postsecondary Education Commission, using federal teacher-quality aid, is supporting the 134,000-student San Diego school district's work linking the arts with science in grades 3-5.

"It's not just teaching science through the arts, but teaching science and the arts together, and what comes from that is more than either of them standing alone," said Karen Childress-Evans, the district's director of visual and performing arts.

The Wolf Trap Foundation for the Performing Arts, based in Vienna, Va., has recently developed early-childhood initiatives that blend STEM learning with the arts. The work—supported in one instance by a 2010 federal Education Department grant, in another by the philanthropic arm of aerospace giant Northrop Grumman—involves performing artists in theater, music, dance, and puppetry working alongside classroom teachers in preschool and kindergarten settings.

The ArtScience Prize, meanwhile, is built around the ideas of Harvard University professor David A. Edwards, the author of *ArtScience: Creativity in the Post-Google Generation*. High school students work in small teams on projects over a year's time in an after-school or in-school setting. The program has quickly expanded beyond Boston to include Minneapolis and Oklahoma City, as well as international locations.

The winning team in Oklahoma City earlier this year developed a biodegradable water bottle, while the top-rated Boston team is creating public art installations that communicate how people around the world struggle to gain access to fresh water.

"We're empowering young people to come up with their own ideas while exploring and playing in the arts and science," said Carrie Fitzsimmons, the executive director of ArtScience Labs, the Cambridge, Mass.-based organization that manages the ArtScience Prize. "It's all fun, experiential learning, but we're teaching them to be critical thinkers and problem-solvers."

In Ohio, the Dayton Regional STEM School takes the integration of subjects, including the arts, seriously.

Jenny Montgomery, an art teacher at the school, said her colleagues in other disciplines often approach her about working together. Last month, for instance, she team-taught with a biology teacher as part of a project in which students made watercolor paintings of cells.

"We were studying cell structure," she said, "and we were looking at paintings [the students created], these beautiful artistic renderings, and students could pick out the structures that they had been studying."

Ms. Montgomery said her work with science teachers has helped her make connections between the disciplines.

"One thing we looked at ... was how artists and scientists have common methodologies in observing the world around them," she said.

At the same time, Ms. Montgomery said, even in a STEM school, it's important for art not simply to be valued for its application to other disciplines.

"I also uphold the value of making art for art's sake," she said, "that students have an opportunity just to engage in art for the sheer joy of it."

*Coverage of leadership, expanded learning time, and arts education is supported in part by a grant from The Wallace Foundation, at www.wallacefoundation.org.*

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*Published on May 18, 2011*

# 'Math Anxiety' Explored in Studies

## It's more than just disliking math, according to scholars

By Sarah D. Sparks
*Chicago*

Math problems make more than a few students—and even teachers—sweat, but new brain research is providing insights into the earliest causes of the anxiety so often associated with mathematics.

Experts argue that "math anxiety" can bring about widespread, intergenerational discomfort with the subject, which could lead to anything from fewer students pursuing math and science careers to less public interest in financial markets.

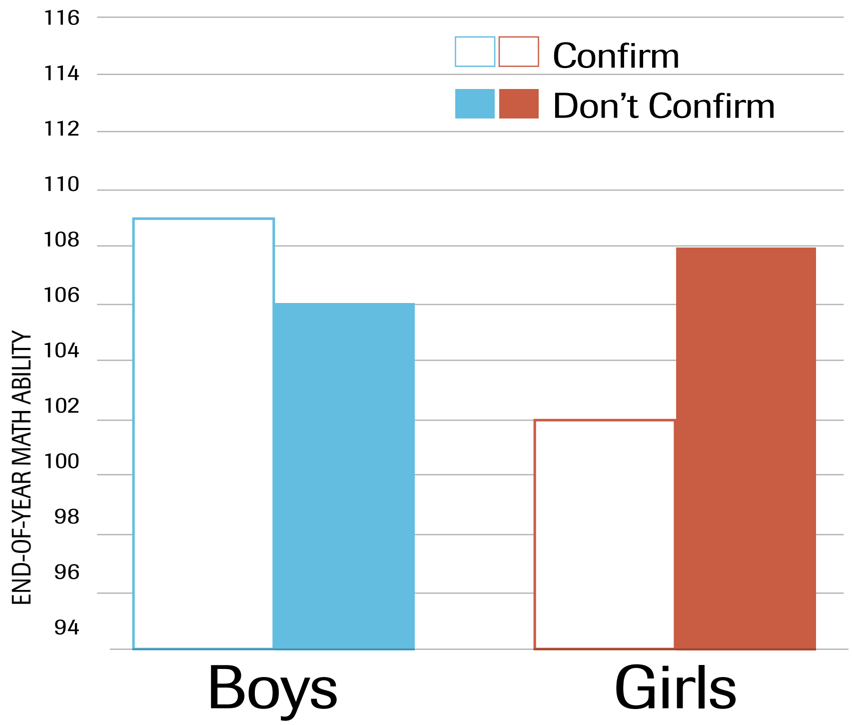
"People are very happy to say they don't like math," said Sian L. Beilock, a University of Chicago psychology professor and the author of *Choke*, a 2010 book on brain responses to performance pressure. "No one walks around bragging that they can't read, but it's perfectly socially acceptable to say you don't like math."

Mathematics anxiety is more than just disliking math, however; someone with math anxiety feels negative emotions when engaging in an activity that requires numerical or math skills. In one forthcoming study by Ms. Beilock, simply suggesting to college students that they would be asked to take a math test triggered a stress response in the hypothalamus of students with high math anxiety.

Ms. Beilock and other experts at a Learning and the Brain conference held here May 5-7 are searching for the earliest problems in a child's math career that can grow into lifelong fears and difficulties. The conference, put on by the Needham, Mass.-based Public Information Resources, Inc., brought together several hundred educators and administrators with researchers in educational neuroscience and cognitive science.

### Stress in the Brain

Anxiety has become a hot topic in education research, as educators and policymakers become increasingly focused on test performance and more-intensive curricula, and neuroscience has begun to provide a window into how the brain responds to anxiety.




### Anxieties and Stereotypes

Researchers have found that the more anxious their female teachers were about math, the more likely girls—but not boys— were to endorse gender-related stereotypes about math ability. In turn, the girls who echoed those stereotypical beliefs were performing less well than other students in math by year's end.

SOURCE: University of Chicago

Anxiety can literally cut off the working memory needed to learn and solve problems, according to Dr. Judy Willis, a Santa Barbara, Calif.-based neurologist, former middle school teacher, and author of the 2010 book *Learning to Love Math*.

When first taking in a problem, a student processes information through the amygdala, the brain's emotional center, which then prioritizes information going to the prefrontal cortex, the part responsible for the brain's working memory and critical thinking. During stress, there is more activity in the amygdala than the prefrontal cortex; even as minor a stressor as seeing a frowning face before answering a question can decrease a student's ability to remember and respond accurately.

"When engaged in mathematical problem-solving, highly math-anxious individuals suffer from intrusive thoughts and ruminations," said Daniel Ansari, the principal investigator for the Numerical Cognition Laboratory at the University of Western Ontario, in London, Ontario. "This takes up some of their processing and working memory. It's very much as though individuals with math anxiety use up the brainpower they need for the problem" on worrying.

Moreover, a series of experiments at the Mangels Lab of Cognitive Neuroscience of Memory and Attention at Baruch College at the City University of New York suggests this stress reaction may hit hardest the students who might otherwise be the most enthusiastic about math.

Jennifer A. Mangels, the lab's director, said she tested college students on math in either neutral situations or in ways designed to invoke anxiety, such as mentioning gender stereotypes about mathability to girls being tested, or telling students that their scores would be used to compare their math ability with others'.

Ms. Mangels found, in keeping with other research, that students tested in stressful situations had lower math performance. She also found that stress hit otherwise promising students the hardest.

In nonstressful tests, the students who most identified with math, defined as those who sought out more opportunities to learn within the math program, had the highest performance. While under stress, those same students performed worse than those who didn't identify with the subject.

"We're reducing the diagnostic ability of these tests by having students take them in a stressful situation," Ms. Beilock agreed.

## Dyscalculia and Bias

Two problems in a child's earliest school experiences—one biological, the other social—can build into big math fears later on, experts say.

In a series of studies, Mr. Ansari and his colleagues at the Numerical Cognition Laboratory have found that adults with high math anxiety are more likely to have lower-than-typical ability to quickly recognize differences in numerical magnitude, or the total number of items in a set, which is considered a form of dyscalculia.

As part of normal development, children become increasingly adept at identifying which of two numbers of items is bigger, but Mr. Ansari found those with high math anxiety were slower and less accurate at that task, and brain scans showed activity different from that of people with low math stress doing the same tasks.

Because understanding numerical magnitude is a foundation for other calculations, Mr. Ansari suggests that small, early deficiencies in that area can lead to difficulties, frustration, and negative reactions to math problems over time.

Moreover, math anxiety can become a generational problem, with adults uncomfortable with math passing negative feelings on to their children or students.

Ms. Beilock found female 1st and 2nd grade teachers with high anxiety about math affected both their students' math performance and their beliefs about math ability. In a study of a dozen 1st grade and five 2nd grade teachers and their students, researchers found no difference in the performance of boys and girls in math at the beginning of the year. By the end of the school year, however, girls taught by a teacher with high math anxiety started to score lower than boys in math.

Moreover, those girls were more likely to draw pictures supporting a gender bias—"Boys are good at math; girls are good at reading"—and the stronger the bias, the worse the girls performed.

That study, and similar ones, highlight a need for more training for parents and teachers on how to conquer their own math fears and avoid passing them to children, Ms. Beilock and Mr. Ansari said.

"Teacher math anxiety is really an epidemic," Mr. Ansari said. "I think a lot of people go into elementary teaching because they don't want to teach high school math or science."

Eugene A. Geist, an associate professor at Ohio University in Athens and the author of the 2001 book, *Children Are Born Mathematicians*, works with math teachers to create "anxiety-free classrooms" for students. He advises teachers to have students focus on learning mathematics processes, rather than relying on the answer keys in a textbook, which can undermine both their own and the teacher's confidence in their math skills.

"If I give the answer, you immediately forget about the question. If I don't give you the answer, you will still have questions and you will be thinking about the problem long after," he said.

By contrast, constantly referring to an answer key can undermine both students' and teachers' confidence in their own math skills, and encourage students to focus on being right over learning.

Likewise, Dr. Willis, the California neurologist, said that teachers can help students reduce their fear of participating during math discussions by asking all students to answer every question, using scratch paper or electronic clickers to "bet" on answers, and then talking about the problem as a group.

"It helps with wait time [between question and answer], increases participation, and decreases mistake fear," Dr. Willis said. The key to helping students learn not to fear math, she said, is to "get students to expose faulty foundational knowledge, which they can only do if they make mistakes and participate."

> "The key to helping students learn not to fear math, is to "get students to expose faulty foundational knowledge, which they can only do if they make mistakes and participate."
>
> JUDY WILLIS, M.D.
> Neurologist, Santa Barbara, Calif.

*Published June 27, 2011 in Education Week*

COMMENTARY

# Putting Virtual Assessments to the Test

By Pendred Noyce

With everyone from the nation's top CEOs to President Obama stressing the importance of science, technology, engineering, and mathematics, or STEM, learning in order to prepare students for a competitive 21st-century workforce, we need better measures of how well students are mastering those subjects. Science and other complex subjects are not served well by conventional testing; answering A, B, C, D, or "all of the above" doesn't lend itself to measuring science proficiency, scientific thinking, or deeper knowledge and understanding.

While traditional paper-and-pencil testing gauges student knowledge on distinct facts or concepts, virtual performance assessments allow students to actually use scientific inquiry and problem-solving through interactions with their virtual environments. In a VPA, students, represented by computer-generated icons, or avatars, make a series of choices. They tackle authentic science problems, investigate causal factors, and choose which virtual experiments to conduct in a virtual lab. The assessment is no longer focused on a single right answer, but on the result of decisions and knowledge applied by the student. This approach allows a finer measure of students' understanding and provides a truer assessment of what students know and don't know about complex science content.

An exciting VPA model is being developed and tested by Jody Clarke-Midura and Christopher Dede at the Harvard Graduate School of Education, with funding from the federal Institute of Education Sciences. The goal of the VPA project is to provide all states with a new model of statewide assessment in the form of valid technology-based performance assessments linked to the National Science Education Standards for middle schoolers.

In the Dede and Clarke-Midura model, a student logs on to a computer, selects an avatar, and enters the virtual world of a science experiment. She's given an aerial view of the space, in this case a farm with several ponds. The camera then focuses on a six-legged frog, which prompts the student to wonder what could be causing such a mutation. The assessment then begins with several farmers offering the student various hypotheses about the cause of the mutation. The student is told to select her own explanation and back it up with evidence. To do this, the student must consider a hypothesis, make decisions about the type of data that would support her claim, decide whether to consult prior research, collect evidence in a virtual backpack, examine data, modify her ideas as necessary, and, finally, make an evidence-supported claim.

Students with varying proficiency will, of course, take different approaches. The beauty of the VPA model is that it's perfectly suited for such different problem-solving strategies. A virtual performance assessment can gauge how well students reason based on available evidence. It can reveal how students gather evidence and whether they select data that are relevant or irrelevant to the hypothesis they are investigating, something a paper-and-pencil test cannot do. With VPAs, educators can literally track and analyze the trajectory of students' thinking and generate reports that provide such data in the form of feedback to both teachers and students.

By 2014, the states that have adopted the common-core standards will be expected to implement new computer-based assessments. They'll have to decide whether to go with simple, digitized versions of paper-and-pencil tests, or to embark on the far more complex world of VPAs. Virtual performance assessments cost more to develop, but they do not cost more to administer, and they offer a greater payoff.

VPAs provide a detailed record of student actions. Even essay questions on traditional tests can't compare with the realistic context of VPAs for mimicking the steps required for legitimate scientific inquiry. And such assessments are largely immune to the practice of teaching test-taking strategies that can distort results of multiple-choice assessments. If teachers "teach to the test" with a VPA, they will actually be providing relevant and rigorous instruction. Moreover, because VPAs can adjust the available evidence (and therefore the valid conclusions) of each scenario for different test administrations, strict test security is not a great problem.

A logical question is whether these tests are biased toward video and computer gamers. The Harvard researchers are testing that, too, and they note that prior research in virtual immersive environments showed no correlation between computer-gaming experience and performance in the curriculum. At scale, these virtual assessments are much more practical and cost-effective than hands-on performance assessments and are on a par with other forms of computer-based testing.

In "The Road Ahead for State Assessments," a report released in May, the Rennie Center for Education Research and Policy and the group Policy Analysis for California Education urge state education leaders to give serious consideration to implementing VPAs, especially in science. They offer the following recommendations for practical, scalable implementation of such assessments as part of comprehensive state assessment systems. State education agencies should:

- Provide teachers and students with the opportunity to try out virtual performance assessments so they get comfortable with the technology, so that the technology is not a barrier to demonstrating knowledge;

- Provide teachers with professional development to foster instruction that will lead to high performance on these assessments;

- Similarly, provide opportunities for parents, school boards, and community members to try their own VPA investigation to alleviate fears that this new teaching and testing approach promotes playing video games in the classroom; and
- Support the infrastructure to do it right, ensuring that the devices and networks deployed can fully deliver the features that make VPAs stand out as a student-assessment tool.

There are a number of ways to integrate technology into the classroom to improve teaching and learning. Virtual performance assessment is one use of technology that could yield great results. VPAs are already changing the way assessments are executed in medicine and the military. Why not in education? If we're serious about the importance of STEM learning and adequately preparing the next generation of students for real-world careers and decisions, leveraging technology to better assess students' knowledge can help pave the way.

*Pendred Noyce is trustee of the Noyce Foundation, the chair of the board of the Rennie Center for Education Research and Policy, co-editor of* New Frontiers in Formative Assessment *(Harvard Education Press, 2010), and the author of* Lost in Lexicon: An Adventure in Words and Numbers *(Scarletta Press, 2010), a fantasy for readers in grades 4-8.*

*Published February 1, 2012 in Education Week*

**COMMENTARY**

# Bringing STEM Into Focus

By Jean Moon & Susan Rundell Singer

What do we intend when using the acronym STEM? It literally stands for science, technology, engineering, and mathematics, but what does it mean? Arguably, attempts to provide a meaningful response to these questions have not stuck. It is not for lack of trying, however. State education agencies, national membership organizations, advocacy groups, and state policymakers have been seeking definitions for STEM for quite some time, and with good reason. Today, not only do we have numerous definitions of STEM, but we also have branded numerous entities to be STEM councils, STEM schools, STEM networks, and STEM curricular outcomes. Despite the well-intended branding, understanding of the brand itself remains elusive. It is a conundrum.

While the STEM-definition conundrum can cause confusion, there is reason for optimism. It is our belief that some important conceptual ground has been gained on this conundrum, and it is ground worthy of exploration.

Several recent reports, including the National Research Council's "A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas," offer a vision for science and science education with significant implications, if not clues, for the "what is STEM?" question. For example, the K-12 framework effectively turns attention away from a content-specific definition of STEM to a more epistemic one—the sources, strategies, or practices from which science and, by extension, STEM knowledge comes and, in turn, is shared. It may well be that this long-standing inability to come up with an appropriate definition for STEM is an outgrowth of framing STEM as a fixed entity, an "it" instead of an assemblage of practices and processes that transcend disciplinary lines and from which knowledge and learning of a particular kind emerges.

Re-visioning school science around science and engineering practices, such as model-building, data analysis, and evidence-based reasoning, is a transformative step, a step found in the NRC report, which is critical to STEM learners and teachers, both K-12 and postsecondary. It puts forward the message that knowledge-building practices found under the STEM umbrella are practices frequently held in common by STEM professionals across the disciplines as they investigate, model, communicate, and explain the natural and designed world.

In addition to shared science and engineering practices, the NRC framework introduces us to crosscutting concepts (major ideas that cut across discipline lines) such as scale, proportion, and quantity or the use of patterns. Likewise, disciplinary core ideas (ideas with major explanatory power across science and engineering disciplines) are introduced. Together with shared practices, these three dimensions of the NRC framework—practices, crosscutting concepts, and disciplinary core ideas—reflect the realities of contemporary science and engineering, inclusive of mathematics, where concepts and practices, often very dependent on technologies, create productive bridges across STEM disciplines. Such bridges make interdisciplinary collaboration possible and, most importantly, provide a set of strategies and tools unique to the process of STEM learning and teaching.

Lest some believe this is setting up another false dichotomy in science or mathematics education between content and process, let us quickly add a strong evidentiary note: Epistemic practices and the learning and knowledge produced through such practices as building models, arguing from evidence, and communicating findings increase the likelihood that students will learn the ideas of science or engineering and mathematics at a deeper, more enduring level than otherwise would be the case. Research evidence consistently supports this assertion. Simply put, the centrality of the "means" by which STEM knowledge is learned, produced, shared, and revised allows us to grasp what constitutes STEM, what it is, and what it brings to the teaching and learning process.

Messages in other recent reports are also nudging us toward a new, clearer vision of STEM, and helping set learning priorities in these subjects. When we look at these messages as a whole, a clarity about the reality of STEM as a field of shared knowledge and practices moves us beyond STEM as an acronym or a branding mechanism or a theoretical dimension.

Weaving meaningful connections across STEM learning is beginning to echo across all levels of education. For example, learning to build models as a form of explanation and evidence-gathering can be found in the life science education fields, the scientific competencies for premedical and medical students, as well as the common-core mathematics standards. Whether by coincidence or via an implicit, shared vision, numerous thoughtful STEM communities have converged on a means of understanding STEM, creating the beginnings of an implementable infrastructure, a field of unique knowledge, practices, and expertise.

We believe, as well, that a potential for more meaningful alignment between education and workforce is emerging in parallel with a clearer vision of what constitutes STEM as a field of knowledge and practices.

Collectively, these advances give us a clearer, more mature understanding of what constitutes STEM work. Continuing to mine these efforts for common threads is one way to unpack the essential elements characterizing STEM.

This is a unique moment in time. It is defined by synergistic shifts in the framing of K-12 and undergraduate STEM subjects supported by a rich research base on how students learn. It is fueled as well by a groundswell of collective interest, if not will, to re-vision what STEM education "is."

Moving STEM from a conundrum and a loose affiliation of disciplines to a powerful domain for structuring K-16 learning based upon a coherent set of shared practices and crosscutting concepts appears to be within our collective reach. This is a moment to build on the assembled wisdom now being conveyed. Work focused on K-12 in addition to postsecondary education offers complementary visions that have significant meaning for clarifying the STEM question. Much more work remains to be done, however. While the pieces of the puzzle, the outlines, are now more understandable, the next critical step is to organize the efforts, conversations, and scholarship needed to deepen and clarify these outlines, bringing STEM as a unique entity into a sharper, more meaningful, and enduring focus.

*Jean Moon is the founder and principal of Tidemark Institute, a national and international voice in STEM education, located in Damariscotta, Maine. Susan Rundell Singer is the Laurence McKinley Gould professor of natural sciences at Carleton College, in Northfield, Minn.*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6935 Arlington Road, Suite 100
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# Resources on STEM

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**Bridging STEM to STEAM: Developing New Frameworks for Art-Science-Designing Pedagogy (Vimeo presentation)**
http://stemtosteam.org/
Rhode Island Schools of Design, June 2011

**Grand Challenges for Engineering**
http://www.engineeringchallenges.org/
National Academy of Engineering

**Green Ribbon Schools Program**
http://www2.ed.gov/programs/green-ribbon-schools/index.html

**Naturebridge**
http://www.naturebridge.org/

**The Opportunity Equation: Transforming Mathematics and Science Education for Citizenship and the Global Economy**
http://carnegie.org/fileadmin/Media/Publications/PDF/OpportunityEquation.pdf
Carnegie Corporation of New York, June 2009

**Prepare and Inspire: K-12 Education in Science, Technology, Engineering, and Math (STEM) for America's Future**
http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-stemed-report.pdf
President's Council of Advisors on Science and Technology, September 2010

**The Road Ahead for State Assessments**
http://renniecenter.issuelab.org/research/listing/road_ahead_for_state_assessments
Rennie Center for Education Research & Policy May 2011

**STEM High Schools Specialized Science Technology Engineering and Mathematics Secondary Schools in the U.S.**
http://ctl.sri.com/publications/downloads/STEM_Report1_bm08.pdf
*Barbara Means, Jere Confrey, Ann House, Ruchi Bhanot*
SRI International, October 2008

**Surrounded by Science: Learning Science in Informal Environments**
http://www.nap.edu/catalog.php?record_id=12614#description
*Philip Bell, Bruce Lewenstein, Andrew W. Shouse, and Michael A. Feder*
National Research Council, 2009

**Women in STEM: A Gender Gap to Innovation**
http://www.esa.doc.gov/sites/default/files/reports/documents/womeninstemagaptoinnovation8311.pdf
*David Beede, Tiffany Julian, David Langdon, George McKittrick, Beethika Khan, and Mark Doms*
U.S. Department of Commerce Economics and Statistics Administration, August 2011

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