Education Week
SPOTLIGHT
2015

MathScience Innovation Center

Students from the Richmond Technical Center in Richmond, Va., build a model that allows them to compare the effectiveness of nano particle sunscreens to regular sunscreens in a workshop on nanoscience.

STEM IN THE CLASSROOM

Editor's Note: In this Spotlight, explore inclusive STEM high schools, inter-district and museum resources for teaching STEM, how nanoscience lessons can engage students in science, and the civic importance of science instruction.

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COMMENTARY

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Published April 7, 2014, in Education Week's Digital Education Blog

Model 'Inclusive' STEM High Schools Share Common Traits, Researchers Say

By Benjamin Herold

The recent proliferation of open-enrollment STEM high schools has been a "bolt of lightning" to the field of K-12 science, technology, engineering and math education, researchers say, but more study is needed on what makes such schools effective.

"All of a sudden, here is an education intervention aimed at kids of color and low-socioeconomic-status kids that isn't trying remediate them, but is giving them an opportunity to take rigorous STEM courses and everything that goes along with that," said Sharon Lynch, an education professor at George Washington University, in Washington, D.C. "But there isn't much research on these schools, so we're trying to understand what the successful ones are doing."

Along with colleagues from George Mason University, in Fairfax, Va., and Princeton, N.J.-based research nonprofit SRI International, Lynch presented recent research on what she dubbed "Inclusive STEM High Schools," or ISHSs, last week at the national conference of the American Educational Research Association, held in Philadelphia. Prior to the conference, I caught up with the academics by phone.

Their research includes case studies of eight "exemplary" open-enrollment STEM high schools—both charter and district-managed—around the country.

Those schools, Lynch said, have ten "critical components" that should serve as the basis for guiding the design, implementation, and evaluation of other such schools —which the researchers said are becoming increasingly popular, with dozens or possibly hundreds of ISHSs coming online in recent years.

"Anybody can call themselves a STEM school," Lynch said, but living up to the term involves "more than just putting a banner out."

The 10 critical components of effective, inclusive STEM high schools identified by the researchers:

- STEM-focused curriculum
- Instructional strategies focused on project-based learning
- Integrated, innovative technology use that can "flatten hierarchies" between students and teachers
- Blended formal and information learning beyond the typical school day, week or year, which might include apprenticeships, mentoring, and after-school clubs
- Real-world STEM partnerships that connect students to the work world
- Early college-level coursework
- Well-prepared STEM teaching staff
- Inclusive STEM mission
- Administrative structure that is flexible and nimble, and
- Support for underrepresented students, which might include bridge and tutoring programs or an extended school day and year.

In their recent paper, published in the academic journal *Theory Into Practice*, the researchers say that recent data from the National Science Foundation (which also funded their case studies) indicated that "traditional science domains of biology, chemistry and physics remained entrenched as siloed disciplines in the majority of American high schools" and that "direct whole-class instruction by the teacher was the most commonly reported strategy in high schools."

Effective open-enrollment STEM high schools, they say, take a different approach, focusing on mastery- or competency-based learning requirements instead of student seat time and teaching "students to be consumers of reliable digital resources" rather than relying on textbooks. Collaborative group projects are also a "hallmark" of effective ISHSs, the researchers found.

On the administrative side, the researchers found, the schools in their case studies had "transformational" leaders who "fostered close relationships between staff and students characterized by mutual and trust and respect." Just as important, they said, the schools had "wide latitude and support from the district [central office] or [charter] management organization to champion innovation."

And when it comes to providing student supports, effective open-enrollment STEM high schools evidence a "commitment to the success of diverse learners, advisories, data management systems, and tutoring," as well as intensive college and career counseling. A family atmosphere focused on understanding and addressing students' personal and financial challenges is also key, they said.

"Historically, STEM high schools are for elite students," said report author Erin Peters-Burton, an assistant professor of science education at George Mason University. "These schools will take everyone, and the exemplars are doing a good job of providing systemic supports."

"All of a sudden, here is an education intervention aimed at kids of color and low-socioeconomic-status kids that isn't trying remediate them, but is giving them an opportunity to take rigorous STEM courses and everything that goes along with that."

SHARON LYNCH
Education professor, George Washington University

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Published April 2, 2014, in Education Week

Local STEM Hubs Emerge to Bolster Math, Science Ed.

By Liana Heitin

For Emmely Briley, a high school chemistry and physics teacher, working in the rural logging community of Molalla, Ore., for the past 13 years has at times felt isolating.

While students 30 miles north in Portland had access to STEM fairs and camps, Ms. Briley's students have historically had few such programs for science, technology, engineering, and mathematics closer to home. Although Ms. Briley would have liked to make her classes more authentic—by bringing in scientists as guest speakers or having her students conduct experiments in the community, for instance—she wasn't sure how to go about forging the connections to do so.

"I've felt cut off from some opportunities," she said. "I always wanted somebody I could call up at Xerox and say, 'Hey, we want to take a tour,' but I didn't know how or who to call."

Now, Ms. Briley says, that's changing. The 2,400-student Molalla River school system, where she works, is one of many districts across the state involved in a regional STEM hub—essentially a coalition of K-12 schools, universities, businesses, and community organizations, such as nonprofits and museums, that work together to improve education in the STEM fields.

These sorts of coalitions are popping up in many places around the nation—from Oregon and Washington State to Michigan, New York, and Ohio—as a way to catalyze and better connect STEM education efforts in local communities.

Last month, the Oregon Education Investment Board, chaired by Democratic Gov. John Kitzhaber, awarded $2.8 million in grants to six regional hubs across the state.

"The idea behind the regional STEM hubs is we need to connect these isolated pockets of excellence across the state," said Mark Lewis, the STEM director for the board. "We've got to create a more dynamic culture of exchange."

Excited and Engaged

Across the country, establishing such hubs has become a common strategy of statewide STEM education networks and councils that are looking to advance student engagement in science, technology, engineering, and math.

The South Metro-Salem STEM Partnership is made up of 15 Oregon school districts, including Molalla, serving a total of 120,000 students. Six postsecondary institutions and 20 businesses and community organizations are also involved.

The backbone organization for the hub, which received $600,000 in the OEIB grant process, is the Oregon Institute of Technology, based in Klamath Falls. Lita Colligan, an associate vice president at the university and the co-chair of the Salem hub, said she began focusing on forming partnerships in 2012 when Oregon Tech opened a satellite campus in Wilsonville and was looking to build a pipeline of students.

"We didn't feel like we were connecting enough with schools and teachers and kids," she said. "We convened a group of partners and community organizations and said, 'What do we need to do to help get more kids excited about and engaged in and going into science?' "

The Salem STEM hub now has three initiatives: providing professional development for teachers, connecting organizations and schools through an online network, and bringing more college-level courses to high schools. Ms. Colligan said that while she's been working on the partnerships for nearly two years, the formal hub is still in the early stages, working on "figuring out how to go across silos."

For their part, industry partners are interested in getting involved both to engage their employees and help develop the STEM workforce, said Craig Hudson, the co-chairman of the Salem hub and an engineering team leader at the satellite-navigation company Garmin, which has an office in Salem.

"Every business is thinking about how to grow and how to manage what talent pool we draw from," he said. "It makes more sense to educate kids that are local. We get some nice diversity when we bring kids in from out of state, but if they don't have a strong family connection here, they're not likely to stay here for the long term."

Mr. Hudson said he is hopeful that the online network will help businesses connect with classrooms in a way that's more meaningful than, for instance, simply dropping by a school for a career fair.

"Ideally, we'd like to be able to partner with them to build something tied to the curriculum, so a relevant speaker can come in and say, 'This is what I do,' and show there are jobs connected back to that particular strand in the Common Core [State Standards]," which Oregon and the majority of other states have adopted.

The hub's success will be gauged by a variety of measures, Ms. Colligan said, including changes in scores on standardized tests, the number of hours of math and science instruction in schools, how many students participate in voluntary STEM activities, and the number of college-credit courses available to K-12 students. However, she emphasized, the returns won't come quickly.

"To see real educational change, I think you're talking like 10 years," she said.

Portland Partnership

The Salem hub is taking a horizontal approach, said Ms. Colligan, trying to reach as many teachers and schools as possible for STEM training.

Meanwhile, the Portland Metro STEM Partnership, another grant recipient and the oldest of the groups, having begun about four years ago, is conducting both broad outreach and some deeper work focused on individual schools.

Led by William Becker, the director of the Center for Science Education at Portland State University, the Beaverton, Ore.-based hub includes four school districts serving 116,000 students and 40 community partners, such as Vernier, Intel, and the Oregon Zoo. In addition to facilitating professional development and industry connections, the group is working with seven STEM "transformation" schools "to do essentially a makeover" using an improvement model based on research by the Carnegie Foundation for the Advancement of Teaching, said Mr. Becker.

The transformation schools "want to build their programs and help the student body establish an image of being successful at STEM," Mr. Becker explained. "We've taken a look at various models the school might adopt, and had the very hard conversations with the faculty and principal about where they want to make investments. They've developed and created, with our help, a STEM investment plan—a road map for how they see themselves moving forward."

"They've been real thought leaders out

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there," said Mr. Lewis of the OEIB about the Portland hub. "Their model is an implementation program model, not as much high-level policy coordination."

Yet even under the nascent and more horizontal Salem model, classroom teachers are starting to feel the hub's effects. In fact, experienced science teachers are the ones organizing and leading the professional development sessions.

"This is all grassroots-driven," said Ms. Colligan of Oregon Tech.

And for Ms. Briley of Molalla, who serves on STEM work groups and has been integral to the hub's development, being involved with the coalition has helped her make those previously missing connections.

"I now know people all over the place—engineers and college vice presidents—and they're all very passionate about something I've been passionate about," she said. "It's exploded the amount of information and connections available for our school district."

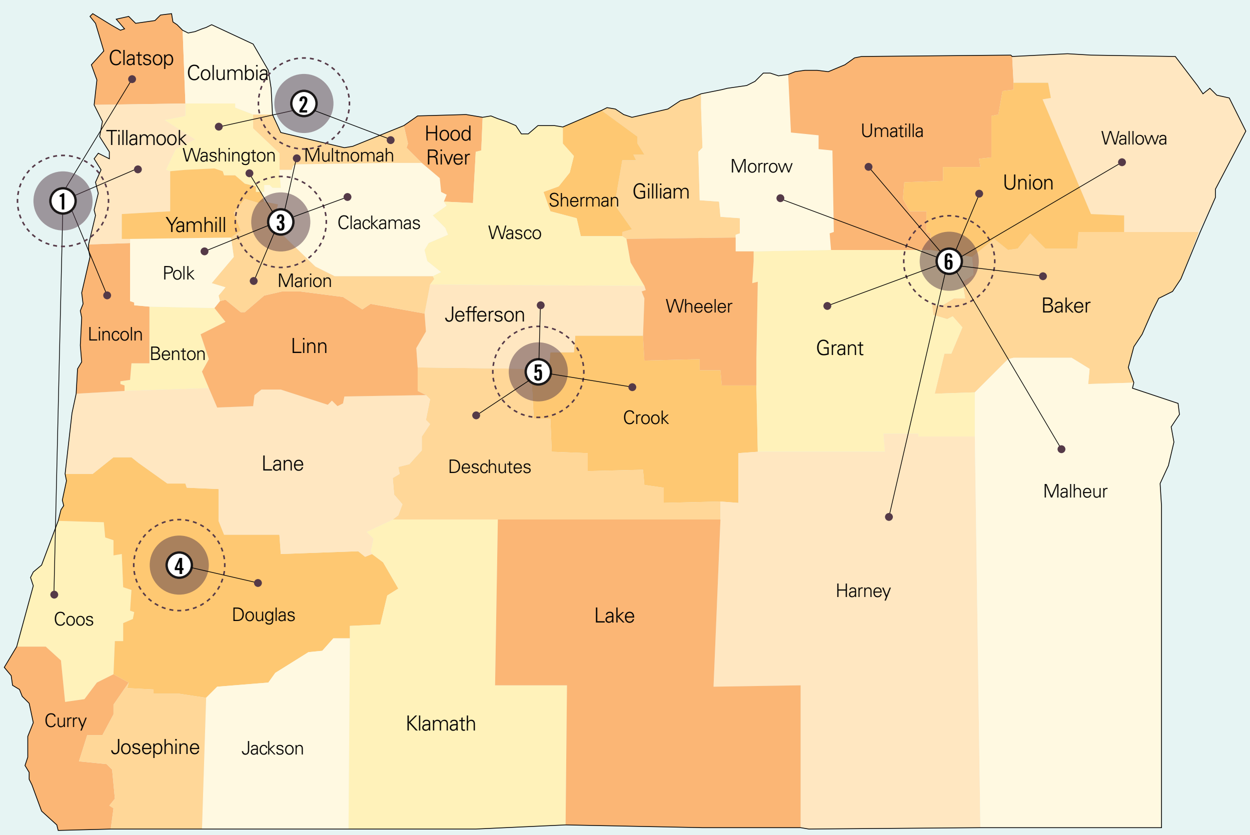
In fact, prior to getting involved in the hub, Ms. Briley did not even know Oregon Tech's newest small campus in Wilsonville existed.

"Thirty-five minutes away, there were all these opportunities and yet our little district out here in rural isolation had no idea," she said.

Coverage of informal and school-based science education, human-capital management, and multiple-pathways-linked learning is supported by a grant from the Noyce Foundation. Education Week retains sole editorial control over the content of this coverage.

FORGING CONNECTIONS IN COMMUNITIES

The Oregon Education Investment Board, led by Gov. John Kitzhaber, awarded $2.8 million in grants last month to support the work of six regional STEM hubs across the state.



1 OREGON COAST REGIONAL STEM HUB led by the Lincoln County school district

2 PORTLAND METRO STEM PARTNERSHIP led by Portland State University

3 SOUTH METRO-SALEM STEM PARTNERSHIP led by Oregon Tech

4 UMPQUA VALLEY REGIONAL STEAM HUB led by Umpqua Community College

5 CENTRAL OREGON STEM HUB led by the High Desert Museum

6 GO STEM COLLABORATIVE led by Eastern Oregon University

SOURCE: Oregon Education Investment Board

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Published January 7, 2015, in Education Week

For Integrating STEM, Experts Recommend Teaching Nanoscience

By Sarah D. Sparks
Arlington, Va.

As schools look for ways to implement the Next Generation Science Standards, some scientists and educators argue that schools should start small—really, really small.

The topic they have in mind is nanoscience, the study of particles in the range of a billionth of a meter. To put that in perspective, one strand of human DNA is a little more than 2.5 nanometers, and there are about 1 million nanometers in the period at the end of this sentence.

Nanoscience is a rapidly expanding part of fields from medicine to high-tech manufacturing. Federal and industry experts at a National Science Foundation meeting last month believe it could provide a path to break down some of the silos separating science, technology, engineering, and mathematics classes and link their concepts to future careers for students.

"We focus a lot on the pure sciences, the sizes and scales and models and simulations, but [students'] eyes really get wide and they really get excited when they see gold turn red at the nano scale, or you take them to the lab and they see carbon nano-fibers being spun," said Daphne Schmidt, the coordinator of professional development at the MathScience Innovation Center in Richmond, Va., intended to provide STEM-related professional development and informal science learning.

"This is really about expanding the scale of understanding," she added. "It's not new; it's just a more holistic way of teaching science."

Leading the Way

Among states, Virginia is at the leading edge of the effort to promote nanoscience education. In its 2010 science-standards revision, the state added recommendations for ways to use nanoscience applications in existing topics. For example, as part of physics, the revised standards suggest students learn to understand how high-powered equipment such as atomic force microscopes and scanning tunneling microscopes are used to determine nanoscale properties and forces.

"We have to institutionalize nanoscience and technology into the curriculum for all K-12 students throughout the United States," said James G. Batterson, a retired aerospace engineer with NASA and a former teacher in the Newport News, Va., school district who consulted on Virginia's new science standards. "We've seen what happens if you don't institutionalize it. The wealthy schools and parents make sure their students get it, and the stu-

Students from the Richmond Technical Center in Richmond, Va., build a model that allows them to compare the effectiveness of nano particle sunscreens to regular sunscreens in a workshop on nanoscience.

MathScience Innovation Center

dents in poor schools don't."

Yet in most states, nanoscience is not an explicit part of the curriculum. The Next-Generation Science Standards, which have been adopted by 26 states, don't use the words "nanoscale" or "nanoscience," but the field offers a way to organize and approach many existing topics, like properties of atoms or exponential notation, said Patricia Simmons, a past president of the Arlington, Va.-based National Science Teachers Association, at the NSF meeting.

Integrating STEM

For example, Jonathan Home, the leader of the Trapped Ion Quantum Information Group, a team at the Institute for Quantum Electronics in Zurich that is building a computer tinier than an atom, suggested that high school math teachers could use nanotechnology to give a new "spin" to teaching matrix problems—those with sets of numbers—in algebra. Electrons' spin has both magnitude and direction, and problems using them might be calculated using two-by-two matrices, said Mr. Home, who was not at the meeting. "I think students at most schools can multiply two-by-two matrices—at least we did at school—so they would also see the relevance of matrices to the real world."

Becoming more oriented to processes and practical applications can also help schools keep up with rapid advancements in science, said Anne Lynn Gillian-Daniel, the education director for the Materials Research Science and Engineering Center at the University of Wisconsin-Madison. "Kids are still memorizing what amino acids look like," she said. "Why? I can look that up on Google in 10 seconds."

Instead, she argued, students should be learning how to pull together concepts and techniques from different branches of science, and using communication and writing skills, to complete projects.

Celia I. Merzbacher, the vice president for innovative partnerships at the Semiconductor Research Corporation, in Durham, N.C., agreed. She surveyed leaders of businesses hiring in nanoscience industries and said nanoscience careers call for more interdisciplinary understanding of science, technology, engineering, and math.

"These people are living in a team environment, working with others coming from different disciplines, and they need to have both the knowledge—and the ability to continue to learn—to thrive in that kind of environment."

Many careers associated with nanotechnology—from an aeronautical engineer fashioning 1.3-nanometer carbon tubes to make super-strong materials to a pharmaceutical researcher designing cancer treatments smaller than a single cell—require students to move smoothly among different fields, she said.

But such cognitive flexibility can be difficult to teach. "We don't know as much about interdisciplinary learning at any level to be able to build a workforce for this converging workplace," said Susan R. Singer, an NSF division director. "The beauty of the kind of work we are seeing [in nanoscience education] is it is very tightly linking learning and understanding to specific fields."

It's a challenge, too, to prepare teachers and provide support for them to work together across disciplines, said Ms. Schmidt of the MathScience Innovation Center. The center has developed a fellowship program that trains teachers with a three-day summer boot camp on concepts and experiments using nanoscience, followed by in-person and online meetings throughout the year for teachers to discuss how the experiments played out in the classroom and share successful practices.

"It's beautiful in a way, because that's how science works in the real world, but it's tough coming out of our silos," Ms. Schmidt said.

The center now has 13 Virginia school divisions in a consortium testing nanoscience instructional materials, and has trained more than two dozen middle and high school teachers in the last three years.

Not 'Just One More List'

The greatest danger, educators and scientists at the meeting warned, is that nanoeducation might become "just one more list" of concepts for students to memorize rather than more-practical applications for students to explore.

"Listing groups of particles in astronomy, or talking about nanoscience, might inspire students to be interested in physics, which is good," Mr. Home said, "but I think there is very little development of the mind that goes on if you do this too early" in the elementary grades.

But Ms. Simmons argued that even primary-grades students should learn scientific processes and get a chance to experiment with them. "Students will either turn off to sciences or turn on to sciences in the upper-elementary level," she said. "In elementary you ask who's a scientist and everyone raises their hands. By middle school you ask the same question and everyone points to one kid at the back of the class."

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Museums Step Up as Resource for New Science Standards

By Liana Heitin

As a small but growing number of states adopt the Next Generation Science Standards, science museums and centers are positioning themselves as a key resource for helping teachers adapt to the vision for instruction reflected in the new guidelines.

Some educators say that professional-development sessions held at museums—unlike those at conference centers, universities, or districts—give teachers immediate access to the kinds of hands-on activities that the common science standards call for. In addition, such institutions often bring a wealth of expertise on both content and pedagogy, employing a mix of scientists and professional educators.

A new study bolsters the claim that teachers should look to science centers for effective training, finding that a museum-based professional-development program at the Museum of Science and Industry in Chicago led to gains in both teacher content knowledge and student achievement.

However, some educators caution that museums need to be purposeful in creating professional-development curricula and exhibits that align with the common science standards—adopted by 11 states and the District of Columbia so far—rather than assuming what they're already doing fits the bill.

Anthony "Bud" Rock, the CEO of the Association of Science-Technology Centers, a nonprofit group representing about 600 science centers internationally, said the U.S. institutions are putting "a special emphasis now on how to provide techniques for the Next Generation Science Standards and the common core, and more broadly on interdisciplinary approaches to science education. We're very attuned to the evolving landscape for teachers right now when it comes to science education in the classroom."

Just last week, the Connecticut Science Center in Hartford was scheduled to gather more than a dozen leaders from science centers across the country for a workshop on how to better align their work with schools' needs, with particular attention to the new science standards.

Greater Need

Hank Gruner, a vice president at the Connecticut Science Center, said that although museum-based professional development is not a novel idea, schools are newly interested in preparing teachers for inquiry-based learning, prevalent in both the Next Generation Science Standards and the Common Core State Standards, which cover literacy and math.

"I do think you're going to see more centers starting to look at professional development now that there will be more of a need for it," he said. "Our feeling is there are opportunities here."

The Next Generation Science Standards, completed in April 2013, were developed by 26 "lead state partners" in collaboration with national organizations. In some states, science centers and other informal STEM learning institutions were among the most vocal proponents of the science standards, which focus not just on mastering scientific facts, but also engaging young people in scientific practices, such as doing investigations, building models, and analyzing data.

"Science centers excel by definition" in that type of learning, said Mr. Rock of the Association of Science-Technology Centers.

Each of the lead states convened a broad-based team of stakeholders to review drafts of the standards, and many of those included representatives from science centers.

In Illinois, where the common science standards were adopted earlier this year, the Museum of Science and Industry provides free professional-development courses, led by scientists, university professors, and K-12 educators, for about 200 teachers a year in physical, life, earth, and environmental sciences.

The standards dovetail nicely with what the museum has been doing, said Nicole Kowrach, the museum's director of teaching and learning.

"Asking questions, designing and carrying out investigations, that's the kind of learning and way of thinking we've encouraged," she said.

The new study of Chicago's science museum found that its course about energy was successful in improving teacher knowledge and student learning. For the study, 85 teachers in grades 4-8 who applied to participate in the program were randomly assigned to either take the course or be part of the control group and receive no training. On a post-test about energy, the mean score was a statistically significant 8 percent higher for teachers who took the six-session course than for those who did not.

Also, the participants' students were assessed, and those whose teachers had the professional development performed better by a statistically significant amount on an assessment of student understanding and on a separate test of their application of that knowledge.

William H. Schmidt, a professor and the co-director of the Education Policy Center at Michigan State University, who led the study, said the random assignment—a feature not present in most research on professional development—allows for causal inference, meaning the professional development explains the difference in test scores.

It's significant that museums "have the real world inside their buildings," Mr. Schmidt said. "And the results came to show that, in this particular case, that worked."

Ms. Kowrach agreed that having hands-on activities and exhibits on-site is a boon for teacher training. "If you're doing professional development in a school or university," she said, "you can't walk outside the classroom and have a giant inclined plane and start experimenting with potential and kinetic energy."

Teachers who receive professional development at the museum walk away with a bin full of tools and activities for their classrooms.

Ronald Hale, a 5th grade teacher at Chicago's Hayt Elementary School who has both taken and led professional development at the Chicago museum, said the take-home resources are key to teacher buy-in and classroom implementation. When instructing other teachers, "the number-one question you get is, 'Can we have this?' They want it in their bin," Mr. Hale said. "It's like when Oprah gives out keys to cars. They get so excited."

'A Safe Place for Teachers'

Another reason science museums can be an attractive professional-development option is that they exist outside the K-12 bureaucracy.

"We're a safe place for teachers," said Ms. Kowrach. "Schools have the pressures of testing and teacher assessment, and we're not part of a school district, the state, or a university where [teachers are] trying to complete a degree."

"We are neutral, we don't have any baggage associated with us," said Mr. Gruner of the Connecticut Science Center, which offers everything from one-day workshops to three-year professional-development programs for schools.

That outsider status also makes science museums potentially more nimble than many formal learning environments. The Museum of Science and Industry in Chicago is "years ahead of the district," said Mr. Hale, in staying up to date with teaching practices. For instance, although Illinois only formally adopted the Next Generation Science Standards in February, the museum has been incorporating the ideas behind the standards into professional development for several years, he said.

Some other science centers ramping up their teacher offerings pegged to the new science standards are in states that have not adopted them, such as Connecticut, where the regional conference for science centers took place.

The American Museum of Natural History, in New York City, is developing tools to help teachers create lessons and assessments on the standards, said James B. Short, the director of the museum's Gottesman Center for Science Teaching and Learning.

New York was a partner state in developing the standards, but has not yet adopted them.

"Even if New York doesn't adopt, we're finding these tools help teachers think better and think more deeply about instruction," Mr. Short said.

The Exploratorium in San Francisco, which has been offering teacher programs for 30 years, is making a concerted effort to ensure that all of its professional development and related activities are aligned with the Next Generation Science Standards. (California adopted the standards last September.)

"Even though our bread and butter has always been hands-on activities and inquiry-based [learning], I hesitate to just do what I see happening a lot—to put the Next Generation Science Standards sticker on what we're already doing," said Julie Yu, the director of the museum's teacher institute. "We're trying to be thoughtful on what this means and what teachers need."

Ms. Yu said the Exploratorium is sifting through its more than 1,000 STEM activities to create a portfolio of only those that are a good fit. She urged other science centers to do the same. "We felt the [new science standards embody] what we do, but we all need to take a step back and make sure that we're honestly doing it," she said.

Coverage of informal and school-based science education, human-capital management, and multiple-pathways-linked learning is supported by a grant from the Noyce Foundation. Education Week retains sole editorial control over the content of this coverage.

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How to Increase Student Engagement in Mathematics

By Theresa Corry, Ed.D.

"Wow! I finally understand what a pie graph really means!" the student exclaims, loudly enough that the whole class pipes in as well.

"This is so cool. Now I see how the parts are related to the whole," another remarks.

"I can totally see the connection between percentages and fractions this way," declares another.

Does this sound familiar ... light bulb understandings clicking on so quickly and brightly in your mathematics class that you can almost touch the ultraviolet waves? The difference in this scenario is that instead of elementary, middle or high school students, these are the educators of those students. They are participating in coursework that helps them bring more active student engagement into their mathematics classroom.

Here are four methods you can use to increase student engagement in math:

1 Involve everyone through partner games.

When students are engaged in games, they are more intensely working with the content. With partner games, there is more likelihood of 100% attention to task by each student. We naturally want to do well in a game, so we use as many strategies at our disposal as possible and stay focused for longer periods of time.

For example, in a game I call *Equal the Expressions*, one student places number cards on one side of an equal sign along with operations to form a mathematical expression (addition, subtraction and so forth). Another student tries to make an equivalent expression by manipulating number cards and operations on the other side of the equal sign. Because of the game format, students stay focused to really understand combinations of operations, especially the order of operations.

Increasingly, teachers and administrators are recognizing that digital games engage students and make learning fun. According to Paul Howard-Jones, a neuroscientist at Bristol University, it's all about dopamine. It's a simple cycle; computer games stimulate the brain to produce dopamine. Dopamine helps orient attention and encourages the creation of connections between neurons. These connections (or synapses) are the physical basis for learning.

Many digital learning games are available on the internet. Dr. Keith Devlin is the National Public Radio "Math Guy" and a Stanford mathematician. He sees digital math games as an "instrument on which to play mathematics." He likens it to a piano keyboard: "You can't help but learn something about music if you sit down and tinker."

Manipulating some digital math games is enacting the functions of arithmetic. Put math functions together and you're doing math in the same way that pressing a piano's keys creates tone. According to Dr. Devlin, "Try learning to ride a bike by listening to a lecture, reading a book or even watching a video. It just doesn't work!"

2 Incorporate interactive journals for increased time on task.

With interactive math journals, students have their own "how-to guide book" that they have personally established with interactive games included. They are more likely to understand, practice and review the content when it is easily accessible to them and they have put forth the effort to get it into their journals.

These journals can be created by students, furnished to students or downloaded from the Internet. Many teachers have their students work with journals about once each week, often using them to lead off a new concept. In this way, students can use them as a reference tool.

Some teachers spend extra time helping students with their initial entries. Over time, as students become more accustomed to the process, those teachers turn more and more of the responsibility for the entries over to the students.

3 Increase depth of understanding through integrated lesson plans.

Integration helps students become engaged and able to connect mathematical concepts to their real-life world. Mathematical integration with other subjects, such as language and science, or with other mathematical strands, such as measurement and data analysis, brings more meaning and connection to application of the concepts.

In fact, teachers are finding ways to integrate math with almost any subject including language arts, history, literature, geography, health, art, music and just plain fun. One popular approach to integrating lesson plans is to have students plan a trip. On this trip, students can keep track of statistics such as distance and speed, allowing them to estimate arrival and departure times. They can visit popular sites and cities and study the geography and history of the places they visit.

4 Encourage application of content knowledge through projects.

Students want to put in much more time on mathematics when projects are part of the mix. A few thorough projects dispersed throughout the academic year draw the students in to understanding what they can accomplish with mathematical knowledge.

Project-based learning can help students improve critical-thinking skills and develop interpersonal and intrapersonal skills. This is particularly true when students work in teams.

The best results are achieved when students perceive that the work is meaningful to them and when teachers emphasize the need for students to commit to the project and the team.

Lastly, students will be more motivated to invest in their project if they know that it will be presented to an audience. This is especially true if they understand that the presentation itself will be evaluated.

Websites that offer math games:

education.com/games/educational

learn-with-math-games.com

mathwire.com/games/games.html

nctm.org/classroom-resources/interactives

For more ideas about how to inspire your students in math and other STEM topics, consider online Continuing Teacher Education courses from University of Phoenix College of Education.

For information, call **800.520.4054**.

About the author

Dr. Theresa Corry has taught 2nd through 6th grade for over 20 years in the Clark County School District and Shawnee Mission School District in Nevada. She also teaches math and science methods courses for University of Phoenix in Las Vegas, Nevada. She currently serves on the Nevada STEM Advisory Council. She is listed in Who's Who Among America's Teachers, and is a recipient of the Vic Regnier Award, Teacher of the Year Briarwood, and New Teacher of the Year Clark County School District.

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Study: Struggling Math Students Need Direct Instruction, Not 'Fun' Activities

By Sarah D. Sparks

First grade teachers facing a class full of students struggling with math were more likely to turn to music, movement, and manipulative toys to get their frustrated kids engaged, finds a new study in the journal Educational Evaluation and Policy Analysis. Yet researchers found these techniques did not help—and in some cases hindered—learning for the students having the most difficulty.

Pennsylvania State University researchers Paul L. Morgan and Steve Maczuga and George Farkas of the University of California, Irvine analyzed the use of different types of instruction by 1st grade mathematics teachers, including teacher-directed instruction, such as explicit explanations and practice drills; student-centered, such as small-group projects and open problem-solving; and strategies intended to ground math in real life, such as manipulative toys, calculators, music, and movement activities.

The researchers tracked the use of different strategies by 1st grade teachers with both regular students and those with math difficulties, defined as students who had performed in the bottom 15 percent of their kindergarten math achievement tests. Educators taught an array of math skills, from ordering and sorting objects into groups, writing numbers up to 100, naming shapes, copying patterns, and single-digit addition and subtraction, among others. The researchers found that students of average math ability learned equally well using teacher-directed or student-centered instructional approaches, but struggling students improved only when teachers used directed instruction, and particularly extra practice with basic concepts.

"In general education there's been more focus on approaches that are student-centered: peers and small groups, cooperative learning activities. What can happen with that for kids with learning difficulties is there are barriers that can interfere with their ability to take advantage of those learning activities. Children with learning disabilities tend to benefit from instruction that is explicit and teacher directed, guided and modeled and also has lots of opportunities for practice."

Moreover, neither struggling nor regularly achieving math students improved when using manipulatives, calculators, music, or movement strategies; these activities actually decreased student learning in some cases. Ironically, a regression analysis of the classes found teachers became more likely to use these strategies in classes with higher concentrations of students with math difficulties.

"If I was going to offer a conjecture, what might be happening, as the teacher gets more students in the classroom that are struggling, they might be using the manipulatives or music to work around the students difficulties and make the math seem more real ... but our results don't indicate that those practices will lead to more student achievement gains," Morgan said.

Older students may still benefit from manipulatives and other math activities, and the findings don't argue for filling students' days with "drill and kill," Morgan said, but early elementary school—when students are learning basic math concepts for the first time and when few students have been officially identified as having math learning disabilities—can create a perfect environment for students to founder in math.

"I don't want kids to be bored, I don't want them to look at math as drudgery, I don't want my kids to go to school and do worksheets all day. I want them to be engaged by what they are being taught," Morgan said, "but I think sometimes we touch on concepts too briefly; we only give kids two or three opportunities to practice it."

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COMMENTARY

Go Beyond Method to the Civic Purposes of Science

By John L. Rudolph

On a snowy day in December a little over a century ago—in 1909 to be exact—the well known progressive educator John Dewey appeared before the scientists assembled for the annual meeting of the American Association for the Advancement of Science. It was as outgoing vice president of the Association's education section that he made his way to the main hall of the Walker Building on the campus of MIT in Cambridge. His goal was to convince his audience that something radical needed to be done about science education in America.

For too long, Dewey believed, the goal of science teaching had been to impart to students the vast catalog of natural facts that researchers had accumulated in their work. But not only did this content-focused approach not appeal to the masses of students in schools across the country (who were turning away from science courses at alarming rates), but it failed to convey the true value science had to offer members of the lay public. That value, Dewey insisted, lay not in the facts of science but rather in the methods scientists used to arrive at those facts about the world.

The text of Dewey's address was published in *Science* the following year under the title "Science as Subject-Matter and As Method." It's an article that has since been held up again and again by educators as a classic statement of the need to teach scientific process over content. Indeed, in that address Dewey was striving to find a solution to the problem of how a (then) modern society should go about preparing its citizens to live in an increasingly scientific and technological world.

Beyond Teaching Scientific Method

The challenge Dewey faced then is one we continue to face today, even more so given the tremendous advances we've witnessed in science and technology. And some point to Dewey's address to argue that if we really wish to achieve an appropriately enlightened public—

a *scientifically literate* public—we just need to find a way to realize Dewey's vision of a science education grounded in the methods of science rather than its content. We all recognize, after all, the drudgery and counter-productive effects of rote content mastery.

This is where most policymakers, scientists, and educators often leave things. A focus on method (or inquiry or "research experience" or problem-based learning, or what have you), they believe, is the magic bullet. Such an approach is sure to engage students in learning, generate positive perceptions of science, enhance critical thinking for everyday use, and potentially entice more students to consider scientific careers for the betterment of our national economic productivity.

There's a fundamental flaw in such thinking, however, and it lies in the assumption that science education is somehow a generic endeavor, that good science teaching can be "good" without any consideration of the goals we as a society are aiming to accomplish. Here's where the hundred years since 1909 makes all the difference.

Beyond Vocation to The Civic Purposes of Science

In Dewey's time, indeed from the 1800s through the 1940s, schools were primarily about providing the knowledge and skills individuals needed for their moral development and intellectual growth so that they could engage in the affairs of life as full citizens. Schools served as the "pillars of the Republic" in the words of the eminent historian Carl Kaestle—there was a moral and civic goal to schooling. Science education, it was argued, had the power to contribute to this intellectual and moral development in its own way and could add some practical knowledge to boot.

Today the focus of our schools is primarily on workforce training or preparing students for the rigors of higher education of some sort with the promise of a good job down the line. Learning about science or any of the STEM fields seems particularly attractive in this hyper-vocationalized environment.

The turning point from then to now was World War II during which government officials and policymakers came to recognize the power of advanced technical knowledge for national security in that conflict, during the ensuing cold war with the Soviet Union, and then later for economic development during global battles with first the Japanese and now with China and India.

The educational response to this was simply to overlay the technical-training goals of science education onto the earlier civic, general education goals of the earlier era. If we did it right, so the argument went, good science teaching could prepare both citizens and more scientists and STEM workers.

But it has become increasingly clear that the civic goal has been well overshadowed by the workforce-training goal. This has resulted in more content-focused instruction in classrooms in an effort to do everything from improving test scores in an ever-expanding accountability environment to expanding enrollments in Advanced Placement courses to prepare students for more advanced science instruction in college and university classes.

Feeding the STEM Pipeline Isn't the Only Goal

The lesson to be learned from Dewey's address is not that we just need to refocus science teaching on process over content. More research-immersion experiences or hands-on science activities in the hopes of funneling more students into the STEM pipeline isn't the answer to the problem of living in a world infused with complex scientific and technological systems and problems. Replacing a narrow content focus with a similarly narrow process approach is no solution.

Looking back on Dewey's address at MIT a hundred years ago has more value in its ability to remind us of a time when science education (and education in general) was designed to help us live together as a community, as citizens with common interests in making sense of and ordering the world in ways that improve life for everyone.

For Dewey, such an education was necessarily about how we come to reliable knowledge about the world—it was about understanding the value of science and expertise not only for ourselves individually, but also so that society might better find the most effective ways to organize the way we live. His science education was all about understanding science in the broad context of society as an instrument for social progress, not about narrow technical training.

In our current age, where various groups are willing to discount science (think climate change, the carcinogenic effects of cigarettes, supply side economics, and on and on), we need a science education for understanding how, why, and where science works, not for training the very small fraction of students who may end up pursuing careers in the STEM fields. When fewer than 10% of students ever go on to STEM-related advanced education and careers, we would do well to re-think the purposes of science education for the remaining 90%.

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