Smithsonian

FOCUS ON THE STUFF

When you combine digital tools with hands-on activities, learning sticks. A Smithsonian expert tells how.

Advancements in technology have made digital science learning popular in many school districts. But, even as tech plays an important role in the science classroom, it's important to approach learning from a multimodal perspective. "Digital learning tools are important, but always keep in mind the importance that physical, object-driven learning has in the science classroom," says Smithsonian Science Education Center Director Carol O'Donnell.

Science education has gone through a three-stage metamorphosis, says O'Donnell. "Before the first satellite was ever launched into space in the late 1950s, science education was driven by words on a page," O'Donnell explains. "Students were given facts and definitions. Objects were not used for learning. And textbooks were simply called 'Science.'"

During the 1960s, some developers gradually progressed to involving students with the physical object. "This 'object-based learning' was a good step forward," says O'Donnell. "We would ask students to work in groups. Examine the properties of the objects. Teachers constructed science learning that encouraged students' perceptions of the interesting objects—what they could see, hear, touch, smell or taste."

By the 1980s and 1990s, curriculum developers such as the Smithsonian Science Education Center were writing science programs with books that were no longer just called "Science". They were named after the object, such as "Rocks and Minerals," "Plants" or "Water."

"The focus was on the 'stuff,'" says O'Donnell, "but the stuff was still removed from the context of its environment."

Fast forward to today. Science education now puts the object into its broader context, which cognitive psychologists say helps to enhance students' memory of the experience. It's called "phenomenon-based learning."

"Teachers are asking students to use that science phenomenon to solve real-world problems," O'Donnell explains. "Today, it's no longer about just the 'stuff.' It's about the story that surrounds the 'stuff.'"

K-12 science teachers and curriculum developers are setting science objects into the context of real-world problems. "And now those books are no longer called 'Science', or even 'Water,' but 'How do you provide freshwater to those in need?'," she says.

O'Donnell worries that science textbooks are simply being replaced by science "tech" books at the peril of hands-on interactive learning. "Tech books often include hyperlinks, videos and augmented reality, so there are obviously benefits of tech books over textbooks," says O'Donnell. "But our premise is that hands-on experiential learning engages students in these perceptions, and sets objects into the context of a real-world phenomenon, invoking students' memories."

HANDS-ON SCIENCE IN A DIGITAL WORLD

Physical and digital learning models both have their merits. A study from the University of Chicago found that when students engage with science concepts through hands-on activities, they deepen their understanding of the material. A report from Stanford Center for Opportunity Policy in Education (SCOPE) states that digital and interactive content—including videos, simulations and interactive maps, among others—give science students opportunity to explore concepts through multiple lenses.

So how do we bring these two approaches together? How do we order physical and digital experiences to drive learning?

"The best order depends on the domain of science and what students already know," O'Donnell explains. "For young novice learners—for students who are not experts in a particular area or have inaccurate prior knowledge—researchers say that object-driven learning before digital learning is critical for student understanding."

And providing guidance to teachers on how to structure the use of digital resources in a lesson also matters.

TACKLING THE ISSUES OF THE SCIENCE CLASSROOM

Creating opportunities for phenomenon-based, real-world science learning can be challenging for teachers. Among the biggest obstacles are:

- **Competing priorities:** Not having enough time to teach science, given the focus on math and literacy.
- **New standards:** Uncertainty and lack of confidence around teaching to new standards.
- **Scarce resources:** Teachers' concerns over having to source their own materials for hands-on science.

These headaches can be addressed with a strong science curriculum that emphasizes interactive, inquiry-based learning and is easily integrated throughout the instructional day. The program should meet Next Generation Science Standards, provide sufficient scaffolding for teachers and include a rubric to help principals and other instructional leaders understand what successful science teaching and learning look like. It's also important to select a program that includes the supplies necessary to provide hands-on experiences to students.

For example, eighth grade students who use a physical convection tube to observe how air moves in response to temperature changes might apply their understanding of unstable air to tornado formation by using a free digital resource, like Disaster Detector, to analyze and interpret data to forecast future catastrophic events. Fifth grade students studying how to bring fresh water to those in need might set up stations in their classroom to physically move water from one area of the room to another and then engage in a simulation, like Aquation, to take actions to balance the world's global water resources.

Of course, none of this matters if we don't help students link their observations—whether physical or digital—to conceptual ideas and support students' thinking in explicit ways.

SCIENCE, READING AND MATH SCORES INCREASE

The Smithsonian Science Education Center and the University of Memphis recently completed a five-year validation study — called the LASER i3 Research Study (Leadership and Assistance for Science Education Reform) — with 60,000 students in elementary and middle schools in 16 districts in three states across the country. A randomly assigned subset of schools in the study used the Smithsonian's STC Program (Science and Technology Concepts™), an experiential, inquiry-based science curriculum.

Evidence from the study supports the efficacy claims of hands-on science learning in K-8. The biggest improvements charted by students on the Partnership for the Assessment of Standards-Based Science (PASS) assessments were in performance-based tasks and then open-ended questions. "Students are able to apply what they have learned in science to hands-on tasks, just as professional scientists apply their expertise to conduct scientific investigations and solve complex problems," the researchers wrote.

We also know that learning science by doing science leads to improved math and literacy skills.

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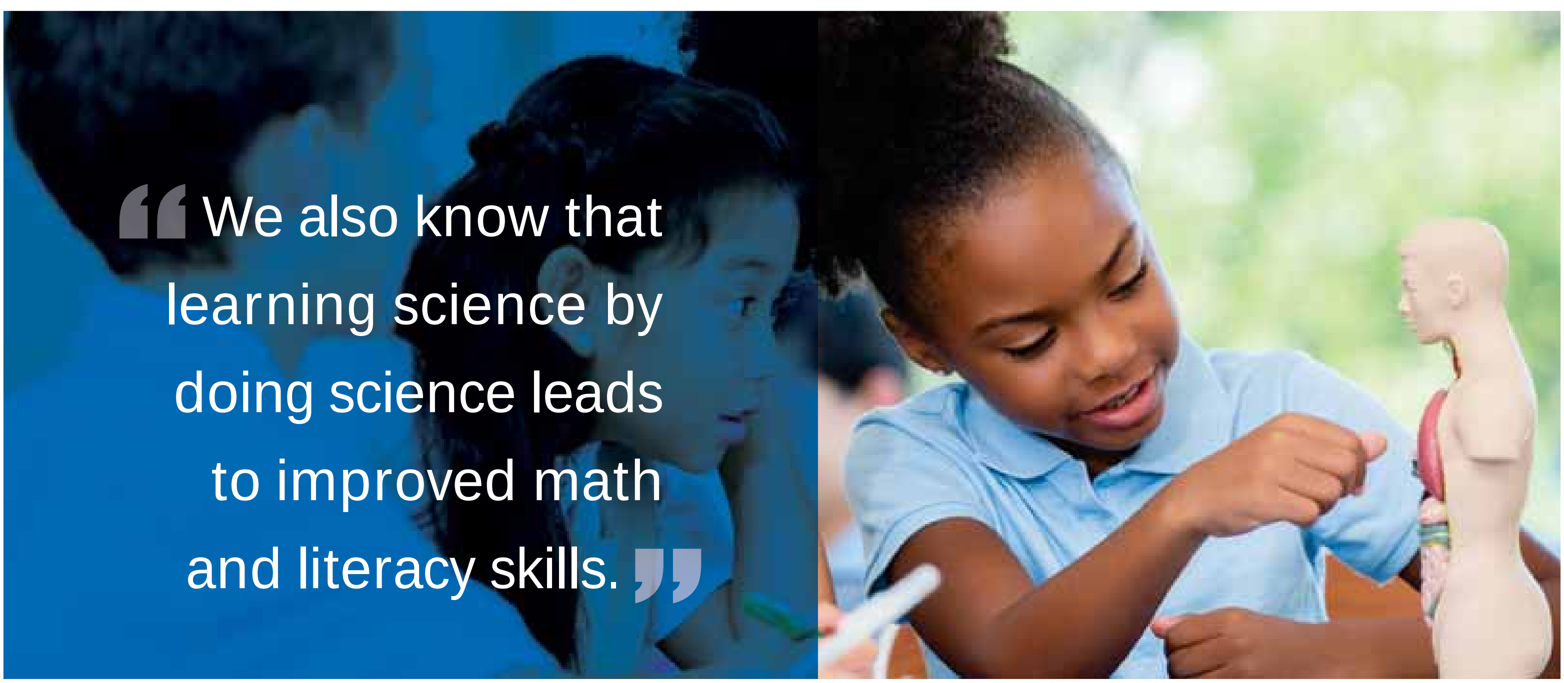

"We now have evidence from state-level reading and math tests that for students who receive this kind of hands-on multimodal learning, their math and reading scores go up," O'Donnell notes. "Why? Because they're engaging in an activity about plants or the motion of cars, calculating the growth of the plant over time or the acceleration rate of the car, and then reading about it, writing about it, communicating about it. So their literacy skills are also improving."

For example, in the Houston Independent School District, students in elementary and middle school classrooms using the LASER model experienced "statistically significant and/or educationally meaningful improvements" in state reading, mathematics and science assessments. Elementary and middle school students from subgroups that are of high concern to administrators benefited markedly on state tests for science and math.

"What the researchers found was that with students who were the most underserved—students who are English-language learners, students with disabilities, females, and students who are receiving free and reduced-price meals—hands-on learning had the greatest impact relative to doing business as usual; that is, textbook-based learning," O'Donnell says. "This is not a correlation; this is from two rigorously designed randomized-control trial studies… and now we know that this kind of teaching does make a difference in student learning."

'STUFF' STILL RULES

It's not just learning experts who think this. O'Donnell says young people participating in the Smithsonian Secretary's Youth Advisory Council agree.

"Their overwhelming response is that, absolutely, don't give up on focusing on the stuff," she says. "For many kids, hands-on learning is a novelty, and, as a result, is much more enticing than technology alone, since students already spend nearly nine hours a day consuming media online. They think it's so cool to be able to interact with objects firsthand in person.

"That's why the Smithsonian has over 154 million objects — like the Woolly Mammoth or the Apollo 11 Command Module. We believe in the power of physical objects!" ■

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ABOUT THE PARTNERSHIP:

CAROLINA BIOLOGICAL SUPPLY COMPANY AND SMITHSONIAN SCIENCE EDUCATION CENTER

The STC Program is a research-based science curriculum from the Smithsonian and Carolina proven to raise test scores. For more than 25 years, the partnership has developed inquiry-based science instruction that integrates science and engineering practices, crosscutting concepts and disciplinary core ideas into daily lessons. The program helps teachers transition to the new standards with relevant class materials, valuable resources and professional-development support.

"There's been a huge push lately for the importance of public/private partnerships," says Carol O'Donnell, director for the Smithsonian Science Education Center. "You want to achieve the goals of the public sector; that's the Smithsonian. But you can't do it unless you have true collaboration; true communication; obviously, shared goals that you have with your partner. And that's why we value our partnership with Carolina Biological."

"[Hands-on learning] keeps the curiosity of students alive, so they want to do more, and they want to continue with science," explains Irwin Shlachter, head of the Alexander Robertson School in New York City. "When science is taught this way, it's not something you study for a test, it's part of the learning environment every day."

The effectiveness of hands-on science is exciting but not surprising. Students prefer reading real books to e-books, and much research bears that out, especially as texts get harder and more domain-specific background knowledge is required. Researchers also have evidence that students who write by hand, especially when taking notes, learn more effectively because having to write by hand precludes them from typing up every word they hear, thus requiring evaluative thinking and knowledge-focused decision-making.

Tech will always be an important part of instruction and exploration, but in science in particular, technology-mediated learning will always need the support of direct tactile experiences. Science is the study of the natural, physical and chemical realities of our lives. Doing real science with real tools and real materials will always have its place and often its primacy, as well. ■

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