Smithsonian Science Education Center

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Focus on the Stuff

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

Advancements in technology and its role in keeping education going as schools shifted to remote learning during the pandemic 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, phenomenon-based, problem-based 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," she 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, problem-based learning."

"Teachers are asking students to use science and engineering to solve real-world problems and understand real-world phenomena," 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 objects into the context of real-world problems and phenomena. "And now those books are no longer called 'Science,' or even 'Water,'" she says, "but instead are called 'How can we provide freshwater to those in need?'"

O'Donnell worries that science textbooks are simply being replaced by science "tech" books at the peril of hands-on interactive learning. "Technology platforms often include hyperlinks, videos, and augmented reality, so there are obviously benefits of using digital tools over printed textbooks alone," 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 or problem, 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 naïve ideas—researchers say that object-driven learning before digital learning is critical for student understanding."

TACKLING THE ISSUES OF THE SCIENCE CLASSROOM

Creating opportunities for phenomenon- and problem-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 concerns can be addressed with a strong science curriculum that emphasizes interactive, three-dimensional learning and is easily integrated throughout the instructional day. The program should meet Next Generation Science Standards* (NGSS), 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.

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

For example, eighth grade students who observe the scientific phenomenon of a tornado might use a physical convection tube to observe how air moves in response to temperature changes, then use 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.

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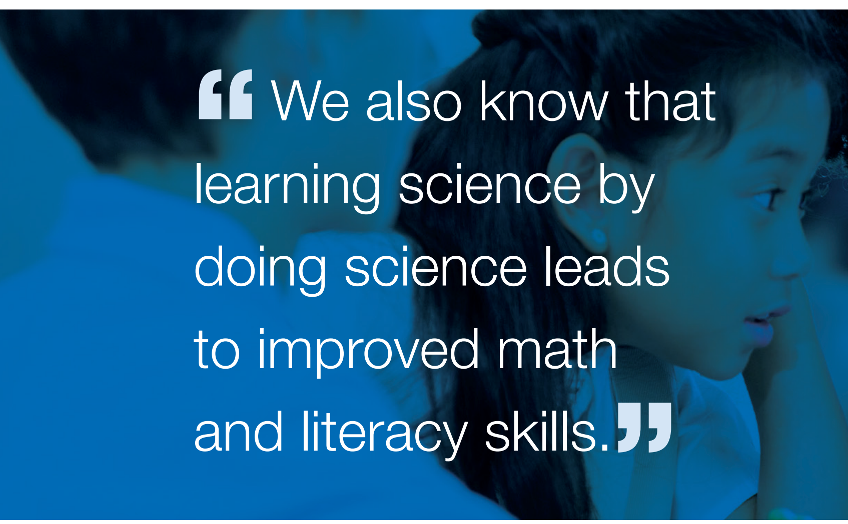
Science, Reading, and Math Scores Increase

The Smithsonian Science Education Center and the University of Memphis 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.



"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 Smithsonian curricula 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. Young people who participated in the Smithsonian Secretary's Youth Advisory Council agreed.

"Their overwhelming response is that, absolutely, don't give up on focusing on the stuff," O'Donnell 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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"Stuff" in the Context of the Real World

What does the study of water look like in the context of phenomena-based learning?

In past object-driven science classrooms, students may have examined the properties of water. They may have noticed that it takes the shape of the container it's in, examined its clarity, and measured its temperature.

In three-dimensional science education, water is put in the broader context of the real world. Students in a grade 5 classroom, for example, may be shown glasses of water and asked, "How much of this water, if it were all the water on Earth, would be fresh?" Students then consider how to solve complex problems regarding that water, such as constructing ideas and models to move fresh water to areas in the world where it is needed.

"Suddenly, it's no longer just about the water," O'Donnell says. "It's about the story that surrounds the water. The water is now set into the context of a sociopolitical problem and the stuff is now the story."

Tech will always be an important part of instruction, but doing real science with real tools and real materials will always have its place and often its primacy as well.

Examples of Three-Dimensional Science Lessons in Real-World Contexts

Grade	Driving Question	Core Idea	3-D Real-World Task
K	What do plants and animals need to live?	Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things.	Students analyze plans for a play area that minimizes its impact on the land and the organisms that depend on it.
2	How can we stop soil from washing away?	Wind and water can change the shape of the land.	Students analyze the effectiveness, structure, and function of models for four materials that could be used to slow down erosion.
4	How can we provide energy to people's homes?	Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not.	Students use information they have learned about energy to design a solution to cause a decrease in a family's home electricity use.
6—8	Why are honeybees disappearing?	Human activities have altered the biosphere. Changes to Earth's environment can have different impacts for different living things.	Students research colony collapse disorder (CCD) and design a solution to minimize human impact on the phenomenon. They develop a communication plan to bring awareness of CCD to the community.

Examples are from Smithsonian Science for the Classroom and Science and Techenology Concepts™ Middle School.

How the Smithsonian Science Education Center Supports Phenomena-Based and Problem-Based Learning

The Smithsonian Science Education Center (SSEC) is transforming K–12 education through science in collaboration with communities across the globe. One way to achieve this ambitious objective is by designing science curricula that support direct tactile experiences in conjuction with technology. Each Smithsonian Science for the Classroom (grades K–5) and Science and Technology Concepts™ Middle School (grades 6–8) module intentionally builds opportunities to drive students' curiosity and keep learning relevant through hands-on investigations that engage students in addressing real-world problems and phenomena.

Learn more about Smithsonian Science for the Classroom: **www.carolina.com/ssftc**

Learn more about STCMS: **www.carolina.com/stcms**

Carolina Biological Supply Company: **www.carolina.com/curriculum**

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Smithsonian | SCIENCE for the classroom

STC Science and Technology Concepts™ MIDDLE SCHOOL

CAROLINA K-8 CURRICULUM

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