Smithsonian
Science Education Center

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Finding Balance in Middle School Science

How to maintain the integrity of phenomena-based middle school science programs when learning environments change

When the 2020–21 school year began, 39 of the nation's 50 largest school districts—affecting more than 6.1 million students—were among those that chose a remote learning instructional model (*Education Week* 2020). They weren't alone. Many school districts began the year with remote learning only; others followed a hybrid model that combined remote and in-class learning in various forms, and still some districts began with full in-person learning. But in the age of COVID-19, districts have already experienced how instructional models can change on a moment's notice.

"It's a moving target," Cory Ort, a former physics teacher and physics afficionado who now serves as a national education consultant for Carolina Biological Supply Company, says of how students will learn in the current school year. "Teachers can't plan for the semester, because in two weeks, everything can change. The challenge is how do we come up with a strategy that maintains the integrity of science learning in this nonideal situation to make it as ideal as possible?"

This fluidity of the learning environment can be particularly arduous for teachers who facilitate hands-on, three-dimensional science education. The Next Generation Science Standards* (NGSS) and others based on *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* require students to figure out the world around them—to make sense of phenomena and problems—by designing investigations that weave together science and engineering practices, crosscutting concepts, and disciplinary core ideas to demonstrate learning.

"We don't want to abandon the philosophy of three-dimensional science learning—full inquiry, full engagement—just because we're virtual," Ort says. "We still need to meet the standards effectively. These kids are going to wind up in high school. These kids are going to wind up in careers. These kids are going to go to college. They need these skills."

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NGSS Expectations for Achievement, Grades 6–8			
Discipline	**Upon completion of grade 8, students should have a deeper understanding of . . .**	**As they explore topics that include . . .**	**Preparing them for advanced high school and college classes such as . . .**
Physical sciences	Physical and chemical interactions that affect the world around us	Atomic chemistry, forces and fields, thermal energy, and wave motion	Physics, forensics, and chemistry
Life sciences	Factors that affect organism survival and reproduction	Cells, gene variation, biodiversity, and adaptation	Biology, physiology, and genetics
Earth and space sciences	Factors that influence the Earth and solar system	The solar system, Earth's history, and energy flow	Astronomy, environmental science, and geology
Engineering design	How to optimize design solutions	How to refine criteria and constraints when designing engineering solutions	Mechanics, robotics, and engineering-enriched science courses

From "Preparing Students for a Lifetime of Success," nextgenscience.org

Critical Thinking and Procedural Development

There's value in becoming scientifically literate citizens regardless of where students learn and the academic and career choices they make later in life. When students learn to behave as scientists and engineers—observe, question, analyze, test, evaluate, and communicate—they're developing the critical-thinking and problem-solving skills that will help them better understand the world around them. The need for teaching hands-on science and sensemaking has been exemplified as scientists strive to find solutions during the pandemic.

"People who are better able to think critically about the information they are receiving and weigh up for themselves the available evidence are more empowered to make important choices, not only about their own health, but as a citizen," *Medical News Today* reports (McNamee 2014).

The NGSS and similar standards support a robust middle school science education that sets expectations for achievement (see the table), opening the door for increased opportunities in high school, college, and future careers. To develop critical-thinking and sensemaking skills, students engage in true inquiry as they design and execute investigations to explain phenomena and solve problems. In a virtual learning environment, facilitating students' inquiry can be a delicate task for teachers but it is possible.

"The NGSS require student to use science and engineering practices to solve problems and explain phenomena," says Katya Vines, acting division director for curriculum at the Smithsonian Science Education Center and author of several student-centered books aligned to the NGSS. "The trick is to come up with a way for kids to still use the practices that scientists and engineers use while learning remotely, and that can be hard."

Strategies for Learning Continuity

What are the best ways to provide authentic science, technology, engineering, and math experiences that continue to engage middle schoolers in investigating phenomena no matter where they are learning? For the teacher, the lessons need to be practical and flexible to meet every possible learning scenario, integrate key aspects of the investigation when students must learn remotely, and maintain the integrity of three-dimensional science learning.

"When all the kids are in class, we're going to teach as we normally would. When all the kids are at home, we're still going to have students working in small groups on a platform with breakout rooms," Ort says. "The hybrid model of optional attendance, meaning students in the classroom learning concurrently with students who are remote, is going to be the most challenging for the science teacher—keeping those kids watching at home engaged and as part of the lab group while engaging the kids in the classroom."

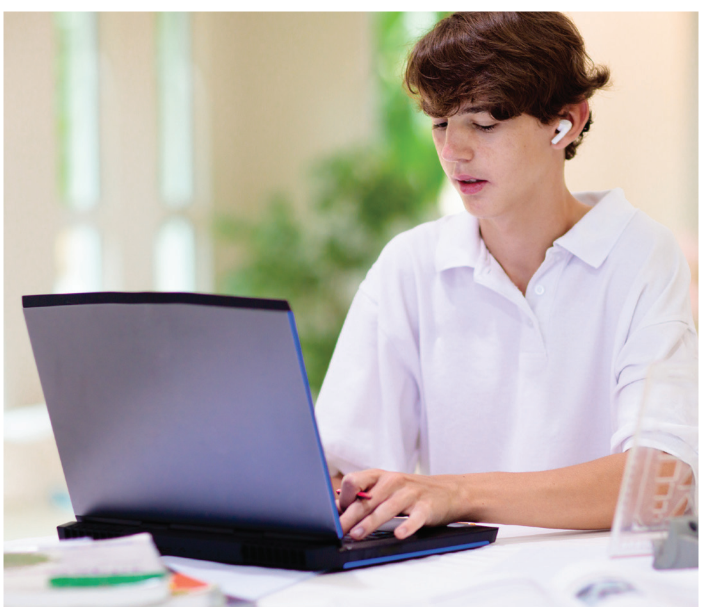
There are several strategies teachers are using to address various learning environments.

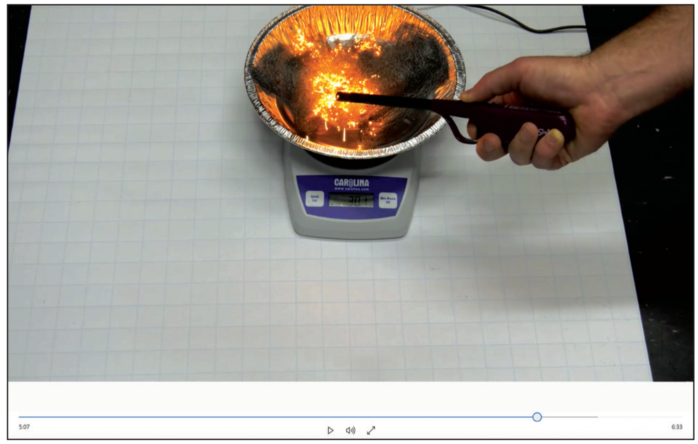
The teacher demonstrates the lab to remote students while on-site students conduct their own investigations.

The teacher does the lab for students who are remote, prompting them with questions: "What did we say yesterday?" "What's the next step?" "How could we test our idea or design that better?"

- ***The problem:*** The teacher is less available to monitor on-site lab groups.
- ***The solution:*** Use videos developed specifically for that curriculum to demonstrate the lab for remote students after they develop the procedure. "Once they've come up with a procedure, they chat with the teacher, who may say, 'Here are some problems, fix them.'" Ort says. "When they come up with the perfect procedure, the teacher shows them the video of that procedure taking place—the kids are recording their observations, they're recording their data, and they're moving to the conclusion and analysis phase." This lets the teacher float around the classroom and balance the needs of both the students in the building and at home.

"We of course know that middle school students are never going to have the perfect procedure on the first try," Ort says. "But in a class of 30, the perfect procedure is there. Group 1 is going to have some of it, group 2 has some, group 3 has some, and the teacher can facilitate that discussion in the classroom or on a digital platform." The teacher can then wrap up the lesson with a video of the investigation and an important discussion about the pros and cons of different solutions to further develop critical-thinking skills.





Videos, like this one created for an STCMS™ unit on matter and its interactions, can be used by teachers to demonstrate phenomena.

Students follow step-by-step instructions to achieve an anticipated result.

Whether on site or at home, this investigation guides students through each step of the procedure.

- ***The problem:*** Students aren't mentally and conceptually engaged, and the investigations typically lack coherency. "In a cookie-cutter lab, students aren't engaged in their critical-thinking skills," Ort says. "They're not engaged to the fullest, and they're not meeting standards." The National Science Teaching Association agrees: "They [labs] should not be a rote exercise in which students are merely following directions, as though they were reading a cookbook, nor should they be a superfluous afterthought that is only tangentially related to the instructional sequence of content."
- ***The solution:*** Use investigations that encourage student inquiry and, for virtual learning, home in on key aspects of the lab—those that are crucial to promote understanding and that make it practical for students to develop the procedure and participate in hands-on experiences at home.

Students watch a simulation.

Students experience phenomena by using interactive computer simulations.

- ***The problem:*** While simulations are compelling and help students explore the world around them, they often aren't carrying out science and engineering practices, which are key to meeting science standards. "Simulations can be an excellent way for students to use a model to explain a phenomenon," Vines says. "However, too often they just involve students clicking around to find the right answer and not using science and engineering practices."

- ***The solution:*** Recognize that making sense of phenomena requires students to engage in hands-on experiences, but when remote learning creates obstacles, simulations can serve as an alternative until kids are back in the classroom. In general, use simulations to extend understanding in conjunction with a curriculum that has proven results in supporting three-dimensional learning by integrating science and engineering practices in every investigation.

Students read a reader or textbook.

As schools transferred to virtual classrooms in the spring of 2020, some teachers found a temporary quick fix in textbook-based learning.

- ***The problem:*** While readers and textbooks can be important components of a well-rounded science program, when used on their own, they don't address science and engineering practices that enable students to achieve performance expectations.

- ***The solution:*** Use the literacy component of a phenomena-based program to extend learning by helping students make real-world, cultural connections while developing skills in reading nonfiction text and in writing (note-booking). Students can also obtain information from a text as part of a research project and use it to make an argument.

Effective Hands-On Learning for in School and at Home*

	In-School Instruction	Remote Instruction Strategies
Life science	In a structure and function unit, students dissect a frog to study the interdependence of organs and their systems.	***Strategy: Teacher Demonstration*** Avoid safety and disposal issues by demonstrating the dissection through a video chat. Students can create technical drawings and follow along using an instructional mat to help them identify internal and external structures.
Physical science	Students take understanding of electric circuit components to the next level with the introduction of voltage and voltmeters.	***Strategy: Simulation*** When materials aren't available, use a simulation, such as the circuit construction kit from PhET Interactive Simulations. Students create the procedural design to plan the investigation, present their conclusions, and follow up with class discussions.
Earth and space science	In studying Earth's dynamic systems, students explore earthquake building safety and design as they study Earth's gradual processes, such as plate motion and fossilization, and catastrophic events, such as earthquakes and volcanoes.	***Strategy: Hands-On in the Kitchen*** The same hands-on classroom activities can be done at home with readily found materials: students use uncooked spaghetti and marshmallows to design an earthquake-resistant structure, test their designs by shaking the table beneath their structure, make modifications, and then retest.
All	Knowing how to write a research paper is a middle school skill that's important in all content areas. Small groups of students collaborate to research a topic, organize the information, write a report, and present it to the class.	***Strategy: Virtual Breakout Rooms for Collaborative Learning*** Scientists can remotely read and research topics, write reports, present information, engage in argumentation, and check the validity of sources. Students behave as scientists as they collaborate in breakout rooms on online video conferencing platforms. The teacher oversees by consulting with the groups virtually.

**Examples are from Smithsonian Science and Technology Concepts™ Middle School units.*

Students conduct hands-on investigations at home. Science and engineering practices require students to experience hands-on learning. "Kids don't care that they're learning virtually. They still want to do the same things they've always done," Ort says. "They still want to see the cars crash together. They still want to see chemical reactions."

- ***The problem:*** In addition to safety concerns, every student doesn't have the materials at home to complete a hands-on investigation as they would in the classroom.
- ***The solution:*** Look for programs that make hands-on investigations accessible by substituting materials in the classroom investigation with those commonly found at home. "Kids aren't going to have copper(II) sulfate at home, but can we substitute something?" Ort explains. "We can use substitutes so kids can still see the reaction, record it, and be excited about it."

Finding a rhythm and support

As educators adapt their teaching styles to focus on the advantages as they overcome obstacles in their current learning environments, they can develop a rhythm for science investigations and discover strategies through curriculum providers that offer professional development and live online support.

"For example, in that hybrid model where groups of students rotate between on-site and remote environments, students who are remote should develop the procedure, plan their investigation, and get what they need in front of them at home so they can jump right in to do the investigation when they get to the classroom," Ort says. "When you get kids in the classroom, don't waste time talking to them about science. You want to use that time *doing* science because, let's be honest, that's where kids thrive."

After completing the investigation, when students are again remote, they can read informational text that supports their learning; analyze and record the data; and, in groups facilitated by the teacher, present information to the rest of the class in an online platform. By reflecting on their experience, they provide an opportunity for assessment.

"Science units should tell a story, just like a novel does, from the introduction where we get kids engaged—that's our preassessment—to the very last lesson, which is the assessment where kids solve a real-world problem using the information they learned," Ort says. "That's the engagement, as we're all challenged to do in the Next Generation Science Standards, where kids get to become budding scientists and engineers. That's what we want the kids to be."

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How Smithsonian Science Supports the Integrity of Virtual Investigations

The Smithsonian Science Education Center developed the Science and Technology Concepts™ Middle School (STCMS) curriculum from the ground up to engage students in three-dimensional, hands-on learning that incorporates science and engineering practices in every unit.

STCMS units center around specific bundles of NGSS performance expectations that engage middle schoolers in investigating phenomena following a coherent progression while integrating engineering concepts, literacy, and math. With print, digital, and lab materials in one all-inclusive package, the lessons are designed for classroom use while supporting key aspects of each investigation for at-home learning.

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