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SPRING 2021

A Natural Fit: 3-D Science and Outdoor Learning

How to make the most of open-air classes through phenomena-based science

- Kindergartners examine differences in the Sun's warming effect on rocks, soil, and sand as they learn about temperature.
- Students in a fifth-grade class apply what they've learned about properties of matter to design a water filtration procedure.
- Seventh graders construct barometers to measure air pressure and use the data to determine weather trends.

This is what three-dimensional science education can look like in elementary and middle school outdoor classes. Students are immersed in the real world through meaningful hands-on, phenomena-based learning experiences that align to science standards based on the National Research Council's (NRC's) *A Framework for K–12 Science Education.*

In response to the COVID-19 pandemic, school administrators began reconceptualizing schools to enable in-person, socially distanced, and equitable learning. One solution that continues to increasingly gain attention is outdoor learning, from establishing permanent outdoor classrooms to identifying spaces for teachers to take students outside for a single class every day.

Green Schoolyards America, a cofounder of the National COVID-19 Outdoor Learning Initiative, sums up the issue: "Repurposing outdoor spaces is a cost-effective way to reduce the burden on indoor classrooms while providing fresh air, hands-on learning opportunities, and the health benefits associated with increased access to nature."

Studies have shown that creating outside learning opportunities is not only beneficial for teachers and students but also doable in most schools. "Sometimes teachers think that outdoor learning involves taking a giant field trip and finding a hiking trail for the students," Environmental Educator Mary Rosa says. "That's not the case. Outdoor learning can be as simple as changing the location of the classroom to a greener space, an outdoor space—to an outdoor playground, an urban rooftop, a basketball court. It doesn't have to be complicated to benefit students."

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Why Teach Outside?

The epidemiology of the COVID-19 virus has shown that people are more at risk of cross-infection in indoor environments, and infectious disease experts have recommended that school districts find ways to get students outside as often as possible as a safer strategy for in-person learning (Marcelo 2020). But long before the COVID-19 pandemic began, numerous researchers have over several decades highlighted social-emotional and cognitive advantages to taking students outside for instruction.

- Children who were exposed to outdoor education had improvements in concentration, behavior, and learning, while teachers experienced better health, well-being, and job satisfaction (Swansea University 2019).
- Because learning in nature simultaneously engages all students' senses, it increases memory performance and attention spans and leads to fewer discipline problems, improved attitudes, and expanded learning opportunities (Louv 2011, 66–70).
- Students who learn in their school's surroundings and in their communities developed higher-level critical-thinking skills, performed better on standardized assessments, had reduced discipline and classroom management problems, and had increased engagement and enthusiasm for learning (Lieberman and Hoody 1998, 8).
- Students who participated in an outdoor education program as part of their science curriculum reported significantly more intrinsic motivation to learn and felt more competent (Dettweiler, Lauterbach, Becker, and Simon 2017).

Researchers have also shown that the benefits of learning outside continue when students return to an indoor classroom. "The findings here suggest that lessons in nature allow students to simultaneously learn classroom curriculum while rejuvenating their capacity for learning, or 'refuel in flight,'" a study published in *Frontiers in Psychology* found (Kuo, Browning, and Penner 2018). Lead researcher Ming Kuo explained: "This is nice for teachers, because you don't have to stop teaching and you still get that bump in attention."

Phenomena-Based Science Outside

Phenomena, observable events in nature that can be explained or predicted using scientific knowledge, are essential in the implementation of Next Generation Science Standards* (NGSS) and others based on the *Framework* (NGSS Lead States n.d.). These are the driving points of three-dimensional science teaching and learning, leading students to build knowledge by engaging in science and engineering practices and crosscutting concepts as they strive to explain a phenomenon or problem solve. By shifting focus from the teacher to the students and immersing students in the process of reasoning, learning becomes more consequential and leads to a more robust understanding of disciplinary core ideas.

"It's important to remember that phenomena don't need to be phenomenal to facilitate learning," Rosa advises. A phenomenon can be something as simple as observing how shadows change over the course of a day or investigating the flow of energy from a waterwheel. Students' curiosity is heightened when they are able to make connections in the world around them and engage all their senses as they strive to explain the phenomenon and problem solve.

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The NGSS is designed to connect scientific principles to the real world by learning in a hands-on, collaborative, and integrated environment rooted in inquiry and discovery. "Changing the environment from an inside classroom to the outdoors naturally guides students to make observations and ask questions," Rosa says, adding that crosscutting concepts—such as structure and function, patterns, and cause and effect—are cultivated when students examine phenomena in an outdoor space.

Outside Science Explorations

Grade	Anchoring Phenomenon	Investigation	SEPs	CCCs
K	Weather affects our daily lives.	Students explore surfaces that are warmed by the Sun and create a structure that reduces the Sun's warming effect on sand.	• Analyzing and interpreting data • Constructing explanations and designing solutions	• Cause and effect
2	Natural materials—such as water, minerals, rocks, and soil—are important parts of Earth's surface.	After analyzing the components of soil from a local area, students consider solutions to reduce the effects of soil erosion.	• Constructing explanations and designing solutions	• Cause and effect • Stability and change
4	The Sun is Earth's ultimate source of energy.	Students learn about the structure of a wind turbine, then construct and test their models.	• Asking questions and defining problems • Constructing explanations and designing solutions	• Cause and effect • Energy and matter
6	How can human impact on the environment be monitored and minimized?	Students design and conduct an experiment to explore how human activities impact plant growth.	• Constructing explanations and designing solutions • Planning and carrying out investigations	• Cause and effect • Stability and change
8	How can gravity affect the motion of objects on Earth?	Students demonstrate when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.	• Planning and carrying out investigations • Analyzing and interpreting data • Using mathematics and computational thinking • Engaging in argument from evidence • Obtaining, evaluating, and communicating information	• Cause and effect • Stability and change • Energy and matter

***Examples are from the Building Blocks of Science® 3D and STCMS™.**

For kindergarten through grade 2 students, the NRC stresses observation skills and explanations in its progression of practices for three-dimensional learning (*Framework* 2012, 34). Students demonstrate sensemaking when they can accurately identify a pattern and use it as evidence to support an explanation about the causes of a phenomenon. "Outdoor learning spaces are a natural fit," Rosa says. "You're in those spaces to hone observational skills, to look at patterns in nature."

For older elementary and middle school students, an outdoor environment leads them to naturally raise questions that encompass multiple disciplines as they develop models to help explain observable phenomena. For all students, writing or drawing observations in science notebooks promotes engagement in science and engineering practices.

Finding Support

Despite multiple benefits, there are challenges to teaching in the outdoors, most notably making adjustments for inclement weather and shifts between on-site and remote learning. Teachers can be prepared by using an all-inclusive, phenomena-based curriculum that incorporates the flexibility of multiple methods of learning in every unit of study.

"Look for a curriculum that has options and is easy to apply in an outdoor learning space," Rosa says. "It should have multiple places where the students are encouraged to make connections to the local ecosystem and supports teachers as effective outdoor instructors."

Start with a strong storyline. In a classroom or learning remotely, engage students with a **driving question** and share a **phenomenon-based video** to generate curiosity. Incorporate relatable outdoor experiences to help answer, "Why am I learning this?" When students are able to investigate a phenomenon in its environment, the phenomenon becomes more relatable and the core idea becomes more apparent.

Explore the phenomenon through a series of **hands-on investigations** that lead students to observe, experience, and discuss as they develop explanations for the phenomenon or solve a problem related to it. Use **digital simulations** that students can manipulate to create additional explanations for deeper understanding.

Exchange students' desks once again for a quiet outdoor spot for reading **nonfiction content** that supports the core idea. This also provides an ideal opportunity for science journaling as students analyze data, record

Take a Listening Walk

Looking for an easy-to-do outdoor experience that yields powerful learning results? Put students at the center of learning by taking them outside to listen to their environment, providing a unique, hands-on perspective while leveraging assets of the community.

While outside, spark students' observational skills as they differentiate between manmade and natural sounds. "They're hearing and smelling and feeling," Rosa says. "That lets students explore all sorts of phenomena. Why does it sound like this? Why can I hear this thing? Why can I hear it but can't see it?"

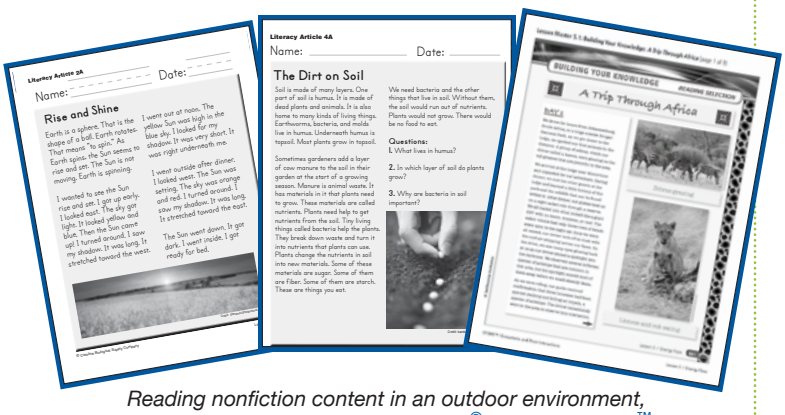
To incorporate physical science, have students cup their ears to investigate the difference in sounds and consider what they already know about soundwaves. For life sciences, invite them to relate what they hear to the structure and function of animal ears. Introduce the structure and function of the eye by having students use their peripheral vision. Guide them to relate that to how other animals' eyes are structured and function.

"You could go on for days with just this simple observational learning experience," Rosa says. "And you would be able to combine not only quite a few of the core ideas but also science and engineering practices and crosscutting concepts."

notes, and prepare to share their observations. Then spread out in the more spacious outdoors to incorporate engineering skills as students design models by applying concepts that support their explanations and provide evidence of learning—and create an opportunity for formative assessment.

Provide **take-home or at-home learning activities** so students can validate science knowledge through family and community connections, expanding evidence to demonstrate understanding. "Take-home science activities are a missed opportunity if they're not done," Rosa says. "Plus, they provide another way for students to experience science in the outdoors if they're not able to at their schools."

The NGSS describes science as a way of explaining the natural world. By actively relating a core idea to phenomena in natural environments, students are able to participate in and demonstrate learning that lasts as they apply the three dimensions to achieve the vision outlined in the *Framework:* to engage in public discussions on science-related issues, to be critical consumers of scientific information, and to continue to learn about science throughout their lives.



Reading nonfiction content in an outdoor environment, like these [Building Blocks of Science® 3D] and [STCMS™] articles, invites further exploration of phenomena.

Setting the Tone for Success

For purposeful outdoor learning, elicit students' input to establish appropriate behavior and rules before going outside.

- Stress to students that they are to work as scientists and engineers in their outdoor investigations, and guide them to agree on what those behaviors should look like.
- Emphasize that an outdoor class is not recess but an extension of everyday science learning.
- Designate a specific location to gather for instructions, check-ins, and class discussions. Have a plan in place for emergencies.
- Set a routine for distributing and collecting tools and equipment. Students should always be prepared with their notebooks or clipboards for recording observations and taking their outdoor learning seriously.
- The day before an outdoor lesson, have students investigate the weather forecast and determine the clothes they should wear so they are comfortable when outside.

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Carolina Biological Supply Company is a leading supplier of science teaching materials. Headquartered in Burlington, North Carolina, it serves customers worldwide, including teachers, professors, homeschool educators, and professionals in health- and science-related fields. Carolina is the exclusive developer and distributor of the Building Blocks of Science® 3D curriculum and the new BBS3D@Home digital component.

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The Smithsonian Science Education Center (SSEC) aims to transform and improve the teaching and learning of science for K–12 students. It developed the Science and Technology Concepts™ Middle School (STCMS™) curriculum to engage grades 6–8 students in three-dimensional, hands-on learning that incorporates science and engineering practices in every unit.

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