More Than "Just" Science

How Math and Reading Are Bolstered in 3-D Science Class

Credit: Knowledge Matters Campaign

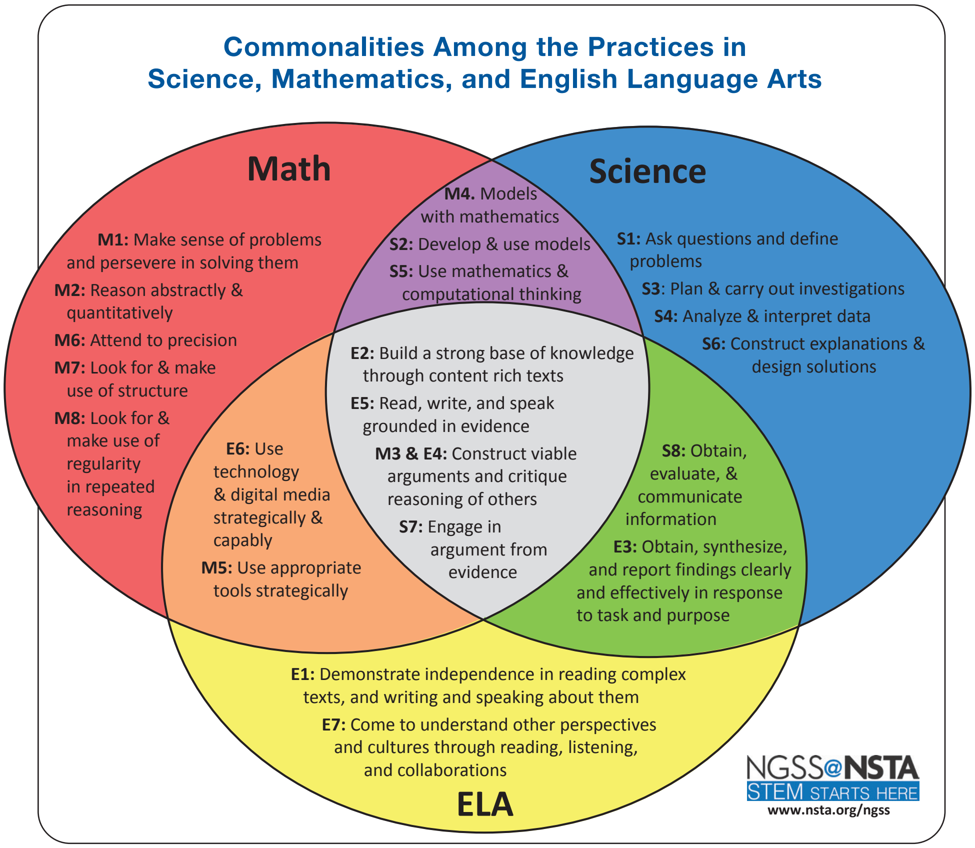
In a middle school science classroom, students are investigating natural hazards. Through text and video, they experience the phenomenon of a tsunami, wonder about how it forms and moves, and engineer design solutions and technologies that could reduce its damages.

In three-dimensional science classrooms like the middle school example, students develop critical-thinking and problem-solving skills as they engage in science and engineering practices to make sense of phenomena. But high-quality investigations such as the natural hazards unit (OpenSciEd, n.d.) create additional opportunities to revisit, reinforce, recover, and develop skills beyond "just doing science." In this grade 6 unit:

- Students reinforce elementary school **math** concepts as they build scatter plots with large data sets and look for patterns and trends between multiple variables.
- They strengthen **language arts** skills as they gather, evaluate, and communicate information and write explanations for midpoint and summative assessments.
- For **social-emotional learning**, the unit supports empathy and emotional responses as students relate to natural hazards, empowering them to prepare for and respond during an event that may impact them and their community.

"By students engaging in phenomena—learning to ask questions and developing their own investigations—it intuitively and immediately helps with critical-thinking skills in a variety of subjects," Cory Ort says. Ort is a veteran teacher with 25 years' experience in science classrooms. As a national science consultant for Carolina Biological Supply Company and certified professional learning facilitator for OpenSciEd, he now supports science educators and school administrators across the United States in understanding three-dimensional science education.

There are multiple commonalities among science, math, and English language arts (see the Venn diagram, page 2). But when it comes to three-dimensional science, Ort explains that real-world applications of reading and math embedded in students' investigations provide relevance and value for learning these skills. This meaningful application offers an additional avenue to facilitate learning recovery for students whose skills suffered during the COVID-19 pandemic.



Credit: National Science Teaching Association, Based on work by Tina Cheuk

The 2022 National Assessment of Educational Progress (NAEP) shows scores for grades 4 and 8 in both math and reading declined for most states compared to 2019. These 2022 test scores translate to students, on average, being about 15 to 24 weeks behind in math and nine weeks behind in reading compared to 2019 (Bryant et al. 2023).

"They're not just missing content," Ort says. "They're missing those skills that come from applying information, that cognitive connection. Through inquiry-based investigations, students see why it is important that they know these skills moving forward."

Making Math Relevant

In developing *A Framework for K–12 Science Education*, the framework on which the NGSS and other similar science standards are based, there is an apparent intentionality by the National Research Council (NRC) of the National Academies to draw attention to the prominent role math plays in science and engineering, stating, "Increasing students' familiarity with the role of mathematics in science is central to developing a deeper understanding of how science works" (NRC 2012, 65).

Math garners two specific mentions within the *Frameworks'* eight scientific and engineering practices (SEPs):

- Practice 2: Developing and Using Models
- Practice 5: Using Mathematics and Computational Thinking

Additionally, the *Frameworks'* crosscutting concepts (CCCs) of patterns; cause and effect; and scale, proportion, and quantity embrace mathematical relationships across disparate elements.

In a recent national survey of parents and teachers, respondents said math should be "relevant to the real world," should be "useful," and is the top academic subject "most in need of updating and improvement" in how it is taught (Global Strategy Group 2022). While there is ongoing debate between proponents of traditional math that emphasizes procedures and algorithms versus those favoring inquiry-based, problem-solving math learning, researchers have found that students using inquiry-based instruction

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associate math with greater interest, perceptions of utility, and self-efficacy (Riegle-Crumb et al. 2019, 1).

"Explaining sound as a wave using mathematics; explaining the motion of a mountain in speed, scale, and proportion; and to support your ideas of answering those questions is huge," Ort says. "These are algebra skills the students are using to answer a question that they're engaged in through science. It's not doing math as I learned math. It's not solving for *x* and then doing it 15 more times. It's the ideas of understanding why and knowing *x* is important. There's a purpose behind it, there's a logic behind it as opposed to just do."

This is particularly important in middle school—a key period when students' confidence in doing math and science can wane, leading them to avoid these subjects in high school and beyond. Presenting math and science to middle schoolers through an inquiry-based lens can serve as a potential catalyst that bolsters positive attitudes and motivates students to pursue and succeed in STEM trajectories (Riegle-Crumb et al. 2019, 1–2). "With middle school students, how many times do you hear, 'Why do I need to know this?'" Ort says. "Middle school students are very good at being middle school students."

In a high-quality science curriculum that effectively supports math learning recovery and growth, investigations are sequenced with the corresponding math standards. Each unit should support the

Examples of Middle School Science Units and Math Prerequisites*

Science Unit	Focal SEPs	Prerequisite Math Concepts That Can Assist in Learning Recovery
6.2 Thermal Energy How can containers keep stuff from warming up or cooling down?	• Developing & Using Models • Planning & Carrying Out Investigations • Analyzing & Interpreting Data • Constructing Explanations & Designing Solutions • Engaging in Argument from Evidence	Beginning in Lesson 4 and throughout the unit, students focus on pooling and then averaging test results and building an understanding of temperature as a measure of average particle movement. They take measurements in the tenth or hundredth in decimal points, and must consider negative and positive numbers as they mass systems.
7.1 Chemical Reactions & Matter How can we make something new that was not there before?	• Constructing Explanations and Designing Solutions • Analyzing and Interpreting Data • Engaging in Argument from Evidence	Density is a property that students measure, graph, and calculate from mass and volume data in Lesson 8.
8.6 Natural Selection & Common Ancestry How could things living today be connected to the things that lived long ago?	• Analyzing & Interpreting Data • Constructing Explanations & Designing Solutions • Engaging in Argument from Evidence	Throughout the unit, students engage in mathematical thinking. They use ideas from 6th grade CCSS related to measures of central tendency and variation to compare the distribution of trait variations in a population over time. They use ideas from 7th grade CCSS related to drawing inferences from sampling a population. They analyze and interpret scatterplots, lines of best fit, histograms, and box-and-whisker plots.

**Examples are from OpenSciEd grades 6–8 curriculum.*

teacher by presenting prerequisite math concepts in the background information for the unit, creating an opportunity for science and math teachers to collaborate to forge explicit strategies that plug skills gaps and build student confidence.

"It immediately makes sure the science is working with the mathematics students are going to be using," Ort explains. "That's the tie in. Part of the learning recovery is to be able to know what math skills are up and coming and then being able to review and address any gaps. By doing it based on scientific inquiry, students are able to apply the skills and see why they are important—not just in science class, but in general."

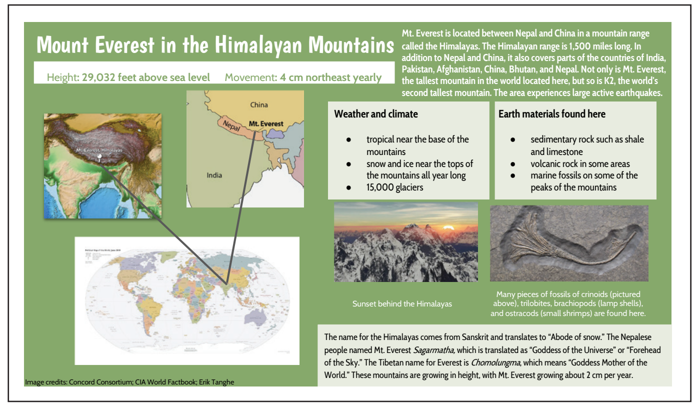
Supporting English Language Arts

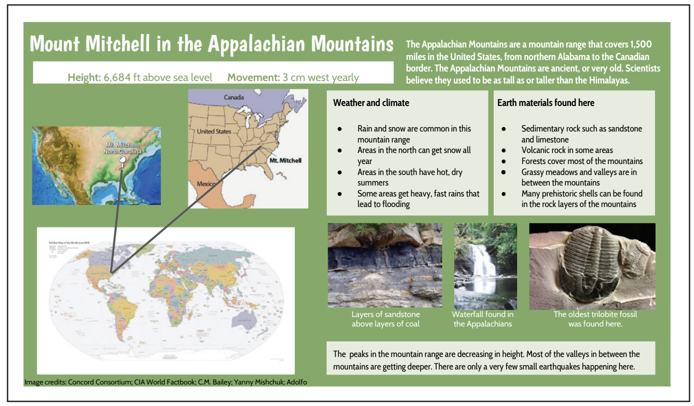
For English language arts (ELA), science education is instrumental in developing students' reading and writing skills in context with real-world phenomena. "Any education in science and engineering needs to develop students' ability to read and produce domain-specific text," the *Framework* states. "As such, every science or engineering lesson is in part a language lesson …" (NRC 2012, 76). Students have a reason to read, write, and verbally communicate their wonderings, ideas, and findings as they engage in sensemaking while using the SEPs of:

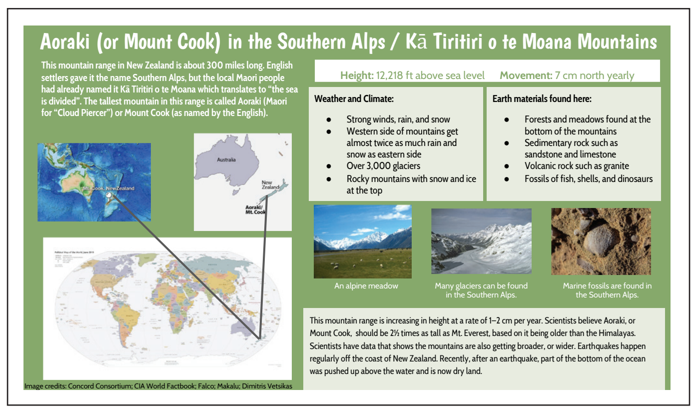
- Practice 1: Asking questions and defining problems
- Practice 6: Constructing explanations and designing solutions
- Practice 7: Engaging in argument from evidence
- Practice 8: Obtaining, evaluating, and communicating information

"Students use a variety of methods to learn about phenomena," Ort says. "Science gives students—especially those who are struggling, who are in learning recovery, and English language learners—the motivation to read something and see how it applies to a phenomenon and then to help explain other related phenomena, which fills a big learning gap."

Ort uses a grade 6 unit on plate tectonics and rock cycling (OpenSciEd, n.d.) as an example. In answering the question "What causes the Earth's surface to change?" he explains, "It's not the teacher saying, 'Well, today we're going to learn about plate tectonics.' Students watch [a video] and read an article, and reading the article is the focus here." In the article, students learn that Mount Everest has increased in elevation over time. They notice and wonder about the article's revelations for them and then analyze data cards about whether other mountains grow and move, leading them to make connections to changes in the land around the places they live and visit.







"They're engaged as they're seeing the bigger picture of Earth science and the dynamic system that Earth is," Ort says. "They're developing their own questions; they're having to make those connections. Those are the skills in three-dimensional learning—whether it's being able to recognize the crosscutting concepts of cause and effect or scale and proportion that tie directly into math and recur along all disciplines—that are tied directly into English language arts. They learn to think critically about the article they just read, to take the noticings and wonderings from a simple science article and apply those actions to a short story in English class: What did you notice the character do? What do you wonder about that character? What inferences can you make?"

Strategies students use in an phenomena-based science class can be especially helpful for English language learners (ELLs). The *WIDA English Language Development (ELD) Standards Framework* states that "multilingual learners are best served when they learn content and language together in linguistically and culturally sustainable ways" (WIDA 2020, 11). Engaging in phenomena-driven science simultaneously supports authentic science learning and ELLs' language development (Lee, Grapin, and Haas 2018), positioning these students as valuable contributors to the class community's understanding.

The National Education Association estimates that by 2025, one out of four US students will be ELLs (NEA 2020).

In high-quality science units, the noticing and wondering in science are part of a routine that ground students' learning experiences in real-world phenomena. These routines provide multiple opportunities to encourage ELLs to share ideas through both linguistic and nonlinguistic modes of communication (OpenSciEd 2019). Look for a curriculum that identifies learning spaces where teachers can leverage ELLs assets' or address potential challenges, such as unpacking the meanings of words in the context of science. All students benefit from experiencing new vocabulary first through ideas for authentic and lasting connections. Rely on a curriculum that provides guidance in "earned" and "encountered" vocabulary.

"A high-quality, phenomena-based science curriculum has the ability to help students learn skills that go beyond the science classroom, that go beyond the school building in general," Ort reiterates. "It goes beyond teaching the kids a series of facts but teaches them a series of strategies and concepts that help structure their thoughts, help them think about the world around them." It is these types of strategies that can lead students to achieve in multiple areas of learning.

Examples of How a High-Quality Science Curriculum Supports WIDA ELD Standard 4: Language for Science, Explain, Grades 6–8

Multilingual learners will interpret scientific explanations by…	**Phenomena-Based Science Strategies***
Defining investigable questions or design problems based on observations, information, and/or data about a phenomenon	Students begin each unit with an Anchoring Phenomena routine. They explore a phenomenon; attempt to make sense of it based on their observations, information, and/or data about it; and develop investigable questions.
Determining central ideas in complex evidence and information to help explain how or why a phenomenon occurs	Through investigative routines, students determine central ideas in evidence and information that help them explain how or why a phenomenon occurs. This evidence can be from a hands-on investigation, data from experts or peers, authoritative texts, and classroom discussions.
Evaluating scientific reasoning that shows why data or evidence adequately supports conclusions	During a Putting the Pieces Together routine, students evaluate scientific reasoning that shows why data or evidence supports conclusions. Students take the ideas they have developed across multiple lessons and figure out how they can be connected to account for the phenomenon the class is working on. This routine helps students take stock of their learning and engage with the class to develop a consensus representation, explanation, or model to account for the target phenomenon.

**Examples are from OpenSciEd curriculum.*

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