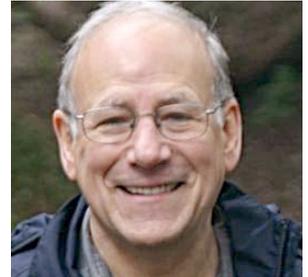


## What Do I Do With Crosscutting Concepts?

Cary Sneider

One of the complaints about science education is that it is fragmented, especially at the elementary and middle school levels. A month-long unit on ecosystems might be followed by a few weeks on motion, and then a short module on weather gets wedged between Thanksgiving and Christmas. Why should our students think that such different topics as ecosystems, motion, and weather are all “science,” other than the fact that they are taught in science class?

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Over his career, Cary has directed more than 20 state and federal grant projects, including several that involved the development and testing of new curricula and methods of assessment.

This is a critical problem, since understanding how all of these topics are related means understanding the nature of science itself, and without that understanding, science is just a collection of facts, or at best a sequence of experiences. To combat this problem *A Framework for K–12 Science Education* (NRC, 2012) identified seven crosscutting concepts that have the potential to help students see the unity of the sciences.

### What is a Crosscutting Concept?

In brief, a concept is crosscutting if it communicates a scientific way of thinking about a subject, and it applies to many different disciplines of science and engineering. A concept is not crosscutting if it does not communicate a scientific way of thinking or if it only applies to one or two disciplines.

The following are brief definitions of the seven crosscutting concepts from the *Framework* (NRC, 2012, page 84) with examples of how they are connected with performance expectations (PE) in the Next Generation Science Standards (NGSS Lead States, 2013). Notice that the crosscutting concept is often embedded in the PE, even if the name of the crosscutting concept is not directly referenced. Although these examples are drawn from grades K–5, the crosscutting concepts are useful at the middle and high school levels as well.

**1. Patterns.** Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

**Example PE: K-LS1-1.** Use observations to describe patterns of what plants and animals (including humans) need to survive.

**2. Cause and effect:** Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

**Example PE: 1-PS4-1.** Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.

**3. Scale, proportion, and quantity.** In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.

**Example PE: 2-ESS1-1.** Use information from several sources to provide evidence that Earth events can occur quickly or slowly.

**4. Systems and system models.** Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

**Example PE: 4-LS1-2.** Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.

**5. Energy and matter:** Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

**Example PE: 5-PS1-2.** Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.

**6. Structure and function.** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

**Example PE: 4-LS1-1.** Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

**7. Stability and change.** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

**Example PE: 5-ESS1-2.** Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.

## Why Are Crosscutting Concepts Considered Powerful?

Take the example of energy. At the end of the 18th century the most popular theory of heat was that it was some sort of fluid substance called *caloric* that could flow from one object to another. If you placed a warm object next to a cold one, caloric would flow from the warm object to the cold one. If you held a hot cup of coffee on a cold day, the caloric would flow out of the cup into the surrounding air.

The theory of caloric was finally overthrown by Count Rumford in 1797, when he noticed that the process of boring a hole in a piece of brass to produce a cannon also produced heat. If caloric was a fluid that flowed from a warm substance to a cold one, where did it come from to heat the brass? The energy must have come from the motion of the tool on the metal! The idea that there are different forms of energy that are interchangeable was born.

In the 1840s James Prescott Joule and other scientists at that time found out just how much energy was transferred by stirring a container of water and measuring how much the water warmed due to the stirring. In the decades that followed, the concept of energy was expanded to include chemical energy, electrical energy, and the energy in food that enabled life processes.

Whether the subject is life science, physical science, Earth and space science, or engineering, the concept of energy is the same, and the route to answering questions and solving problems often involves following the energy. Where does it come from? How is it used? Where does it go?

I can't leave the topic of energy without bringing up energy conservation—the idea that energy never disappears, but transfers from one place to another, or transforms from one form to another. For example, the chemical energy stored in gasoline is transformed to heat (thermal energy) and then to motion in a car engine. The motion energy in the engine is transferred to the wheels and (thanks to friction) to the movement of the car along a road. To say that some of the energy is “lost” along the way is not entirely accurate. Some is transformed to heat energy in the tires and in the air, so it is no longer useful—but if all of the energy could be captured and added up, it would be equal to the energy in the gasoline that was burned.

The same law of conservation of energy used by an engineer to design a more efficient car is used by a nutritionist to calculate the ideal meal for a patient, and by an ecologist to investigate how energy moves through an ecosystem. The crosscutting concept of energy has the potential to help students see how scientists and engineers think, and how the disciplines of biology, physics, chemistry, engineering, and Earth and space science involve similar concepts and ways of thinking.

### Guiding Principles

The *Framework* identified several principles for integrating crosscutting concepts into the teaching of science. These guiding principles are quoted in Appendix G of the NGSS. In brief, crosscutting concepts:

- help students understand core ideas and practices in science and engineering,
- provide a common vocabulary for science and engineering,
- are embedded in performance expectations,
- should be taught in different contexts to build familiarity,
- should grow in complexity and sophistication across the grades,
- should not be assessed separately from practices or core ideas, and
- are for *all* students.

## Teaching Crosscutting Concepts

I recommend that teachers not attempt to teach all crosscutting concepts, but rather decide on 2, 3, or 4 crosscutting concepts that link the major topics that they plan to teach during the year. For example, kindergarten teachers are responsible for the following performance expectations, both of which involve patterns:

**K-LS1-1.** Use observations to describe patterns of what plants and animals (including humans) need to survive.

**K-ESS2-1.** Use and share observations of local weather conditions to describe patterns over time.

During instruction students will be identifying patterns, and using the patterns they observe to classify and better understand the subject. However, the crosscutting concept of patterns is not necessarily taught explicitly; the focus is on plants and animals, or on different types of weather conditions.

In my opinion, the best time to introduce a crosscutting concept explicitly is after the students have used the concept in two different contexts. So, for example, after the students have studied patterns in plants and animals, and again in relation to weather, the teacher can help the students see how both topics involve patterns, and how identifying patterns helps them better understand those subjects.

The lesson may or may not be fully understood by the kindergarteners, but when reinforced in subsequent years, the students will begin to see how identifying patterns leads to more complex patterns, such as patterns of change over time and life cycles.

By the time students reach high school age they should have a good grasp of all seven crosscutting concepts, and a deep understanding of how they unify the different disciplines of science and engineering.

References:

National Research Council (NRC). (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

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