PRACTICING SCIENCE IS HOW WE ADD TO THE BODY OF SCIENTIFIC KNOWLEDGE.

There is plenty of science learning that can be done by reading, listening to lectures, and watching videos about scientific facts that humankind has already discovered. Participating in these activities helps us become more knowledgeable about science. But science can also be practiced, and that is its real power. Practicing science is how we add to the body of scientific knowledge.

National Academies of Science defines science as the "use of evidence to construct testable explanations and predictions of natural phenomena, as well as the knowledge generated through this process." This emphasizes that fact that science (and engineering) are fields that are about doing, as much as they are fields about knowing.

Across the U.S. states have been recognizing this fact about the fields of science and engineering by including practices in their standards. States use a variety of terms to describe these practices (e.g., essential skills, science skills, inquiry skills, inquiry methods, science methods). But regardless of the name, they emphasize students engaging in the work of science and engineering.

"Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world. Engaging in the practices of engineering likewise helps students understand the work of engineers, as well as the links between engineering and science. Participation in these practices also helps students form an understanding of the crosscutting concepts and disciplinary ideas of science and engineering; moreover, it makes students' knowledge more meaningful and embeds it more deeply into their worldview."

Source: NRC Framework, 2012, p. 42

WHAT ABOUT THE SCIENTIFIC METHOD?

The scientific method has been the historical approach to teaching the practices of science. However, there is no single scientific method with a series of neat and tidy steps. To support educators in teaching the breadth of scientific practice, modern standards often identify a collection of practices for students to engage in. For example, in the NRC's Framework for K–12 Science Education, they identify eight Science and Engineering Practices:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

KNOWING SCIENTIFIC SCIENCE CONTENT ALLOWS PEOPLE TO FULLY ENGAGE IN THE WORK OF SCIENCE AND ENGINEERING

To be an informed citizen that can unpack issues and make informed choices, people need to know science content. Knowing scientific science content also allows people to fully engage in the work of science and engineering (where they go on to discover new science and engineering knowledge).

Science content has traditionally been divided into three categories (life science, physical science, and earth science) and often was a series of discrete facts. Typically contemporary science standards identify science content that:

- Is not discrete facts, but instead big ideas that apply to multiple disciplines or are key concepts for a single discipline. For example, students are expected to go beyond memorizing the definition of a push and pull to understanding how pushes and pulls affect matter.
- Are purposeful facts/ideas that need to be used during student investigations into complex phenomena and problems
- Relate to student cultures, personal interests, and their social and community contexts
- Has vertical articulation and is learned across multiple grades with increasing levels of depth
- Includes more disciplines, for example, life science, physical science, earth science, space science, engineering, technology, and science applications

CORE SCIENCE AND ENGINEERING IDEAS

Most modern standards focus on core (or essential) ideas. For example, in the NRC's Framework for K–12 Science Education, they identify four collections of DCIs, as follows:

LIFE SCIENCE (LS)

LS1: From Molecules to Organisms: Structures and Processes
LS2: Ecosystems: Interactions, Energy, and Dynamics
LS3: Heredity: Inheritance and Variation of Traits
LS4: Biological Evolution: Unity and Diversity

EARTH AND SPACE SCIENCE (ESS)

ESS1: Earth's Place in the Universe
ESS2: Earth's Systems
ESS3: Earth and Human Activity

PHYSICAL SCIENCE (PS)

PS1: Matter and Its Interactions
PS2: Motion and Stability: Forces and Interactions
PS3: Energy
PS4: Waves and Their Applications in Technologies for Information Transfer

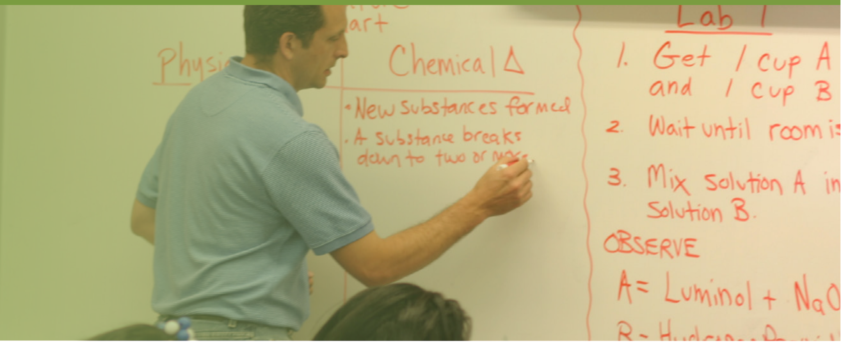
ENGINEERING, TECHNOLOGY AND THE APPLICATION OF SCIENCE (ETS)

ETS1: Engineering Design

Making Sense of SCIENCE

SCIENCE & ENGINEERING CROSSCUTTING CONCEPTS

CROSSCUTTING CONCEPTS ARE THE LENSES THAT SCIENTISTS USE TO LOOK AT THE WORLD



In science, there are some ways of looking at the world that transcend the disciplinary boundaries. These lenses are tools that scientists, be they biologists, paper engineers, chemists, and nuclear physicists, all use in their work.

These ways of thinking go by many names depending on the venue (e.g., Crosscutting Concepts, Overarching Principles, Unifying Ideas, Themes) and the specific ideas included vary, but many share commonalities with the seven Crosscutting Concepts identified in the NRC's Framework for K-12 Science Education. Crosscutting concepts are designed to be "common and familiar touchstones across the disciplines and grade levels" (NRC Framework, p. 83). They differ from science content in that they are ideas that pertain to a multitude of science content and investigations. For example, the idea that energy is a calculable amount that transfers among systems is used by a engineers as they try to design more efficient engines, climatologists as they determine the rate of atmospheric warming, and bacteriologist as they determine how much food is required to sustain the bacterial colonies for their research.

NATIONAL RESEARCH COUNCIL (NRC) FRAMEWORK FOR K–12 SCIENCE EDUCATION CROSSCUTTING CONCEPTS

1. **PATTERNS**
   Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
2. **CAUSE AND EFFECT**
   Mechanism and explanation. Events have causes, sometimes simple, sometimes multi-faceted. 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.
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.
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.
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.
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.
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.

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