Smithsonian | SCIENCE for the classroom

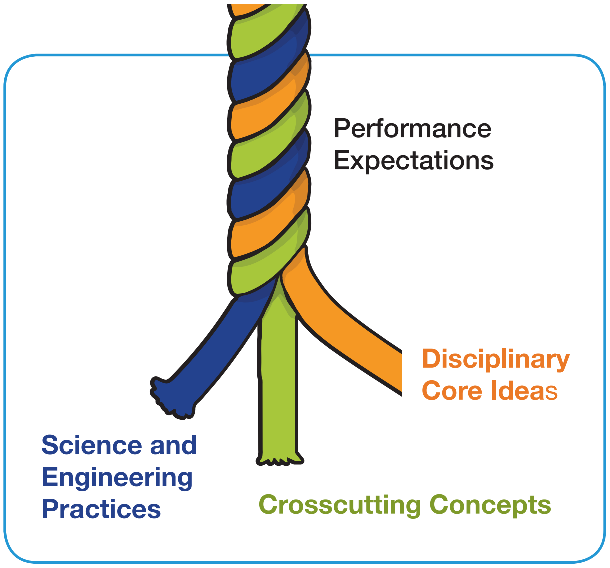
Building Thinkers through Science

Using Three-Dimensional Learning And Assessment In Your Classroom

Solving the problems of the future will require that students not only understand science concepts related to health care, the environment, energy, and new technologies but also that they use skills such as problem solving, critical thinking, communication, collaboration, and self-management (National Research Council, 2012a). To build these skills, new science standards call for students to engage in the processes of doing science and engineering. Asking questions, planning investigations, and analyzing data should not simply be part of an isolated "scientific method" unit or a way for students to reinforce knowledge they have already learned. Instead, students need to use these skills to explain their observations or solve the problems they encounter. Students also need to be able to develop higher order thinking skills to transfer what they have learned to new situations.


Credit: Jamie Dunn, Rosalind Franklin STEM Elementary School

A Framework for K–12 Science Education (National Research Council, 2012b), which is the basis for the Next Generation Science Standards* (NGSS Lead States, 2013) and many state standards, describes this model for science education as three-dimensional learning and assessment. The three dimensions are disciplinary core ideas (DCIs), science and engineering practices (SEPs), and crosscutting concepts (CCCs). Previous standards included aspects of each of these dimensions but did not necessarily require that learning and assessment combine all three. As a result, most assessments focused on facts and concepts. Now, the NGSS provide specific combinations of DCIs, SEPs, and CCCs in the form of performance expectations (PEs)—statements of what students should know and be able to do at the end of instruction.



About the Three Dimensions

A disciplinary core idea, the most familiar aspect of science education for most people, is the content. However, DCIs are not just simple facts—the names of the planets or the parts of a cell. Instead, they are the foundational knowledge that more complex science ideas are built upon. For example, a DCI for grade 1 states, "Individuals of the same kind of plant or animal are recognizable as similar but can also vary in many ways." This is foundational knowledge for understanding a more complex idea: natural selection. It is also a common misconception. Many people believe that there is little to no variation between individuals of the same species and therefore have trouble understanding natural selection (Shtulman and Schulz, 2008). The DCIs in the *Framework* are carefully sequenced to support the understanding of increasingly more complex science ideas.

> "The DCIs are not just simple facts—the names of the planets or the parts of a cell."

Science and engineering practices are what scientists do when they are investigating the natural world and what engineers do when they are solving problems. There are eight SEPs described in the *Framework* (see the table on page 3).

Crosscutting concepts are big ideas or themes that have applications across all disciplines of science as well as engineering. Recognizing these common CCCs helps students make connections across different science domains. For example, patterns exist in the phases of the moon, the effect of gravity on objects, and DNA sequences in living things. Scale and proportion are used to describe the relative size of molecules, distances in space, and spans of time (seconds, days, years). The *Framework* describes seven CCCs (see the table on page 3).

What Does Three-Dimensional Learning Look Like in the Classroom?

Developing learning experiences where students are engaged in all three dimensions at once is daunting. Delivering content isn't enough anymore. Students now need to figure out or apply that content in a way that relates to common themes that connect all of science and engineering. That's really challenging but not impossible.

One solution is to build learning experiences that mimic the real work of scientists and engineers. Scientists explain and make predictions about the natural world, and engineers solve problems. Students will need to use DCIs, SEPs, and CCCs all at once to do what scientists and engineers do.

Let's revisit the grade 1 DCI, "Individuals of the same kind of plant or animal are recognizable as similar but can also vary in many ways." To explain this core idea, students can observe an example from the natural world. This example is known as a phenomenon. For instance, students can observe the tiger moths in the figure from the

Science and Engineering Practices

Behaviors that scientists and engineers regularly engage in

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Disciplinary Core Ideas

Key discipline-specific facts and concepts

Life

- 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

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

Physical

- 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 Design

- ETS1: Engineering Design

Crosscutting Concepts

Concepts that bridge traditional disciplinary boundaries as common themes

- Patterns
- Cause and effect
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter
- Structure and function
- Stability and change

SEPs, DCIs, and CCCs in the Next Generation Science Standards

Smithsonian's National Museum of Natural History (shown right). This observation mimics the real-world work of biologists who examine species of moths and classify them. Ask students, "What do you notice about the moths?" Students are likely to respond that all the moths are orange, black, and white but have different patterns of colors on their wings. They may wonder if the moths are the same type or different types. Ask students what they think and why. Here they use the CCC of patterns as evidence to support their explanation as well as the SEP of constructing an explanation. In the end, tell students that the moths shown are all tiger moths. Students use their observations as evidence to explain the DCI that animals of the same kind are both similar to and different from each other.

Credit: Paul Goldstein/National Museum of Natural History

How Can We Formatively Assess Students Three-Dimensionally?

Formative assessments are tools to provide actionable feedback to students and inform future lesson planning. The learning moment described on page 3 is an example of a three-dimensional task that can be used to formatively assess students. Assessment tables that indicate successful use of the practices and understanding of the core ideas and crosscutting concepts enable teachers to determine where students need more experience to be proficient. The table shown below gives specific indicators of success and indicators of difficulty for the DCI, SEP, and CCC in the task of observing tiger moths.

How Can We Summatively Assess Students Three-Dimensionally?

Just like formative assessments, summative assessments should require students to use the practices and engage with crosscutting concepts to figure out the core ideas. Students should not just repeat core ideas as they learned them in their formative assessments. Instead, students should transfer their learning to a new scenario. This can be done with a new phenomenon to explain, a new phenomenon to make a prediction about, or a new problem to solve.

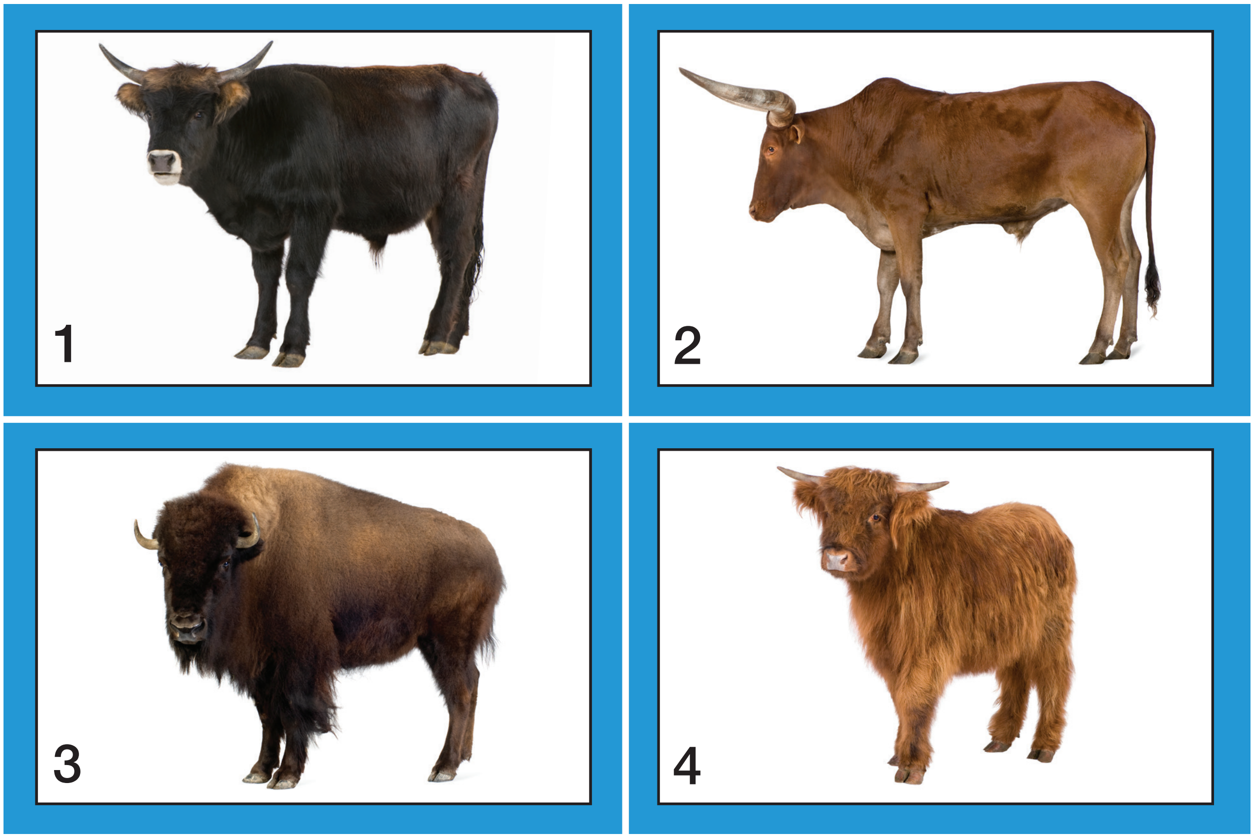
To summatively assess the same DCI, SEP, and CCC in the moth example, students can be given

	Assessed Task: Observing Tiger Moths		
	Concepts and Practices	Indicators of Success	Indicators of Difficulty
Disciplinary Core Ideas	Individuals of the same kind of plant or animal are recognizable as similar but can also vary in many ways.	• Students explain that tiger moths have similarities and differences.	• Students say that all tiger moths look alike.
Science and Engineering Practices	Constructing explanations	• Students use observations of tiger moths as evidence to construct an explanation that animals of the same kind have similarities and differences.	• Students do not explain that animals of the same kind are similar and different. • Students do not use evidence in their explanation.
Crosscutting Concepts		• Students observe patterns in the tiger moths' coloration and use it as evidence.	• Students do not identify similarities between the tiger moths. • Students do not identify differences between the tiger moths. • Students do not use observed patterns as evidence.

Formative Assessment Table

a new set of animals or plants to consider. Show students the animals pictured below. Ask them to circle the animals that are of the same type. Then have students explain why they chose the circled animals and not the other one(s). Students use the CCC of patterns when they observe similarities and differences between the animals. They employ the SEP of constructing an explanation when they use observations as evidence to support their explanation of which animals they think are the same type. It is less important that students correctly identify animals 1, 2, and 4 as the same type of animal and more important that they support their choice with evidence. A student might say, “I think animal 3 is different because it has a different body shape compared to animals 1, 2, and 4. Animal 4 has longer fur, but I think it is still the same type of animal as 1 and 2 because animals of the same type have differences too.”

By using this different set of animals, students are summatively assessed on the same combination



Credit: GlobalP/iStock/Getty Images Plus

> “It is less important that students correctly identify animals 1, 2, and 4 as the same type of animal and more important that they support their choice with evidence.”

of the DCI, SEP, and CCC as the formative assessment but with a new phenomenon. Another way to ascertain students' proficiency is to assess students with a different combination of DCIs, SEPs, and CCCs. The intention of the new science standards is for students to gain enough experience with each dimension so they can transfer their skills and knowledge to a different problem or phenomenon. For example, from their experience identifying patterns of common features between animals, they gain skills that help them identify other patterns, such as patterns of motion in the sky.

The NGSS provide specific combinations of DCIs, SEPs, and CCCs as representations of what students should know and be able to do after instruction. These performance expectations are not the only combination of DCIs, SEPs, and CCCs students should use throughout the year. After many experiences using different combinations of the DCIs, SEPs, and CCCs in a particular grade level, students will gain the skills and knowledge they need to meet the required PEs.

References

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How Smithsonian Science for the Classroom Curriculum Supports Three-Dimensional Learning and Assessment

Previous science standards advocated for students to participate in the process of doing science, but the new science standards require it. The practices and crosscutting concepts are explicit, and students are required to use them both in formative and summative assessment tasks. The Smithsonian Science Education Center has developed a new curriculum series, Smithsonian Science for the Classroom. It was built by Smithsonian science curriculum developers from the ground up to be three-dimensional. Each module is aligned to a bundle of PEs and includes preassessment, formative assessment, and summative assessment tasks. Point-of-use callouts and assessment tables throughout support teachers' growing understanding of three-dimensional learning and assessment.

Providing students with a coherent progression of three-dimensional learning and assessment tasks is not easy. But using thoughtfully crafted curriculum materials, such as Smithsonian Science for the Classroom, makes it possible for teachers and students to realize the power of the new standards.

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