Smithsonian
Science Education Center

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Are They Learning? Prove It.

3-D Science Assessment in K–5 Classrooms

Assessment:
the means used to measure the achievements of students with regard to important competencies

—National Research Council of the National Academies
A Framework for K–12 Science Education (NRC 2012, 260)

When teachers are asked for their thoughts on assessment, opinions range from it being a valuable tool to a necessary evil. Regardless of how it's perceived, assessment is an integral part of every classroom as a way to document student progress. It's a tool for teachers and students to get feedback about what students are able to do and when they need more opportunities to learn.

The Next Generation Science Standards* (NGSS) and similar standards based on the *Framework* focus on engaging students in sensemaking through authentic research as they figure out phenomena and solve problems. Students develop and use elements of science and engineering practices (SEPs), crosscutting concepts (CCCs), and disciplinary core ideas (DCIs) through an integrated, three-dimensional approach. In three-dimensional science

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— Dr. Carol O’Donnell

education, a coherent assessment system strives to demonstrate whether students are developing the necessary elements as well as the ability to apply these elements together in this sensemaking work.

“Students as young as kindergartners have surprisingly sophisticated ways of observing the world around them,” Dr. Carol O’Donnell, director of the Smithsonian Science Education Center (SSEC), says. “We want to guide them to build on and refine their initial observations of phenomena to enable them to think critically as they progressively engage in sensemaking to answer questions, solve problems, and apply their realizations in other real-world contexts. Assessment plays a vital role in providing educators with a means to gather the actionable data that identifies student growth over time.”

Student assessment in three-dimensional science education veers away from familiar, traditional methods of evaluating student learning.

- Traditional assessments are knowledge based. Questions may have one correct answer, which is often demonstrated through multiple choice, true/false, or fill-in-the-blank assignments.
- Three-dimensional assessments are performance based and look at student work in multiple dimensions. Students develop content knowledge as they work through phenomena- or problem-based investigations and other research. They model, explain, and argue about cause and effect, systems, and solutions. Understanding is demonstrated in a variety of ways as students apply their knowledge and skills to a scenario. Teachers must look for “evidence that students can apply their knowledge appropriately and are building on their existing knowledge and skills in ways that lead to deeper understanding of the scientific and engineering practices, crosscutting concepts, and disciplinary core ideas.” (NRC 2012, 263)

While traditional assessments can measure some kinds of conceptual knowledge and provide a snapshot of scientific practices, they don’t adequately measure scientific explanations, communication of scientific understanding, the ability to design and execute steps in carrying out an investigation, and engagement in scientific argumentation (NRC 2012, 262).

“The whole concept of three-dimensional assessment can seem different and intimidating,” Melissa Rogers, SSEC senior science curriculum developer, acknowledges. “But in many cases, the work the students are doing at the moment naturally hits on the multiple dimensions.” Rogers likens the dimensionality to an origami that folds in and on itself, overlapping. “It’s not that, as a teacher, I would have to be looking at all these different things at the same time,” she explains. “But by looking at what the students are doing, the rest falls out from there.”

“One great thing about three-dimensional assessment is that teachers are able to pinpoint areas where students absolutely get it or need additional support, allowing them to modify their instruction and provide useful feedback to students and caregivers,” Dr. Sarah Glassman, SSEC manager of K–8 curriculum, says. “This feedback may not be in the form of a letter grade on a multiple-choice test, however, and that may be frustrating for family members and administrators who are used to traditional assessment reporting."

Three-Dimensional Assessment in the Classroom

"Many hands-on tasks that students complete in the classroom—such as carrying out an investigation or developing and using a model—provide an opportunity for assessing students," Glassman explains. A strong curriculum can support teachers by defining assessment moments, keeping in mind that that there are always opportunities for students to self-reflect and for teachers to collect data that allows them to pivot to a remediation or an enrichment strategy. She refers to the grades K–5 Smithsonian Science for the Classroom 2nd Edition as an example, noting that there are different types of assessments built into the modules: pre-assessment, formative assessment, checkpoint assessment, and summative assessment.

PRE-ASSESSMENT: What do they already know?

Students' initial ideas about a phenomenon or problem are an opportunity for pre-assessment. "It's an opportunity to figure out what students already know about the core science idea you're trying to lead them to," Glassman says.

For example, students can watch a video of the phenomenon of a cat pouncing on what appears to be grass and catching a mouse. Their initial ideas about how the cat was able to catch the mouse are an opportunity to understand what students already know about animal senses.

"This is a very accessible phenomenon. Most students either have a cat or know someone who has a cat," Glassman says. "When you show a video of the cat pouncing, the students respond very positively."

Familiar phenomena allow students to incorporate their previous experiences and observations outside of the class in their initial explanations or solutions. Students should have the opportunity to ask questions and rely on their prior knowledge to drive their understanding

A cat pouncing on what appears to be grass and retrieving a mouse engages students and motivates them to figure out how that could have happened.

and learning. A strong curriculum should provide guidance for reflecting on the questions and initial ideas that students share. The introduction of the phenomenon is also an optimal time to strengthen home-school connections with a family letter that invites information about students' experiences with phenomena and problems in the unit and provides questions that caregivers can use at home to connect with in-class learning.

FORMATIVE ASSESSMENT: What did they learn today?

After the pre-assessment, subsequent lessons should include tasks that provide opportunities for teachers and students to understand students' progress meeting learning objectives that incorporate multiple dimensions. Ideally, these opportunities continue to be tied to explaining the same engaging phenomenon that students shared their initial ideas about. Students who are trying to understand how the cat hunted the mouse could collect evidence to better understand this phenomenon in multiple ways that provide formative assessment opportunities. For example:

- Students could use a model to investigate the role of light in allowing the cat to see the mouse and grass. This is an opportunity to assess students on the science and engineering practice of developing and using models.
- Students could do hands-on investigations to better understand how the cat might have

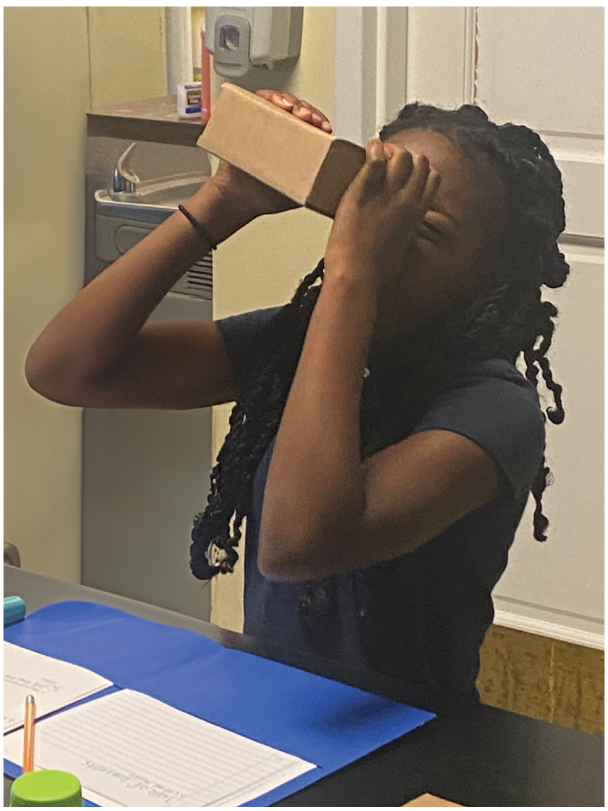
used its ears or whiskers to sense the mouse. This is an opportunity to assess students on their building understanding of animal sense structures and the science and engineering practice of carrying out an investigation.

Rogers notes that the Smithsonian Science for the Classroom 2nd Edition includes a comprehensive assessment map for each module. This feature lays out for teachers the suggested assessment moments, specifying the type of assessment, the three dimensions that are assessed, and the modes of assessment.

"In many cases, the work students are doing in an assessment moment naturally provides an opportunity to assess a crosscutting concept," Rogers explains. "The whole nature of crosscutting concepts is that they show up in lots of places. So often there's overlap in what might be a disciplinary core idea and what might be a crosscutting concept." For example, as students are doing hands-on investigations to better understand hearing and touch through whiskers, they're learning how the structure of these sense organs are connected to how they function to help the cat survive. Structure and function is one of the seven crosscutting concepts described in the NGSS.

CHECKPOINT ASSESSMENT: What should they know before moving on?

At specific points within a unit, students should be able to explain certain science concepts before moving on. Glassman explains that in the Smithsonian Science for the Classroom 2nd Edition, for example, a checkpoint assessment serves as a type of formative assessment that requires students to perform a task to make sense of a phenomenon or solve a problem by using all three dimensions. A task that is assessed as a checkpoint integrates concepts and practices that students have been developing over a few lessons. For example,



A student uses a model to investigate the role of light in allowing the cat to see the mouse.

Students use masks with pipe cleaners attached to understand how the structure of whiskers functions to provide sensory information to cats.

after completing multiple investigations focused on the phenomenon of a cat hunting a mouse, students can use evidence to support an argument explaining how the cats' sense structures functioned to help it.

A curriculum can support teachers in assessing students by providing a table of indicators—guidance in identifying the extent to which students are meeting the lesson objectives and areas where they need additional support. They can use these indicators then to inform future lesson planning and provide specific, actionable feedback for students. Table 1 is an example checkpoint assessment table to assess students' arguments about how the cat used its sense structures to hunt the mouse.

SUMMATIVE ASSESSMENT: What did they learn over the course of the module?

Summative assessment is not the time to switch gears to traditional closed-item assessments, such as fill-in-the-blank or multiple-choice items. Instead, summative assessment should continue to assess students' abilities to use all three dimensions to explain a phenomenon or solve a problem. Summative assessment is an opportunity to see how far students have come by transferring their new knowledge and skills to a new scenario.

For example, students who learned about animal sense structures through the cat example could later encounter the phenomenon of fireflies that flash in different patterns. They could once again use the science practice of developing and using models by modeling how fireflies communicate to find a mate. They could construct a two-dimensional model to show how structures on the firefly body allow the firefly to function in a way that a potential mate can find it. Besides providing an opportunity to assess the practice of modeling, this task enables the teacher to assess the crosscutting concept of structure and function and the disciplinary core idea of animal structures that serve functions in survival or reproduction.

Table 1.

Checkpoint Assessment: Table of Indicators, Grade 4		
Objective: Use evidence to support an argument that explains how internal and external substructures of the cat's eyes, ears, whiskers, and nose functioned to support the cat as it hunted the mouse.		
Concepts and Practices	**Indicators of Success**	**Indicators of Difficulty**
Disciplinary core idea: LS1.A Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.	• Students' arguments describe how the cat used at least one internal and one external structure to hunt the mouse. • Students say the cat needs to catch the mouse so it has enough to eat.	• Students' arguments do not explain how both an internal and external structure helped the cat hunt the mouse. • Students are not sure why it is important for the cat to catch the mouse.
Science and engineering practice: engaging in argument from evidence Construct and/or support an argument with evidence, data, and/or a model.	• Students use evidence to support their argument explaining how different structures functioned so the cat could catch the mouse in the grass.	• Students do not provide evidence to support their argument.
Crosscutting concept: structure and function Substructures have shapes and parts that serve functions.	• Students' arguments include details about specific substructures in cats' eyes, ears, whiskers, and noses that function to help the cat hunt the mouse in the grass.	• Students' arguments are missing details about specific substructures in cats' eyes, ears, whiskers, and/or noses that function to help the cat hunt the mouse in the grass.

Example is from Smithsonian Science for the Classroom 2nd Edition.

Final Tips for Successful 3-D Assessment Implementation

Three-dimensional assessment in the science classroom will likely look different than the traditional assessments students, teachers, administrators, and caregivers are used to. Making that classroom change, however, will ultimately be meaningful for everyone.

Following are some tips for incorporating three-dimensional assessment in the classroom:

- Have a solid understanding of three-dimensional science education and its implementation.
- Be prepared to embrace performance-based tasks, open-ended questions, and real-world phenomena and problems that require students to apply what they've learned and demonstrate their learning progression in a variety of ways. Realize there may not be one correct answer.
- Be ready to pivot with enrichment and remediation strategies.
- Rely on a strong curriculum that incorporates a comprehensive assessment system where assessments have distinct and important purposes that are closely aligned to the target learning goals along with teacher tools for assessing students' progress and performance.

By incorporating performance-based assessment for three-dimensional science learning, teachers can deliver the actionable data that more thoroughly describes students' growth in their progression to become scientifically aware citizens in and out of the classroom.

References

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How the Smithsonian Science Education Center Supports Three-Dimensional Science Learning and Assessment

The Smithsonian Science Education Center (SSEC) is transforming K–12 education through science in collaboration with communities across the globe. One way to achieve this ambitious objective is by designing science curricula that supports three-dimensional, phenomena-based science education. The new grades K–5 Smithsonian Science for the Classroom 2nd Edition thoughtfully incorporates a coherent progression of three-dimensional assessment tasks along with assessment maps, tables of indicators, and scoring rubrics that guide teachers in identifying student proficiency in performance expectations.

Learn more about Smithsonian Science for the Classroom 2nd Edition: www.carolina.com/ssftc2
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