Addressing Common Questions About 21st-Century Science Teaching

By Cindy Hoisington

As of this writing, 18 states and the District of Columbia have adopted the *Next Generation Science Standards* (*NGSS*) for grades K–12, and more than 20 additional states have expressed interest in doing so. As a result, teachers in grades K–3 are increasingly being expected to implement the *NGSS*, and even preschool educators are being asked to pay attention to these standards. The NSTA Position Statement on Early Childhood Science Education (NSTA 2014) makes it clear that children as young as 3–5 are capable of engaging with the core ideas, crosscutting concepts, and practices of science at developmentally appropriate levels. In some states, such as Massachusetts, preschool science standards are being revised to align with the *NGSS* (MDESE 2016). It seems certain that the three-dimensional approach of the *NGSS* will continue to represent science education for the remainder of the 21st century.

However, when early childhood teachers (grades PreK–3) look closely at national or state standards, they quickly notice that the vocabulary used in science education is changing. For example, the term *practices* is gradually replacing more familiar terms such as *inquiry* and *science process skills* and the term *scientific method* has essentially disappeared. As an early childhood science educator who works with teachers at these grade levels, I frequently find myself in discussions with them about the following questions.

WHAT ARE PRACTICES? AND DO CHILDREN NEED TO PRACTICE THEM?

Practices are the activities that a group of people in a profession engage in as they do their work. *A Framework for K–12 Science Education* (NRC 2012) laid the groundwork for the term *science practices* by suggesting that children need to learn science in the way that it is "practiced," or performed, by real scientists. Think about how we use the term *teaching practices* to refer to the range of activities teachers engage in as they teach, such as planning lessons and formatively assessing student progress. The science practices are a set of connected and overlapping activities used by scientists (and children learning science) that include Asking Questions and Identifying 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; and Obtaining, Evaluating, and Communicating Information (NGSS Lead States 2013). Each of the science practices incorporates a whole host of skills—Planning and Carrying Out Investigations, for example, includes making detailed observations and collecting data using standard and non-standard measurement.

Although the language of the practices is sophisticated, 3- to 8-year-old students can engage with each of them at an appropriate level. For example, they *analyze and interpret data* when they compare the sizes and shapes of their shadows at different times of day and *argue from evidence* when they discuss their ideas about why morning and afternoon shadows are different—regardless of whether or not their ideas are scientifically correct. Children's participation in the practices becomes more complex over time and across grades. Table 1 lists examples of how 3-to-8-year-olds might engage in each of the practices.

The authors of the *Framework* viewed this shift from inquiry to practices as an opportunity to emphasize the close relationships between science and the other STEM disciplines (technology, engineering, and mathematics). They incorporated engineering in the practices, devoted a practice to mathematics, and included the use of technologies for exploration, data collection, and communication.

Children who participate in these eight practices by pursuing an answer to a specific question (e.g., *How does light interact with different objects and materials?*) or a solution to a problem (e.g., *How can I fix a ramp so a ball will roll all the way to a bucket?*) are actually doing the work of scientists. In the process, students are introduced to the idea that science is a vibrant, collaborative, and communicative endeavor, not an isolated body of knowledge to be ingested and memorized. They are also introduced to engineering and the idea that designing structures, tools, and systems to meet human needs and wants depends on a knowledge of science and mathematics and requires creativity, innovation, and perseverance. Opportunities to engage in these experiences early on also promote children's confidence and motivation related to doing and learning science.

And yes, it is great for children to "practice" the science practices as long as they are using them in the context of meaningful and interesting physical, life, and Earth/space

TABLE 1

How young children participate in the practices (Worth and Winokur 2016).

K–12 SCIENCE AND ENGINEERING PRACTICES *(NGSS 2013)*	EXAMPLES OF WHAT YOUNG CHILDREN MIGHT DO
Ask questions (science) and identify problems (engineering)	Notice, wonder, and raise investigable questions with support (science) and notice problems or needs that arise during their play or exploration (engineering).
Develop and use models	Make representations of their science observations and ideas in 2D (drawing and painting) and 3D (structures, collage); demonstrate what they did or observed during an exploration.
Plan and carry out investigations	Generate ideas for new ways to explore a phenomenon or topic; act on objects and materials in different ways or observe living things over time; make and record observations; incorporate tool use for exploration and data collection including digital tools.
Analyze and interpret data	Make comparisons; notice and describe similarities and differences; begin to look for and identify relationships and patterns.
Use mathematics and computational thinking	Use mathematics in data collection; use mathematical vocabulary to describe phenomena, make comparisons, and express relationships and patterns.
Construct explanations (science) and design solutions (engineering)	Make claims and generate ideas about how and why things happen the way they do based on evidence (science) and design and redesign a solution that solves a problem or meets a need (engineering).
Engage in argument from evidence	Compare and contrast observations, experiences, and ideas with others; share claims and evidence.
Obtain, evaluate, and communicate information	Document and share data, observations, experiences, and ideas; use books and digital media as resources; use new vocabulary to describe phenomena and findings.

science investigations (e.g., creating structures; playing with light and sound; exploring plants and animals; and experiencing different types of weather). After all, practice is what enables us to get better at something, and that includes doing science!

WHAT EVER HAPPENED TO SCIENTIFIC INQUIRY?

Scientific inquiry is the process of seeking knowledge about the natural world by asking for information, using resources, or doing firsthand investigations. It incorporates many skills such as asking questions, making predictions, exploring, observing, recording, and interpreting data.

However, if you ask a group of 10 teachers what *inquiry* means, you are likely to get 10 different answers. Even researchers have a tough time assessing inquiry because it can look so different from one classroom to the next (Harlen 2013). The practices make the science inquiry process more concrete and pinpoint the specific activities preK–12 children should be participating in when they do science. Focusing on the eight practices also helps us avoid the temptation of viewing the scientific method as the only way to do science (more about that later).

Inquiry also describes an approach to teaching and learning science—and other content—that is learner-centered rather than teacher-directed. This approach is beautifully compatible with the practices because it seats the child in the role of active investigator and thinker rather than passive recipient of science information. In an inquiry-based unit the teacher might plan experiences related to an essential question such as, *How do the building materials and the design of a structure affect its strength and stability?* In one lesson the teacher might introduce several different types of blocks and ask students, *How might we use these blocks to make a tall stable tower?* During the exploration, the teacher can scaffold individual skills in context. For example, the teacher might introduce standardized measurement as children explore questions like *How will we measure the heights of our towers?* and *How will we decide if our towers are stable or not?*

Keeping the inquiry process in mind also reminds us that individual practices are not meant to be used or applied in isolation any more than inquiry skills are. Children can only construct explanations if they have data from multiple investigations to analyze and interpret. They can only argue from evidence if they have observations to share and compare. The practices "hang together" and children need opportunities to use all of them over the course of a unit of study (although they probably won't use all of them in one investigation).

HOW ARE THE PRACTICES DIFFERENT FROM SKILLS?

Supporting children's skills development (including physical, social/emotional, cognitive, and language/literacy skills) has historically been a focus of early childhood education. Thus, the term *skills* is deeply embedded in our teacher vocabulary. There is also a tendency to distinguish between skills (what children are able to do) and content (what children know or understand) and to evaluate them separately. The science practices require teachers to acknowledge higher-level cognitive skills and children's thinking, reasoning, and problem-solving capacities, and to focus more intently on promoting them *in the service of* building children's science understanding. These higher-level thinking skills are integral to a 21st-century education but have previously been missing from many early childhood curricula and standards that reference inquiry (NEA 2012). They are also increasingly important for promoting the scientific literacy of all our students, not only those who will choose science as a career.

The practices focus our attention on promoting children's scientific thinking rather than on skills or facts that can be easily taught in a single activity (e.g., how to hold a hand lens properly or count the numbers of legs on an insect). However, each practice incorporates opportunities to support discrete skills across the domains. Children may, for example, use large motor skills as they investigate their shadows; social/emotional skills as they listen to their peers' ideas about how balls roll; and language and literacy skills as they talk, draw, and write about their plant observations.

The practices also emphasize that using science skills requires knowledge as well as know-how. For example, what do you need to know in order to formulate a good question for investigation? You need to know that a good science question is one that can realistically be investigated considering the space, time, and materials you have available and that will yield data to think and talk about—and not just a *yes* or *no* answer. Questions such as *What animals live in the arctic?* and *Why do magnets stick to metal?* are valid scientific questions but are not good investigable questions for young children. Investigable versions of these questions might be: *How do the animals that live around our school move about, find food, and make homes?* and *What are the characteristics of magnetic objects compared to non-magnetic objects?*

HOW ARE PRACTICES RELATED TO SCIENTIFIC HABITS OF MIND?

Habits of mind, sometimes called scientific attitudes or dispositions, are the positive approaches to learning that we want children to develop, maintain, or strengthen as they do science. They include curiosity, persistence, willingness to take risks with ideas, and "flexible thinking" (the ability to think about things in new ways). Children develop these habits of mind when teachers encourage their initiative, exploration, and problem-solving and value their ideas even when they are not scientifically correct. These ideas—plants are not alive, balls slow down because they run out of energy, mirrors show more of your body the further away you move—can all act as launching pads for further investigation. Positive attitudes toward doing and learning science can influence children's attitudes across subject matter areas and in everyday situations.

WHERE DID THE SCIENTIFIC METHOD GO?

Many early educators still hang on to teaching the scientific method—a step-by-step, linear, and rigid version of inquiry—even to their youngest students. The scientific method goes something like this: Make a hypothesis, collect the materials, do an experiment to test the hypothesis, analyze the results of the experiment, draw a conclusion, and communicate the results. Research scientists use the scientific method regularly, particularly when they want to do an experiment that will rigorously test a hypothesis in which they have great faith (Bradford 2017). Yet most science, and certainly most science done in classrooms, is not a predictable and linear process.

Children's sciencing generally begins with an open-ended question—How does a snail use its tentacles? or How does the texture of a ball influence how far it rolls?—rather than a firm hypothesis and it should focus on children's ideas and thinking rather than correct conclusions. For that reason, the *Framework* and the *NGSS* have essentially replaced the scientific method with the practices for use in schools. Of course, it is important for children to be introduced to the concept of *fair tests*—controlling some variables while investigating others—but the ability to conduct fair tests incorporates multiple skills and knowledge that develops over time and across many experiences.

It's hard for many educators to let go of the scientific method because many of us learned it in school as the only correct way to do science. If you do reference resources that suggest teaching young children the scientific method, keep this in mind—it takes time for all of us to get on board with new ways of thinking about how science is done and practiced and how it should be taught.

CONCLUSION

Changing our own science-teaching practices takes time and lots of practice! It requires us to evaluate our current approaches to teaching science and find the supports and resources we need to educate ourselves about current approaches—as required by the *Framework* and addressed in the *NGSS*. It means learning about how children's engagement in the practices of science develops across grade levels and how we can integrate our science teaching with our teaching in other domains. Know that the effort you expend will be well worth it as you and your students move into this exciting, 21st-century world of science education! ●

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