

Planning NGSS-Based Instruction

Where do you start?

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In 1986, as a young geologist in love with science and teaching, I (Mary) began planning how to start my first year of eighth-grade Earth science. I decided to begin with a mineral identification activity. I knew that many of the clues to understanding Earth’s past are found in rocks, and rocks are made of minerals. A great place to start—or so I thought.

I believed in rigor, so I designed a fairly detailed lab. Students looked at lots of mineral samples and performed tests to determine each mineral’s properties. They used mineral identification tables to identify each of their minerals.

Students willingly engaged with the activity, and I took that as the sign of a successful lab. But they didn’t seem excited. And they weren’t sufficiently curious or interested to explore beyond the scope of the task I gave them.

When the lab was over, and I considered that lack of curiosity, my enthusiasm for the lab waned. Why hadn’t students asked questions beyond “Did I get the right answer?”

Maybe it was because:

- ◆ There was no driving student question behind the activity. Students did their best to learn how to recognize luster, cleavage, and heft, but they had no real reason to do so beyond my asking it of them.
- ◆ The activity focused more on what we know than on how we know it. Students tested hardness and heft, but there was no sense of exploring how we know the deeper mysteries of the Earth.
- ◆ The activity involved no fundamental insight into the character of the Earth—just information about minerals. For example, the activity provided no insight into how minerals tell us about the evolution of the Earth or how mineral-forming processes create an uneven distribution of natural resources.

- ◆ In short, the activity did not engage students in an authentic science investigation.

So what comprises an authentic classroom science experience? A key idea of the *Next Generation Science Standards* (NGSS Lead States 2013) is that authentic classroom science should look a lot like authentic scientific research. If we want to understand scientific practices in the classroom, we should look to the practice of science in a scientist's lab.

Last summer I interviewed Dr. Keith Koper, a Utah geophysicist who does forensic seismology. Forensic seismologists try to recognize, understand, and locate human-made seismic events, such as explosions and nuclear weapons tests. In 2000, Koper was studying the differences in the seismic signatures of earthquakes and explosions. He had heard that a Russian submarine, the *Kursk*, was severely damaged during naval exercises in the Barents Sea and that seismic networks in Northern Europe detected two events occurring at about the same time and location as the *Kursk* disaster. Koper and his colleagues wondered what they could learn about the incident using seismic data. A compelling driving question!

They gathered data and compared it to what they were learning about the differences in seismic waves generated by different types of seismic events. They focused not on what was already known but on how scientific exploration might reveal something new.

They figured out, from the squiggles of the seismograms, that two underwater explosions occurred, the second 250 times larger than the first (Koper et al. 2001). Their research indicated that explosions, not an underwater collision with an American sub, caused the disaster (investigators ruled that the explosions, which happened on board the submarine, were accidental). Koper and his colleagues not only gained new understanding about a fundamental aspect of the natural world—how different seismic events produce different kinds of seismic waves—but they helped answer a politically sensitive question that had made headlines all over the world.

As Koper described his work, I was struck by his curiosity, optimism about making sense of confusing observations, and frank admissions of what he didn't know. His work began with a compelling driving question, proceeded through a scientific exploration of something unknown, and yielded a fundamental insight into our universe.

Can our science students work like Koper's team, making sense of their own observations and ideas? Can curiosity and persistence abound in our classrooms? I think yes. Students can

- ◆ pursue authentic questions, some of which originate from them;
- ◆ make sense of their observations through scientific practices;

- ◆ and situate their hard-won understandings within the larger context of core explanatory ideas of science and engineering.

Authentic questions

Since that first lesson on minerals, I'm learning to let students pursue their own questions more often. The result is almost always greater engagement.

Two years ago, as we looked at patterns of rock ages on a national geologic map, a student asked: "Can we use the scale of this map to measure how wide the United States is?" I said yes, and the students dove in with the special urgency born of ownership.

Scale, spatial-thinking, and problem-solving started right away. I overheard a student say: "I got 13 miles wide for the U.S., but that can't be right. I drive 75 miles to my grandmother's house." After the first day, a student asked: "Can it just be *our* class that does this?" I realized that if the other classes did it, too, the activity would become just another teacher-initiated lesson.

Give yourself—and your students—permission to pursue ideas that students find interesting. Let driving questions originate from the students even if they don't exactly track your goals for the lesson. Then, seize the opportunity to join your students in making sense of their measurements, observations, and tentative explanations.

In 2011, my students and I watched a video of a tsunami rolling over the east coast of Japan. As the water pushed houses, ships, and cars inland like bits of driftwood, questions tumbled from my students like flotsam. One student asked: "Are we having more and bigger earthquakes than we used to?"

What an interesting question. Maybe your students can answer it. Earthquake data is available online. Join them in the journey.

Engage in scientific practices

Engaging students in the practices of science and engineering takes time. I've heard from teachers at all grade levels: "If I give my students the time to figure things out, I don't have time to cover all the material." The writers of the *Framework* recognized this dilemma. They wrote: "Reduction of the sheer number of details to be mastered is intended to give time for students to engage in scientific investigations and argumentations and to achieve depth of understanding of the core ideas presented" (NRC 2012, p. 11).

So, let's say you give yourself permission *not* to cover all the material. How can you change from instruction that relies on sure-fire activities that reinforce concepts to activities that authentically engage students in scientific practices?

I suggest starting small and *NGSS*-ifying a lab investigation that you know well.

For years, I've done a lab on the difference in solar heating on land and water. Over the first few years, I honed the lab procedures, figuring out ways to prevent students from introducing variables that yielded “wrong” answers. This ensured that my students got good data that they could use to explain differences in climate between—for example—San Francisco and St. Louis.

In perfecting the lab, I tried a variety of approaches, interpreted results that didn't at first make sense, and tested the reproducibility of results. I was indeed engaged in scientific practices.

But my students were not. They didn't have the chance to figure out whether they had correctly identified and controlled the variables, to compare their results with classmates', or to interpret what unexpected data meant.

More recently, to NGSS-ify this lab, I posed the question: “Our textbook says that land heats up five times faster than water. Can we test this?”

I set out materials and let students choose their own experimental setup. I gave them time for preliminary measurements and to question each other. Students shared their preliminary data and discussed what the data meant and whether they were valid. Students performed new experiments, followed by more discussions about why our dark soil heated up only two times faster than water.

My role in the NGSS-ified lab was sometimes that of a manager (keeping everyone safe, facilitating discussions), sometimes a coach (providing encouragement and direction), and sometimes that of mentoring scientist (asking questions such as: Have you thought about how this other important idea may apply?). I was truly a participant with them in that I didn't always have a ready answer and had to figure out puzzling results in real time.

We practiced science together.

Big explanatory ideas

Koper not only asked an interesting question and answered it through scientific practices, but he fit his new discoveries into the context of a broader understanding of seismological and geological processes. The *Framework* emphasizes putting classroom learning into a larger context, mimicking the mental activity of the expert:

“The core ideas also can provide an organizational structure for the acquisition of new knowledge. This approach [organizing content around core ideas] will also help students build the capacity to develop a more flexible and coherent ... understanding of science. Research on learning shows that supporting development of this kind of understanding is challenging but is aided by explicit instructional support that stresses connections across different activities and learning experiences” (NRC 2012, p. 25)

As you begin to develop your classroom units, familiarize yourself with the core ideas described in the *Framework*.

The core ideas included there either have broad importance across multiple disciplines or they are key organizing principles of a single discipline (p. 31). Pay attention also to the questions that the components of each core idea address; these questions give a good sense of what the core idea explains about the world.

With that foundation, formulate a few core idea statements, or essential questions, around which you organize your curriculum. Use words and phrases that your students will understand. Use statements or questions to give an overall structure to your instruction and as reminders of the aspects of the world students are trying to explain. Post these statements or questions in your classroom and refer to them often.

As part of planning for instruction at Horizon Middle School, my colleagues and I identified six takeaway statements for our course. These big ideas help keep the big picture in mind as we and our students pursue the many activities and lessons of a unit. For example, I may do a lesson on recognizing some common rocks, but the reason we even care about rocks is ultimately to understand that the “Earth and life on Earth have a history of change; and the clues to understanding those changes are in the rocks.” Note that this big idea statement rests on the disciplinary core idea ESS1.C The History of Planet Earth, which explains how people reconstruct and date events in Earth's planetary history (NRC 2012, p. 177).

Conclusion

In planning to engage students in scientific practices, I have to remind myself weekly of the following ideas: Real learning takes time. Engaging students with the practices takes lots of time. It's okay to not cover everything. It's okay to try something new and fail at it. The six most powerful instructional words in the NGSS-friendly classroom are: “I don't know; let's find out.” ■

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References

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