The Importance of Phenomena in Science and Engineering

I grew up in Biddeford, a small town in Maine next to the Saco River, where a waterfall used to power large textile mills. On the other side of the river was our twin city, Saco. When I was in middle school I walked to school every day. The first mile was nearly flat. Then I came to an abrupt downhill slope for the last quarter mile to my school, which was near the river. If I wanted to visit my cousin in Saco and couldn’t get a ride, I’d have to cross a bridge and walk up a steep hill, where again the terrain became nearly flat for some distance.

I remember reading in our middle school science book about river valleys, including “V-Shaped” young valleys that were etched deeply into the ground by rapidly flowing water, and “U-Shaped” mature valleys that formed as the walls of the valley gradually eroded. But it was not until many years later that it occurred to me that our school was in a river valley. In hindsight, our science teacher might have used our daily journeys to school, from different parts of the city, as an interesting phenomenon to kick off a unit about the role of erosion in sculpting geological formations.

Enabling students to explain phenomena has always been a goal of science education, but in the era of Next Generation Science Standards* (NGSS), engaging students in science and engineering practices and crosscutting concepts in order to learn about phenomena requires a new approach. A brief on the role of phenomena on the NGSS website explains that: "Phenomena are observable occurrences. Students need to use the occurrence to help generate the science questions or design problems that drive learning." The brief describes two kinds of phenomena: anchoring phenomena that provide the overall focus for a unit or lesson, and investigative phenomena that students explore in the course of a coherent series of activities. Phenomena can either refer to occurrences in the natural world of the traditional sciences, or in the designed world of technology and engineering.

Choosing the right phenomenon to anchor a lesson is critical. The phenomenon needs to be both familiar to the students and sufficiently interesting to stimulate their curiosity. It also needs to lead to investigations that target core ideas, crosscutting concepts, and practices that form the objectives of the lesson, while leaving room for genuine student inquiry or creative design processes.

_HMH Into Science™_ begins each lesson with an anchoring phenomenon designed to capture students’ interest. A driving question about the phenomenon elicits their initial ideas, and launches a series of further questions and activities in which students explore related investigative phenomena. At the end of the lesson, and perhaps once or twice during the lesson, students revisit the anchoring phenomenon and offer new explanations in light of what they’ve learned so far. Here are three examples.

**FIRST-GRADE EXAMPLE:**

All About Light

To adults it is obvious that some things glow by their own light, and other things require a light source in order to be seen. However, that is not obvious to first graders, who need a logical sequence of activities to learn about how light allows us to see the world around us.

This introductory lesson in a unit about light for first graders starts with an image of children in a dark room wearing

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colorful glow jewelry. Whether or not students have experience with glowing necklaces and bracelets, they have certainly seen glowing objects in an otherwise dark room. Light bulbs, burners on the stove, smart phones, and computer screens are all glowing objects, so they do not need light to bounce off them in order to be seen.

Students are first asked: What do you notice about the children and the glow jewelry? And what do you wonder about the children and the glow jewelry? Then they are asked the driving question for this lesson: Why can you see the glowing jewelry well, but not see the children very well?

This introduction, in which students talk about what they see using their own choice of language, opens the door for the teacher to introduce the first investigative phenomenon—glowing objects give off their own light—using examples in the room, or other objects that the students are familiar with.

Next, students are introduced to the idea that in a dark cave, they would need to have light in order to see anything. They can see an image of an illuminated cave in their books. This is the second investigative phenomenon—that light is needed to see things that do not glow.

This second investigative phenomenon is reinforced with a hands-on activity in which students are given shoe boxes with objects taped inside. The students peer through a small hole in one end of the box, and there appears to be nothing inside—only blackness. Then they allow a little bit of light to enter the box, so they can begin to see the objects. With more light they can see the objects better; but even with a little light, they can see the objects faintly. This experience introduces the third investigative phenomenon: If more light shines on an object it is easier to see.

Finally, the students are shown the image at the start of the lesson again and reminded of the driving question: Why can you see the glowing jewelry well, but not see the children very well? This gives the students an opportunity to apply what they just learned in the lesson to the initial challenge, so the teacher can determine if they have understood the lesson, or if they need to reexamine one or more of the phenomena.

Following is a diagram illustrating the phenomena in the unit. The anchoring phenomenon is the contrast between the bright jewelry and appearance of the children, who can barely be seen in the dim light. Students are asked a couple of questions to help them think about what they see in the image, and then they are asked the driving question, which motivates the entire lesson. All three investigative phenomena—objects that glow give off their own light; light is needed to see things that do not glow; and if more light shines on an object it is easier to see—are needed to fully answer the driving question.

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**Anchoring Phenomenon:** Glow jewelry appears bright in a dark room.

**Driving Question:** Why can you see the glowing jewelry well, but not see the children very well?

**Investigative Phenomenon 1:** Objects that glow give off their own light.

**Investigative Phenomenon 2:** Light is needed to see things that do not glow.

**Investigative Phenomenon 1:** Objects that glow give off their own light.
Criteria for Using Phenomena to Drive Instruction

The NGSS Early Implementers Initiative in California is a multi-year effort to implement new science education standards in ten pilot districts, involving hundreds of teachers and tens of thousands of students. Experience from the first four years of the effort led to the following criteria for selecting the most useful phenomena to drive instruction. These criteria offer an excellent summary of the way phenomena are chosen and applied in the examples cited above:

• Can students observe and/or investigate the phenomenon, either through firsthand experiences (e.g., directly in a classroom, lab, or outdoor environment) or through someone else’s experiences (e.g., through video presentations, demonstrations, or analyzing patterns in data)?

• Do students have to understand and use science and engineering practices, disciplinary core ideas, and crosscutting concepts to explain how and why the phenomenon occurs?

• By making sense of the phenomenon, are students building understanding toward grade-level performance expectations?

• Would student explanations of the phenomenon be grade-level appropriate?

• Is the phenomenon relevant to real-world issues or to the students’ local environment?

• Will students find making sense of the phenomenon interesting and important?

• Does the potential student learning related to the phenomenon justify the financial costs and classroom time that will be used?

To the extent possible, teachers are also encouraged to think about ways that the anchoring phenomenon of the unit might relate to local phenomena. Perhaps a suggestion of that sort, given to my own middle school science teacher decades ago, might have helped him realize that our lesson on river valleys could be far more meaningful and memorable if he started out by asking us to think about the phenomenon of walking down a steep hill to our school, near the Saco River, and then led us to explain that phenomenon by thinking about how water shaped the entire Saco River Valley over thousands of years.