Formative Assessment Probes

Promoting learning through assessment

Pendulums and Crooked Swings: Connecting Science and Engineering

By Page Keeley

The *Next Generation Science Standards* provide opportunities for students to experience the link between science and engineering. In the December 2011 issue of *Science and Children*, Rodger Bybee explains: "The relationship between science and engineering practices is one of complementarity. Given the inclusion of engineering in the science standards and an understanding of the difference in aims, the practices complement one another and should be mutually reinforcing in curricula and instruction" (p. 15).

In this month's column, we will explore this complementary nature of science and engineering in the elementary classroom. While engineering practices can be used effectively to help elementary students develop scientific knowledge, scientific knowledge gained through use of the scientific practices can also be used to solve engineering problems. The example used in this column will primarily address one aspect of this duality by focusing on how formative assessment can be used to assess students' readiness to define and carry out an engineering problem using knowledge gained through use of the scientific practices.

The Motion and stability: Forces and interactions performance expectation 3-PS2-2 states: "Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion" (Achieve Inc. 2013, p. 23). The clarification statement that accompanies this performance expectation provides examples of motions that can be used, such as a child swinging on a swing (note: the assessment boundary does not include terms like *period* and *frequency*). Since a swing is a type of pendulum, planning and carrying out a pendulum investigation provides an instructional opportunity for students to combine a disciplinary core idea, a scientific practice, and two crosscutting concepts. Furthermore, students can apply the results of their investigation to design a solution to an engineering problem (see Table 1).

The formative assessment probe "The Swinging Pendulum" (see NSTA Connection) can be used to elicit students' initial ideas and launch into an investigation to discover what affects the number of swings a pendulum makes in a given time (Figure 1; Keeley and Harrington 2010). There are two reasons to start an investigation with this probe: (1) If students correctly predict B: *shorten the string* and can support their prediction with an explanation, then why spend valuable class time carrying out an investigation when students can already explain the cause and effects of changing the length of a string, changing the heaviness of the bob, or changing the release angle? If they already have this knowledge, then students are ready to use this knowledge to solve an engineering problem; (2) Committing to a prediction when students are not sure about the outcome creates a desire to gain new knowledge as students carry out the investigation. Let's see how this probe is formatively used to promote student learning and inform instruction that will help students gain the knowledge they will need to solve an engineering problem.

Pendulums in Action

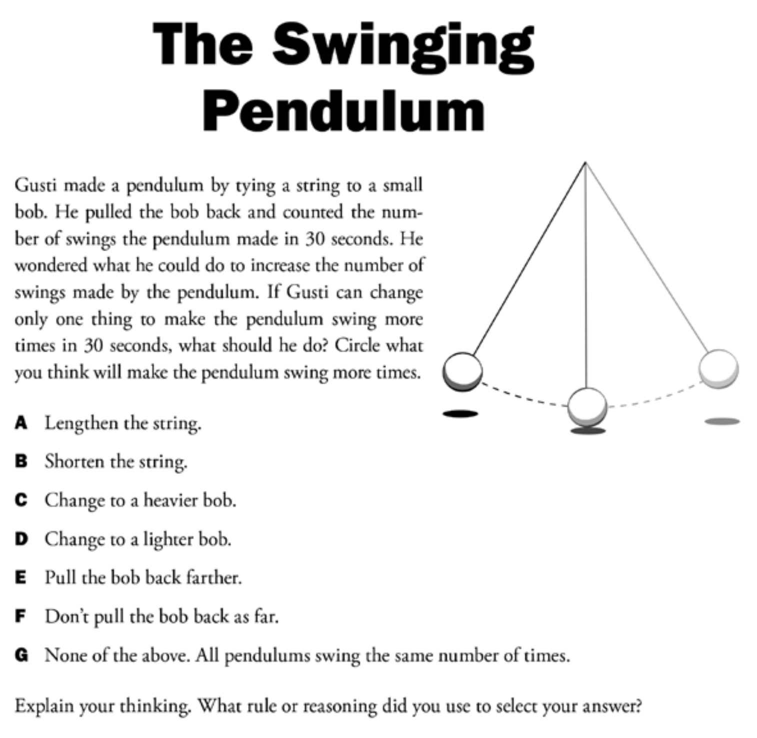
As students plan and carry out a scientific investigation of pendulums using simple materials such as string and washers, observe and listen closely for evidence that students can perform the practice of planning and carrying out an investigation. To what extent can they design a fair test by controlling each variable? How do they collect their data? Do they consider the number of trials? Do they use accurate techniques for measuring time, length of string, number of swings, and angle of release? If you observe that some students are struggling with the practices, provide constructive feedback to students to move their investigation and learning forward.

For example, alert these students to the need to keep all the other variables the same when one is changed. If you observe that several groups are having a similar problem, stop and teach a minilesson or demonstrate a technique to the whole class, such as how to secure the string to a fixed pivot point rather than holding it in your hand, which may affect the swings. During a "scientists' meeting" where the class comes together to share their results and methods of investigating, provide feedback on how students carried out their investigation as they provide the evidence from data that supports their findings. Also, use probing questions to help students recognize the patterns in their data and cause-and-effect relationships.

To see if students can transfer their new learning about the motion of a pendulum, read "The Crooked Swing" story from *Yet More Everyday Science Mysteries* (Konicek-Moran 2011, p. 166). Transfer of learning (applying knowledge to

Figure 1.

The Swinging Pendulum probe.



The Swinging Pendulum

Gusti made a pendulum by tying a string to a small bob. He pulled the bob back and counted the number of swings the pendulum made in 30 seconds. He wondered what he could do to increase the number of swings made by the pendulum. If Gusti can change only one thing to make the pendulum swing more times in 30 seconds, what should he do? Circle what you think will make the pendulum swing more times.

A Lengthen the string.
B Shorten the string.
C Change to a heavier bob.
D Change to a lighter bob.
E Pull the bob back farther.
F Don't pull the bob back as far.
G None of the above. All pendulums swing the same number of times.

Explain your thinking. What rule or reasoning did you use to select your answer?

Table 1.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. **Constructing Explanations and Designing Solutions** Apply scientific ideas to solve design problems.	**PS2.A: Forces and Motion** The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it.	**Patterns** Patterns of change can be used to make predictions. (3-PS2-2) **Cause and Effect** Cause and effect relationships are routinely identified.

Figure 2.

The “crooked” swing.

TAKEN FROM *YET MORE EVERYDAY SCIENCE MYSTERIES* (KONICEK-MORAN 2011)

new situations or contexts) is an important part of formative assessment that takes place after students have had an opportunity to develop scientific ideas. Engineering contexts can be an ideal vehicle to assess whether students can use their scientific knowledge to define an engineering problem.

In the story, children are presented with a problem. A neighbor hung a porch swing from a crooked branch of a large tree in his yard (Figure 2). The neighbor did his best to hang the swing so it was level with the ground. But lo and behold, when he and his wife sat on it, it swung crooked, rather than back and forth like a normal swing. The neighbor was perplexed and asked the children to help him figure out what the problem was and how to fix it. The students are tasked with finding a solution to the story.

This is a wonderful engineering problem for elementary students that uses scientific knowledge they gained from using the scientific practices and applies it to an engineering problem. First, students need to know something about pendulums in order to recognize the problem of the crooked swing. As groups grapple with the problem, listen to see whether students recognize that there are two pendulums—one shorter and one longer—holding up the swing. Based on what they learned about pendulums, do they recognize that one end will swing faster/slower than the other, resulting in a crooked path? Once students recognize that there are two pendulums of different lengths that swing differently, they are ready to engage in using engineering practices to come up with a way to fix the swing. Next, the story launches students into the design process: defining the problem, brainstorming possible solutions, considering constraints, developing and using a model to test their solutions, collect-

Table 2.

The Crooked Swing Problem observation sheet.

Steps in the Engineering Design Process	**Observations and Feedback**
Identifying the problem	
Using scientific knowledge to define the problem	
Generating possible solutions (brainstorming ideas)	
Identifying constraints	
Selecting the best possible solution	
Constructing a prototype (model)	
Testing and evaluating the prototype (model)	
Improve the design	
Communicate the solution	
Other comments or questions:	

ing and analyzing data on how their proposed solution works, refining it, and communicating it to others. Throughout the engineering activity, observe how students systematically use the design process and which parts of the process they may have difficulty with. Use a formative assessment observation sheet such as the one in Table 2 to record observations and provide feedback as you circulate among groups.

A Framework for K–12 Science Education states two implications related to the Swinging Pendulum probe and Crooked Swing story: "The first is that students should learn how scientific knowledge is acquired and how scientific explanations are developed. The second is that students should learn how science is utilized, in particular through the engineering design process, and they should come to appreciate the distinctions and relationships between engineering, technology, and applications of science" (NRC 2012, p. 201). As a final reflection, after students have completed the pendulum investigation and engineering activity, ask them to write about how scientific ideas can be used to solve engineering design problems and how they think engineering design problems can help them learn science. This final reflective writing can be used formatively to see whether students also recognize the other aspect of the dual nature of engineering: how engineering problems can contribute to our knowledge about science. ■

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References

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Internet Resource

NGSS Table: 3-PS2-2 Motion and Stability: Forces and Interactions *www.nextgenscience.org/3-ps2-2-motion-and-stability-forces-and-interactions*

NSTA Connection

For more background on using formative assessment probes and to download the probe, visit *www.nsta.org/SC1310.*

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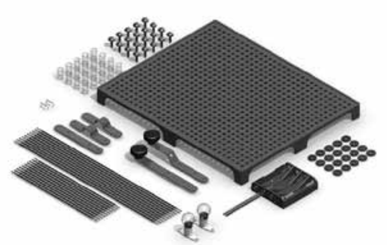

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