CHAPTER 1

Overview of the Feedback Loop

I use a lot of formative assessments, but I feel like I don't really appropriately analyze the data that I gather or use it for reteaching purposes in the most effective way.

—Beginning high school science teacher

Science teachers today are subjected to a deluge of data in their daily work. They are expected to draw on these data to make decisions about what to do during instruction. This trend, often called *data-driven decision making*, is the subject of big policy initiatives in schools right now. The amount of data coming at teachers *is* overwhelming. Let's take the case of an average public school secondary science teacher, who might be teaching upward of 150 students in five different classes a day. Although all of those classes might be repeats of the same course (e.g., eighth-grade physical science), it's more likely that the teacher has at least two different types of courses to teach. Given the current accountability system, it's likely that the students participate in standardized tests one or more times a year, yielding some kind of information for the teacher to interpret during or at the end of the school year. On a more immediate level, all of these students will be completing assignments and assessments daily or weekly. Although data is often confined to some type of written response, valuable data about student learning comes in many other formats, both formal and informal. Student comments during classroom discussions, the written work they generate—from lab reports to verbal responses to worksheets—and even student expressions and emotions can be considered data and can fill in gaps about what students know and are able to do in ways that test scores miss.

To speak even more broadly, the preceding examples are all focused on students. You must also consider what you are learning about your teaching. For example, did the lesson go as you had planned? If students were doing a lab, was there a part that didn't come out as you expected? Did students take longer to finish than you thought they would? Was there a critical reagent that didn't work? Did you have to go from table to table telling students about a minor correction that was vital to the activity? When the lesson was over, did you think, "Well, I'm never doing it that way again," or "Next time, I'll change this part of the activity"? Interpreting and acting on these pieces of information, collected as you teach, is vital to adapting and improving over time and to helping students meet goals.

Taking a cue from the language of science, we might think about all these types of data as "noise" or some type of unwanted signal that can feel overwhelming and might seem easier to ignore. Furthermore, our training as science teachers can push against how we view these data, making us feel that they are not "controlled" or systematically collected and thus are unreliable. However, the idea of informing our daily decisions about instruction with data about what students know and are able to do is founded on the principle that there is a lot of "signal" mixed in with that noise, and it's the teacher's responsibility to find ways to sort through all the noise to identify the signal that they can use. It is important to look beyond the data you have and consider the specific goals you had in collecting it. For example, you may be interested in finding out how well the students understand a disciplinary core idea, such as Motion and Stability: Forces and Interactions, or you might want to assess how well the students are able to engage in a science practice, such as Analyzing and Interpreting Data.

All of these are different goals for which a teacher may want to collect data, and because they are distinct, the way the teacher engages in that data collection will likely vary. That is, to gather informative data that will actually help you assess your specific goal, you will need to use an appropriate tool.

The toughest thing about all information you must analyze and respond to as a science teacher—whether it's about what students are learning or doing or the activities that you give them—is that you must determine what it means. That is, you must look at a combination of students' work, statements in class, and interactions with a given activity, along with your supporting instructional approaches, to decide what students know and are able to do, what they are struggling with, and what that means for your instruction. Should you move ahead even though about half the students are still confused? Were the problems you encountered in the activity mainly a result of the way you introduced it, or were they due to the way the activity itself was written? If the students seem confused, what are they confused about, and are they all confused in the same way?

These questions all revolve around issues related to classroom assessment, that is, assessment conducted by teachers to ascertain what students know and are able to do. More specifically, these questions relate to what is often called *formative assessment*, or assessment conducted during the course of instruction for the purpose of fine-tuning to move students forward in their learning (Shepard 2000). This is distinct from *summative assessment*, which is usually administered at the end of a unit or the end of the year to determine what students know and assign them grades. The distinction between these two types hinges on the way that information about what students know and are able to do is used; if the assessment is conducted *on* learning, it is summative. In contrast, if the assessment is conducted *for* learning, or to improve or enhance the quality of teaching and learning in the classroom, it is formative (Wiliam 2007).

We refer to this distinction in classroom assessment because it relates very closely to the sets of questions raised about all the data produced about teaching and learning in classrooms. Reframing the way we think about those data helps us focus on what is most important and determine what those data are telling us about what students know, what they can do, and where they need help to move forward.

That's where this book comes in. Through our work with practicing secondary science teachers in designing and interpreting assessments and conducting inquiries into their own teaching, we have developed an approach designed to help you efficiently and systematically sort through all of this noise, extract meaningful information, and determine next steps for your teaching and for students' learning. In this chapter, we will zoom out from looking at data alone and present a framework for thinking about the data you are collecting, the goals you have for instruction, the activities you are using to determine what students know, and how you are deciding what students know on the basis of these elements. We will use a framework we call the Feedback Loop (see Figure 1.1, p. 8), which is intended to go beyond thinking about pieces of data in isolation to reorienting them as a part of a larger system that you, the teacher, can design and act on. While the processes in the Feedback Loop could be appropriate for teachers of any grade level and subject, in this book we focus on its specific applications to secondary science teachers and the unique ways its elements can guide our teaching and support student learning.

The Feedback Loop

Our framework for interpreting data is inspired by the methods that researchers and professional assessment developers have been using for years to design approaches for determining what students know and are able to do. Assessment developers never think just about the data they are collecting; instead, they develop assessments as part of a coherent process in which they consider what they want to assess, how they will assess it, what format the data will come in, and how they will interpret the data. There have been a number of ways that these processes have been described; for example, the National Research Council has an assessment triangle (Pellegrino, Chudowsky, and Glaser 2001), the Stanford Education Research Laboratory has an assessment square (Ayala et al. 2002; Ruiz-Primo et al. 2001), and the Berkeley Educational Assessment Research group has the BEAR assessment system (Wilson 2005).

No matter what you call it or what shape it's in, all of these systems have four elements in common. To start, they all build on some form of the question, "What is the goal?" That is, rather than just looking at data, these frameworks deliberately focus on assessing something specific. For a classroom teacher, the goal should be the guiding principle that underlies what you are asking students to do. If students are doing a science lab, what is the reason you are having them do it? Are you interested in them coming to know a particular science concept, or are you interested in seeing the kinds of science practices in which they engage? For example, if you ask students to take measurements of water quality, such as pH levels and concentrations of dissolved substances in a local stream, is there a science practice goal, such as Obtaining, Evaluating, and Communicating Information, or are you more interested in supporting their learning of the crosscutting concept of Energy and Matter: Flows, Cycles, and Conservation?

This first step—being cognizant of the *goal*, or what you want to explore about your students' learning or your teaching—is the cornerstone of the Feedback Loop. Fortunately, policymakers have dedicated a lot of time working out what these goals are in the form of state or district standards or, more recently, the *Next Generation Science Standards* (*NGSS*; NGSS Lead States 2013), which define the disciplinary core ideas, science and engineering practices, and crosscutting concepts for students across grade bands. At the same time, you might have other goals that interest you about your own teaching that you wish to explore or strengthen, such as creating learning environments in which more students are able to participate in scientific argumentation or supporting students from diverse linguistic backgrounds in engaging in the language of science (e.g., Zembal-Saul, McNeill, and Hershberger 2012). These goals can also work as the starting point for the Feedback Loop.

The second element common among assessment development approaches is considering the answer to the question, "How will I know if students have met the goal?" The phrasing of this question leads to considering what we call the *tool*, or the activity, protocol, or other "thing" you are going to use to guide you in finding out what students know and are able to do. We use the term *tool* in the sense of an instrument that is used for a particular function, such as a meterstick to measure length or a spectrophotometer to measure wavelengths of light. In this case, we use a tool to find out what students know. In these examples, the meterstick and spectrophotometers are tools that help us to collect data in the form of different types of measurements. In the Feedback Loop, the tools are the common instruments teachers might use to collect data about student learning, such as worksheets, classroom assessments, external tests, and quizzes, as well as the questions a teacher might write to frame a classroom conversation, an observation protocol used to write down student ideas overheard from small groups, or even a tablet or smartphone used to record a lesson. It can also be something that is not written down or handed out but that you plan to use to get students to share their ideas, such as a really good, open-ended question asked as students engage in a laboratory investigation. The important common feature of all these tools is that they should be aligned with the goal you intend to assess. For example, just as scientists would not use a microscope to observe avian interactions at a distance, teachers should not use tools that are not aligned with the type of data they want to collect.

The third element of the Feedback Loop is *data*, a major focus of this book. Data are all the bits of information that can indicate what students know and that are yielded by the tools we use or create in our classrooms. Picking up from the examples above, the meterstick will yield data in the form of measurements of length, and the spectrophotometer will provide data in the form of measurements of wavelengths of light. In a classroom, data might be students' written responses to worksheets or classroom assessments, a teacher's written notes about student ideas shared in a whole-class conversation or small-group work, or the students' verbal responses to that open-ended question we mentioned above. Although data might seem very formal and official (think standardized test scores), they can also be unrecorded and ephemeral, such as the looks on students' faces when the teacher asks a particular question or a tally of student responses on a sticky note to help track student participation.

The last—and arguably most important—element of the assessment development frameworks has to do with how you make sense of the data you've collected. Since these elements are all connected, the process of making sense of the data is necessarily interwoven with the goals that you had and the tools you used. We call this process making *inferences* about what students know; that is, you're taking the multiple pieces of data you have and trying to determine what they tell you about the goals. When you think about it, it's very similar to the process of reasoning a scientist goes through. The individual pieces of information themselves don't necessarily make a whole lot of sense unless we consider them in light of why we collected them (goal) and what instruments we used to collect the data (tools). But if we consider these three elements together, we can piece together an argument about what the data might mean. For instance, you might infer from low standardized test scores that students have not met expectations for their grade band, or by watching a video, you might see that multiple students participated in a whole-class argument about evidence.

What is important about highlighting these four elements is that they should all be in sync with each other, and it is difficult to think about one element separately from the rest. We do not intend to suggest that the components should always be considered in a stepwise fashion; indeed, teachers often simply receive standardized test score data and must make sense of it. However, reflecting on the data along with the other three elements of the loop, rather than as individual pieces in isolation, empowers you to take ownership of what was being assessed in the first place, the nature of the tool that was used, and the inferences you can make from the data in hand.

Finally, after making inferences about what students know, the last step is to determine the implications for your teaching and supporting student learning relative to your learning goal. What have you learned about what students know and are able to do relative to the original goal? If students have not yet met the goal, what subsequent activities might you engage them in to help them move closer to it?

We bring all of these elements together in the Feedback Loop, shown in Figure 1.1. We represent them this way because, as we will argue in this book, thinking about one element in isolation misses the bigger context in which they are situated. For example, we find it impossible to think about data without thinking about why it was collected and the tool used to do so. Similarly, we find it difficult to make inferences about the implications any set of data might have about teaching and learning without considering why and how the data were collected.

FIGURE 1.1 The Feedback Loop

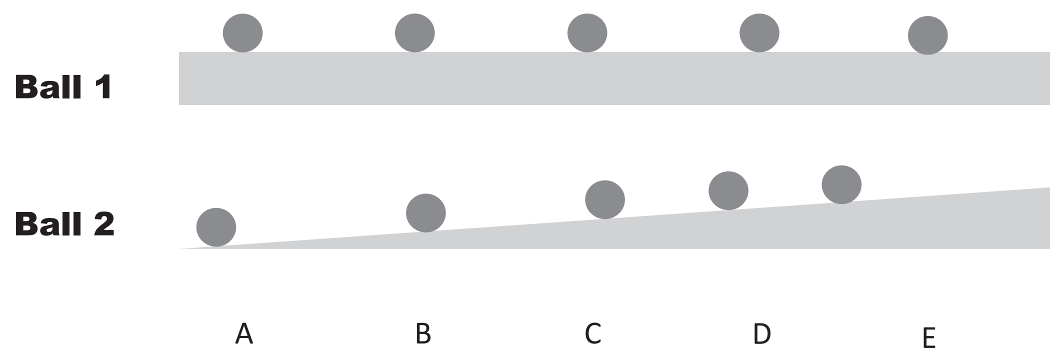
The Feedback Loop in Action: Uniform and Nonuniform Motion

To illustrate the different elements of the Feedback Loop, we will draw on one of our experiences in teaching middle school physical science. Erin was working with a group of seventh graders to find out what they had learned after a series of activities about measuring and representing uniform and nonuniform motion (those who have read Erin's 2009 book on formative assessment will be familiar with this example). Her *goal* was to have students interpret how strobe diagrams represent both uniform and nonuniform motion. At the same time, Erin wanted students to be able to construct arguments in support of their claims about what they observed, that is, to engage in the science practice of Engaging in Argument From Evidence.

Next, Erin went looking for a *tool* that she might use to determine if students were able to interpret strobe diagrams and make inferences about the speed of balls when given a representation of distance covered in constant amounts of time on two different ramps. After looking through several resource books such as *Physics by Inquiry* (McDermott et al. 1996) and some journal articles she had collected, she identified a set of three multiple-choice questions she intended to use to stimulate classroom discussion. Although multiple-choice questions are often thought of as being better fit for summative assessments, they can also work for formative purposes so that students sort themselves into categories in advance of a classroom discussion (Furtak 2009).

Once Erin had created the activity, she gave it to students and asked them to spend a few minutes individually answering the questions it contained. When all students had responded, Erin led a whole-class discussion in which students first voted on the answer they had selected and then provided reasons to justify their responses. In this way, the tool was designed not only to collect data about what students knew about representing motion, but also to determine their ability to engage in a science practice (Figure 1.2).

FIGURE 1.2 A tool created to assess student understanding of strobe diagrams and uniform and nonuniform motion



Source: Adapted with permission from Trowbridge and McDermott 1980.

1. How would you describe the motion of Ball 1?
    a. Uniform
    b. Nonuniform

How do you know?

2. How would you describe the motion of Ball 2?
    a. Uniform
    b. Nonuniform

How do you know?

3. At which point on the diagram do Balls 1 and 2 have the same velocity?
    a. Exactly at point A
    b. Exactly at point C

c. Exactly at point B
d. Sometime between points B and C
e. Sometime between points C and D

How do you know?

The activity created two types of *data*: students' votes for each of the questions and their responses to the "How do you know?" follow-up questions. After asking students to vote on the answers to the first two questions, which asked students if they would describe the motion of each ball as uniform or nonuniform, Erin was able to ascertain quickly that the students understood the difference between the top diagram, which illustrated uniform motion, and the bottom diagram, which illustrated nonuniform motion (slowing down). She asked one or two students per question to share their reasons for selecting their answers and, noting the consensus of the class, moved to the third question.

Asking where in the diagram the two balls would have the same velocity generated more disagreement than the first two questions, with students providing arguments for response (c) and response (d). Erin made a number of *inferences* about what students knew on the basis of their clustering around these two responses. First, Erin knew from her prior teaching experience that a common student idea about uniform and nonuniform motion was that passing objects have the same velocity (Trowbridge and McDermott 1980). The division of students into two categories reflected that while about half the class was looking at the distance covered in a unit of time (response [d]), the rest of the class was identifying the point at which the balls passed as the point at which they had the same velocity (response [c]).

Finally, to take action on what she had learned about what the students knew, Erin decided to do the activity again and this time asked students to make repeated measurements of the ball on the ramp. Calling sets of students to the front of the room, Erin requested they take measurements and construct tables with sample data on both a flat surface and an angled ramp. She then invited students to calculate the speed between each of the strobe images, creating sets of speeds to compare. The students worked for several minutes and then quickly ascertained that the correct answer was response (d) (sometime between points B and C).

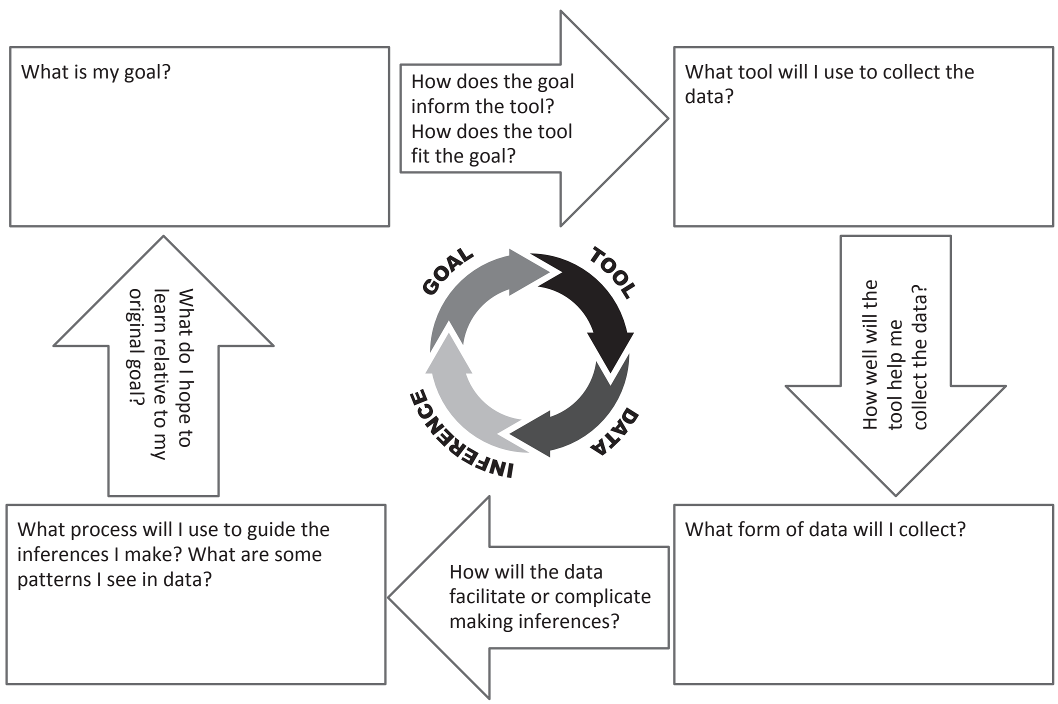
This example illustrates the way in which the four steps of the Feedback Loop guided Erin not only through the process of setting a goal, developing a tool, and collecting data, but also in interpreting those data and providing feedback to close the loop in advancing student learning.

Connections Between the Elements

It might seem that by zooming out and suggesting thinking about all of the elements of the Feedback Loop we are making the issue of interpreting data more, not less, complicated. It's true that we are asking you to think about more than just isolated pieces of data in making inferences about the quality of teaching and learning; however, we contend that thinking about the data along with the goals, tools, and inferences will ultimately help you feel *less* overwhelmed by the information collected. That is, rather than swimming in a pile of paperwork or feeling lost in the midst of a classroom conversation, you will go in one direction of the framework to consider how these data connect with goals. If the data are not aligned with goals, maybe you don’t need to make inferences about it at all. Or, maybe your tools need to be adjusted so that the data you generate allow you to make better, more efficient inferences about what students know.

The Feedback Loop pushes us to consider the connections between the different elements, as shown in Figure 1.3. While a first step for a teacher might be to identify goals, tools, data, and inferences, the questions listed in the arrows in Figure 1.3 can help you evaluate the entire process of data collection and interpretation.

FIGURE 1.3 Connections between elements of the Feedback Loop



The first connection between the goal and tool asks how a given goal informed the selection of a tool and how the tool fit the goal. The next connection raises the question of how well the tool helped you collect the data, and the third connection highlights how particular pieces or sets of data facilitated or complicated making inferences. Finally, the last connection between the inferences and goal help you evaluate what was learned with respect to the original goal that drove the process of data collection and interpretation.

The Feedback Loop in Three Dimensions

However, we do not want to give the impression that the Feedback Loop exists in two dimensions. We see each feedback loop as building on other loops, and even growing upward, as you uncover new insights about what your students know or about your teaching and ask new questions that build on the ones that preceded them. Your inferences may help you determine your next goal; thus, you will design another tool and gather more data as your students gain understanding. Alternatively, your inferences may lead you to decide that you need more data or a different tool. By considering these elements as interconnected and iterative, teachers can continuously adapt and adjust their teaching to meet the needs of the learners in their classroom.

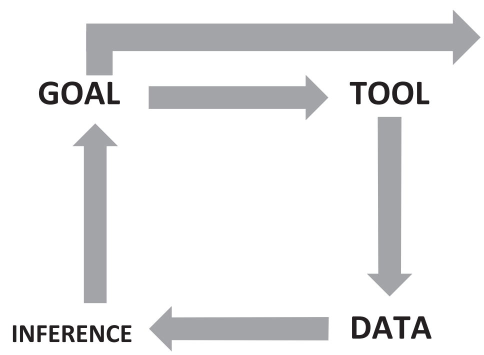
Figure 1.4 illustrates how we see multiple feedback loops building on each other over time. Figure 1.4a shows how inferences made on the basis of a feedback loop built on the initial goal might lead to another goal, and Figure 1.4b shows how each of these goals can lead to another feedback loop and ultimately another goal.

Looking Ahead

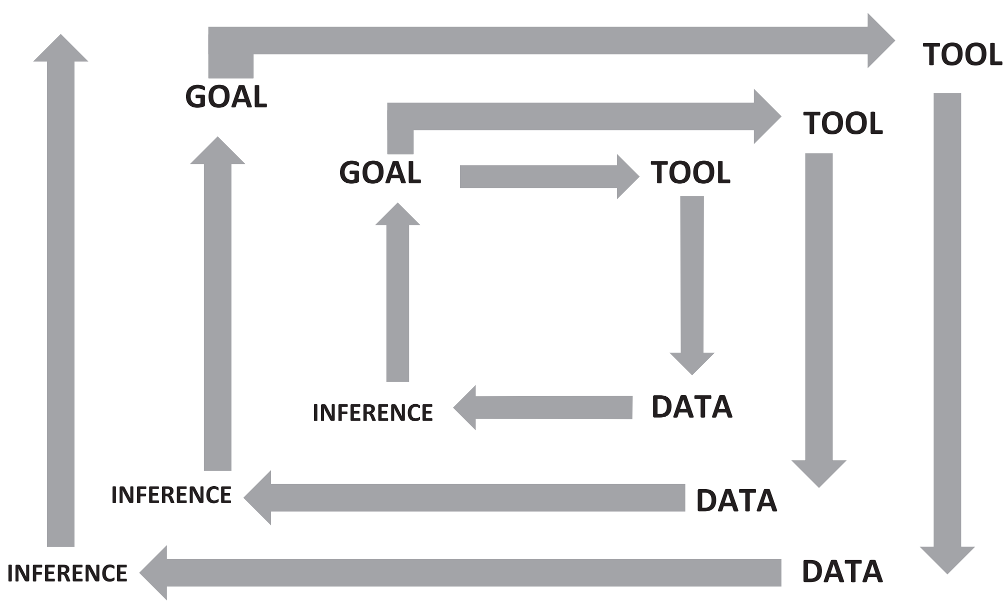
As the book continues, we will dedicate a chapter to each of the elements, providing rich examples and vignettes of practicing teachers working in different parts of the framework. We will also suggest resources and procedures for you as you explore each piece of the Feedback Loop as well as ways of engaging your colleagues in analyzing data using this approach.

FIGURE 1.4 The Feedback Loop in three dimensions: (a) Inferences can lead to a new goal, and (b) these goals can lead to new feedback loops, which lead to new goals.

1.4a



1.4b



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