THE FEEDBACK LOOP

Using Formative Assessment Data for Science Teaching and Learning

ERIN MARIE FURTAK
HOWARD M. GLASSER
ZORA M. WOLFE

NSTA press
National Science Teachers Association

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INTRODUCTION

When we reflect on our reasons for writing this book, each of us can see how the seeds of the ideas it contains were sown many years ago. As full-time science educators, we loved teaching science and working with students but found ourselves struggling to find ways to efficiently explore our instruction in ways that could help us grow in our practice and improve student learning. We wanted to understand how different aspects of our teaching—whether they were new labs we created, different structures for group work, questions we wrote for tests, or problems we posed during lessons—influenced students and their learning. At the same time, we had difficulty figuring out how to select and use the information available to investigate our practice. We wanted to become better teachers but were overwhelmed with other tasks and uncertain how to begin examining these areas. Keeping up with planning and grading kept us incredibly busy and trying to actively generate and analyze other pieces of information was exhausting! We knew this work could be valuable but didn't know where to begin or how to spend our time wisely so the work would be feasible and useful.

Although we each continued to explore ways to improve our science teaching, we also began looking at how other teachers could enhance theirs, too. These interests led our paths to cross in 2011, when we developed and refined professional development experiences for novice teachers. We created resources and provided support that focused on aiding teachers in using data to improve their teaching and enhance students' learning. We have subsequently refined these materials and approaches and have used them with many groups of middle and high school teachers—not only those just getting started in their careers but also with those who have been in the profession for many years. Hearing these teachers' feedback further convinced us that these ideas could be valuable to more than just the specific groups with which we've worked. We wanted to write this book to share and discuss these ideas with more secondary science teachers.

In many schools today, there is a great emphasis for teachers to use "data-driven" approaches to teaching, and many teachers encounter pressure to use practices that will increase student scores on standardized tests. Often, these scores are the major pieces of data other people use to assess the effectiveness of teachers. This book broadens that perspective, drawing on approaches to assessment design (e.g., Atkin and Coffey 2003; Ayala et al. 2002; Pellegrino, Chudowsky, and Glaser 2001) and focusing on how data collected about student learning can help teachers improve their teaching and students' learning. To make this work more manageable, this book also provides numerous tools and resources that we developed in our collaborative work together, as well as in related research studies (e.g., Furtak and Heredia 2014; Furtak, Morrison, and Kroog 2014).

We build out from this focus on data to introduce a framework that we call the *Feedback Loop* as a model for how you can use data to explore your teaching, improve your practice, and enhance students' learning. Although this framework and the related ideas can be valuable for teachers of a variety of grade levels and subjects, the examples we provide focus on middle and high school science. Chapter 1 introduces the Feedback Loop, explaining its structure and usefulness in guiding teachers to consider a number of components when setting goals, developing tools to collect data, and analyzing those data to determine next steps for instruction. Chapters 2–5 each highlight one of the four elements: goals, tools, data, and inferences. We discuss the element's value, explaining what it is and how teachers can use it to grow in their practice and better support student learning.

Chapter 6 explores how to close the loop by connecting inferences and goals through feedback, and Chapter 7 uses the full Feedback Loop to describe an approach for planning and informing instruction. Finally, Chapter 8 discusses how to collaborate with colleagues when considering data and the Feedback Loop to further increase the effect that this work can have. Finally, Chapter 9 provides additional resources to explore.

Throughout the book, we build on the standards that teachers are expected to meet, with a particular focus on the *Next Generation Science Standards* (*NGSS*; NGSS Lead States 2013). We took this approach knowing that not all states have adopted the *NGSS* at the time of printing; however, since the states that have not each have their own form of standards, we took the *NGSS* because they are widely available and we could relate the classroom activities this book includes to them. Furthermore, we recognize that the *NGSS* represent the field's best knowledge of how science concepts and practices can be intertwined during instruction (NRC 2012), and as such, we feel that they are the best available source on which to base the examples. That said, many of the examples were developed pre-*NGSS*; several others took place afterward, in states that had their own sets of standards. While we related these ideas to the *NGSS* to bring them into the present science education policy context, we strongly emphasize that the Feedback Loop can work with any standards, be they *NGSS*, state, district, or even local school curriculum frameworks.

We have incorporated classroom vignettes in each chapter, as well as quotes and perspectives from current science teachers, to ground these ideas in real-life situations (note that all names marked with an asterisk are pseudonyms). We want this book to provide you with useful tools, approaches, and resources that will help you in your efforts to become better teachers. We hope you find these ideas and approaches as exciting and useful as we do!

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CHAPTER 4

Collecting Data

I have data! Now, how should I use it?

—First-year high school chemistry teacher

Say the word *data* to a science teacher and certain images may come to mind, such as spreadsheets, tables, graphs, or lists of numbers. These forms of data are part of the everyday experience of practicing scientists. Depending on the type of science we're talking about, data might also include field notes of animals' behavior, drawings, maps, or samples such as tree and ice cores, rocks, or blood. Our backgrounds in science lead us to call these forms of data most immediately to our attention.

At the same time, the word data is floating around educational reform circles. Everywhere you turn, it seems as if some form of data is being collected and then used as a foundation for a new catchphrase policy; for example, "data-driven instruction" or "data-driven decision making." A recent New York Times article (Rich 2015) summarized this trend:

> *Custodians monitor dirt under bathroom sinks, while the high school cafeteria supervisor tracks parent and student surveys of lunchroom food preferences. Administrators record monthly tallies of student disciplinary actions, and teachers post scatter plot diagrams of quiz scores on classroom walls. Even kindergartners use brightly colored dots on charts to show how many letters or short words they can recognize.*
>
> *Data has become a dirty word in some education circles, seen as a proxy for an obsessive focus on tracking standardized test scores. But some school districts, taking a cue from the business world, are fully embracing metrics, recording and analyzing every scrap of information related to school operations. Their goal is*

to help improve everything from school bus routes and classroom cleanliness to reading comprehension and knowledge of algebraic equations.

As educators, we think data are critically important, too, which is why it's one of the four elements of the Feedback Loop. However, we see data as serving the purpose of improving the quality of instruction through an aligned process. We use data to refer specifically to the multiple forms of evidence generated by our tool that will then guide inferences about whether or not students have met the goal. This chapter will talk about multiple types of data in the Feedback Loop and ways of reducing the amount of data you collect.

The Role of Data in the Feedback Loop

As the *New York Times* article described, the term *data* often conjures the results of standardized tests that are delivered externally and are often difficult to translate into prescriptions for action in the classroom. This view doesn't just see this particular type of quantitative data as superior, it sees all data collected for accountability purposes as superior to any collected independently by teachers, regardless of type. As we turn to discuss the role of data in the Feedback Loop, we will broaden the common idea of data as being external to the teacher and primarily consisting of standardized test scores. In contrast, data in the Feedback Loop are constituted by the multiple sources of information about student thinking that are generated by your tool (see Chapter 3). The tools you select and design to align with your goals should in turn generate data that are useful to you in determining what students understand and are able to do. Just as the form of the tools varies, so can the data those tools generate.

Before we get too far, we'll add a word of caution: Some teachers who have worked with us and the Feedback Loop have been confused by our distinction between the tool and the data that the tool generates. We'll work to be very explicit throughout this chapter as to what we mean by these two elements.

Qualitative and Quantitative Data

Classroom data are most commonly grouped into two categories: qualitative and quantitative. As teachers and as scientists, we know the value of both for different purposes and how both can work independently and together. Quantitative data include anything that can be counted. This could be standardized test scores, class quiz results, or even something as simple as the number of students who answered a warm-up question correctly. Quantitative data can be manipulated statistically and represented in charts and graphs to more easily show trends and patterns. The data could be about the whole class or about a specific student. You might use quantitative data when you are trying to quickly assess the understanding of the class overall or of a particular student, to determine where you might want to explore more deeply.

We tend to be a bit dubious of the traditional "85%" reports teachers can get about how students did on tests and quizzes, because these numbers tend to aggregate a lot of information about what students know and are able to do. If a student has an 85% level of understanding, what does that actually mean? The standards-based language of proficient, partially proficient, and so on gets more at information about what standards students have met and what they still have to learn; however, it is only useful if the information is reported in relation to standards. If you are able to generate reports of this nature, such that your test or quiz is neatly aligned with the goals you set, then the numbers your test generates will be more useful. If not, it might be beneficial to consider alternative forms of data.

In contrast, qualitative data seem to get much less airtime in education reform. They may not have the same perceived level of validity or street credibility as quantitative data, but they have a key place in the Feedback Loop. The problem with the assumption that qualitative data are less useful is that much of the data generated in a classroom daily—including students' written responses, their expressions, and their questions and contributions to whole-class conversations—are qualitative. As a result, if we are favoring quantitative data, we have to find a way, and time, to convert qualitative data to quantitative data by grading and assigning points to everything. Information is inevitably lost in this process, and the delay between when students generate data and when you're able to look at it can get in the way of your instruction being responsive to student thinking.

Ironically, for some science teachers, the idea of using qualitative data in the classroom is baffling. As scientists, they are much more comfortable with facts, numbers, and other data that may be deemed more objective. However, by looking at different types of qualitative data, teachers can get a better sense of how students are thinking and not just see whether or not they "get it." This can be extremely important, particularly in teaching science, because teachers must address preconceptions, partial conceptions, and misconceptions if students are to develop strong understandings in their science learning. By uncovering how a student thinks about a particular concept, you can diagnose and identify what pieces are missing and specifically target your instruction to meet your learning objectives.

This is why we really like using qualitative data in the Feedback Loop. It is closer to what you do every day, and without creating the need to score things and assign points, we open up a whole world of possibilities. In fact, research has shown that it's better *not* to score student responses if you want to use them for a formative purpose; it doesn't just slow down the time to give feedback, but students have been shown to disregard qualitative feedback in favor of looking at their grades anyway (Butler and Nisan 1986).

Let's work through a couple of examples of tools and the data they capture and generate. An ecologist might make field notes in a waterproof notebook about the behavior of pikas (a small mammal living at high altitudes), which are a qualitative form of data. Her observations of the pikas are assisted by the use of binoculars, so she can observe the mammals from afar.

At the same time, this ecologist might quantify the number and location of pika burrows on rocky mountainsides. She has used several different tools: a pen, a waterproof notebook, a pair of binoculars, perhaps a GPS receiver to note the locations of the pika burrows, and a physical map or computer program to record those locations. These tools in turn help her generate and capture several forms of data—field notes and burrow numbers and locations—which together provide rich information about the behaviors and population density of the pikas.

Similarly, in the classroom, the tools we use can similarly generate quantitative and qualitative data about student learning. An environmental science teacher might engage her students with a physical model of erosion using stream tables. The tools she uses include the activity she has developed to guide students to focus on the relationships among variables that influence stream velocity, slope, and characteristics of the water corridor such as meandering. The tools also include the stream table itself, sand, and the water students channel through the sand. As students engage with them, these tools combine to generate multiple sources of data in qualitative or quantitative form that the teacher can collect. As students model different geological features, she notes students' expressions of confusion or frustration while they're working. To be sure that students are engaging in the main goals of the activity, she regularly drops into groups to ask about the variables they are changing and the effects of shifting those variables, such as the velocity of the water or the angle of the stream table, on the features of the riverbed they are creating. At the end of the activity, she collects students' descriptions of the relationships modeled with the stream table and scores them with a rubric. The teacher here has collected multiple sources of data, including the qualitative expressions on student faces and responses to her questions and quantitative responses to the activity via her rubric.

In each of these instances (the ecologist and the environmental science teacher), we can see illustrated the distinction between tools and data. The binoculars the ecologist uses are not the same as the observations she makes when using them, just as the activity that students use to guide their modeling of the stream system is not the same as students' responses to that activity. Similarly, the tools can be used in different ways to generate different types of data: the ecologist may look through the binoculars to gather qualitative descriptions of pika behavior or she may use those same binoculars to identify burrows, which she tallies and later enters into a spreadsheet. The environmental science teacher may simply read through student responses to the activity, noting the nature of student ideas and picking up on themes to visit in subsequent lessons; she may also score those responses according to their accuracy.

In the following sections, we will give several examples of the different types of quantitative and qualitative data that formative assessment tools can generate. Ultimately, the type of data that any tool generates depends on the teacher, and how she or he determines to enact a given tool with students. Just as a multiple-choice question is easily scored (quantitative), it can also generate rich class discussions (qualitative).

Initial and Revised Models in the Feedback Loop

Kate Henson, Miss Porter's School, Farmington, Connecticut

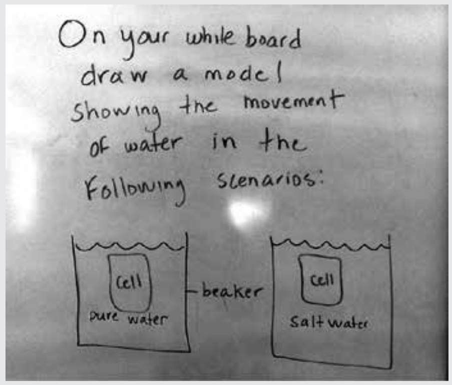
I have been teaching biology since 2001 and have worked in public, charter, and independent schools. Currently, I am teaching at Miss Porter's School, an all-girl, independent day and boarding school in Connecticut. Our student body of 320 students includes US and international students and is socioeconomically and ethnically diverse.

The Feedback Loop really resonated with me because it named the process I have been using for years, although I had never explicitly thought about the steps before. I used the Feedback Loop to formalize my process of designing, enacting, and reflecting on a formative assessment in one section of biology. This year-long course is the second in the required physics–biology–chemistry sequence. This particular class comprised 11 students, including 1 sophomore, 8 juniors, and 2 seniors. Students had already completed a unit on biochemistry before studying cellular biology.

Within the context of cellular transport, my *goal* was to see students model and explain how substances move across the cell membrane. I knew the students had a good working knowledge of the structure and function of the cell and cell membrane, but I hoped that the use of whiteboard models would allow me to understand how they were applying what they already knew about molecules and cells to a new situation.

I developed a simple *tool* to elicit student ideas prior to engaging them in classroom experiences related to transport: a quick set of instructions that I jotted onto my whiteboard. I asked students to create a pictorial model of what they thought would happen to plant cells in different scenarios (Figure 4.1, p. 74).

FIGURE 4.1 The tool prompting students to draw initial models showing the movement of water in and out of a cell

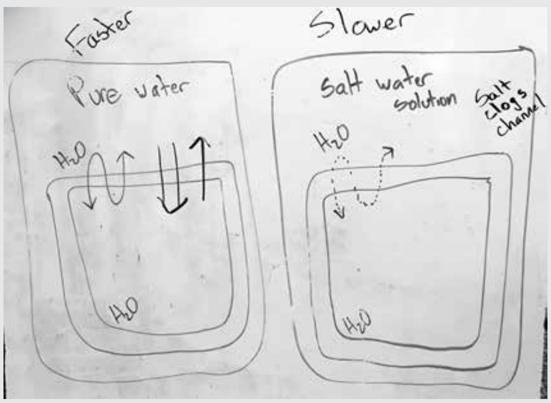


In the first scenario, the plant cells would be put in a saltwater solution, and in the second, they would be put in a deionized water solution. I divided my students into groups of two to three and gave each group a small whiteboard (2′ × 3′) and several dry-erase markers.

The student-drawn models on the whiteboards provided me with the *data* I needed to understand their thinking and determine which classroom experiences should follow. Figure 4.2 shows two sample initial models. In the model in Figure 4.2a, one pair of students predicted that in both scenarios water would flow in and out of the cell, but in the saltwater solution the rate would be slower because salt would block the channels and prohibit the water's movement. In the pure water solution, their model indicated there would be more water flowing in than out but did not indicate why. In the model in Figure 4.2b, another pair of students predicted that in the pure water solution, equal amounts of water would flow in both directions, resulting in no net change, whereas in the saltwater solution more water would flow out than in. They reasoned that the flow of water into the cell would be slowed down by the smaller Na and Cl ions, which would have an easier time flowing into the cell.

FIGURE 4.2 Sample student initial models: (a) Water flows in and out of the cell, but the rate is slower in salt water. (b) In pure water, equal amounts of water flow in both directions and in salt water, more water flows in than out.

a.



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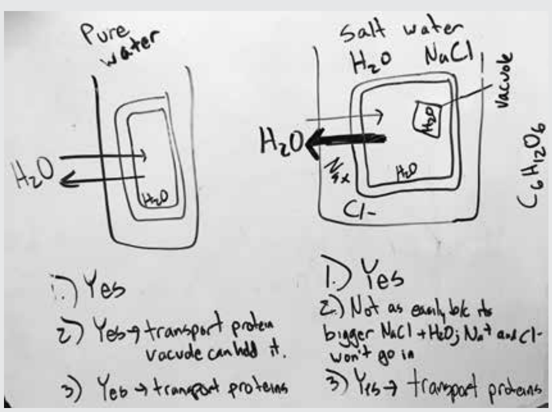
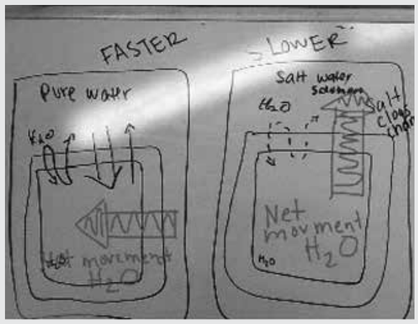


The data from these whiteboard models led me to make several *inferences*. Students could predict that water would move both in and out of the cell. They understood that the cell membrane is permeable to water, but they weren't sure how much water would be flowing in which direction and why.

This led me to set the new *goal* of providing students with an experience that would allow them to revise their original models into an accurate working model. My new *tool* was an activity in which students made wet mount slides of Elodea leaves and looked at them under the microscope. Once the students made their slides and located the cells under the microscope, they treated the cells with a saltwater solution and recorded their observations. They then repeated this procedure with a deionized water solution before discussing results with their partners and revising their models.

These revised models, along with students' descriptions of the models they shared in a whole-class discussion, formed a new source of *data*. Each pair took a turn projecting their modified original models on the whiteboard at the front of the room. Figure 4.3 (p.76) shows revisions students made to their models in lighter-colored ink.

FIGURE 4.3 Revised student model showing how water moves into and out of cells in pure or saltwater solutions



The new model showed the "water arrow" pointing in when the cell is placed in pure water and out when placed in salt water. Students explained that the water "wanted to go where there was less water." This data led me to the make the *inference* that although they may not have been using scientific terms to describe their observations, they were able to construct an accurate model.

No method of learning is linear. We never get to the point where we know everything and stop; that's what's so great about the Feedback Loop. We get new information and go around again. The Feedback Loop gave me a framework to work in, both for my original goal of uncovering student ideas and models for membrane transport and for the new goal of engaging students in an investigation to help them revise their models.

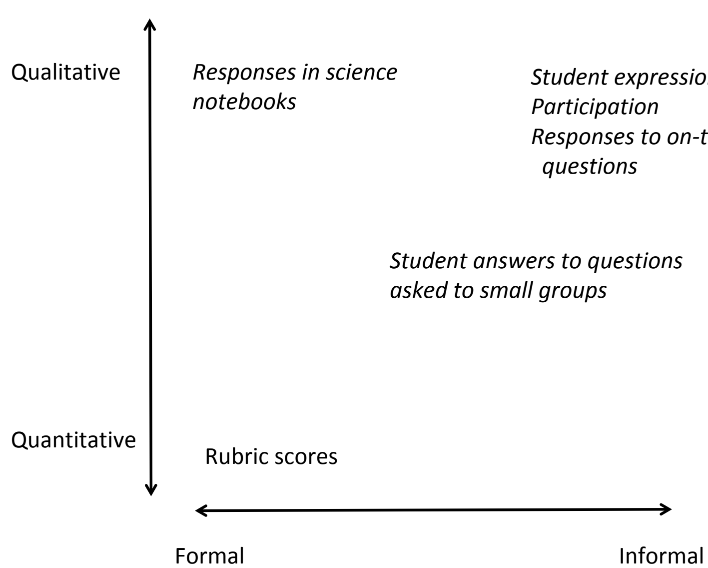
For me, the Feedback Loop was a powerful tool. In addition to helping me revise my goals, it helped me easily construct meaning from the information I was getting from my students. It forced me to listen carefully. As an experienced teacher, I have accumulated a lot of tools, and it's easy to choose an experience for students for the wrong reasons. For example, I might really enjoy a particular lab and think it's fun for my students, but that doesn't make it meaningful or the right experience for where my students are in terms of their understandings. The questions the Feedback Loop made me ask myself are, "What is my goal?" and "What tool will help me reach my goal?" Then, once I had the data elicited from my students, I asked, "Did it work? Did my tool help me reach my goal?" And then, considering my inferences, I asked myself, "Where do we go next? What is my next goal?"

Formal and Informal Data

Data span the continuum from formal to informal (Cowie and Bell 1999; Ruiz-Primo and Furtak 2006, 2007). Formal types of data are usually the result of tools planned in advance; such tools are often handed out to students or shown to them on a screen. Formal data fit into a lesson plan and constitute information you might share with your colleagues (Ainsworth and Viegut 2006). They capture the nature of student thinking at a particular point in time such that you might look back at them later to make inferences to guide your instruction.In contrast, informal data include students' responses to questions asked on the fly, their expressions, and their participation in class. This is what experienced teachers might simply call "good teaching." Informal data are often generated through discussion tools, such as when you ask questions, listen to small-group discussions, pay attention to students' participation or their tone of voice, or do anything else that helps you keep track of how a lesson is going.

To illustrate the difference between formal and informal data, let's return to the environmental science teacher from earlier who collected formal and informal data in addition to the qualitative and quantitative data already discussed. She collected informal, qualitative data about student expressions and participation during the lab. The questions she asked students about the variables were planned in advance, but she also asked improvised questions, making it a semiformal or planned source of data. Finally, she scored students' qualitative, formal responses to the activity that guided their modeling with the stream table. We summarize all these different forms of data in Figure 4.4.

FIGURE 4.4 Summary representation of types of classroom data



Although not all forms of data fall cleanly into this formal/informal, qualitative/quantitative representation, we do find it to be a useful way to think about the types of data we typically collect in our classrooms. If the majority of data you collect in feedback loops are located at the quantitative-formal intersection—aggregating student clicker responses in graphs, for example—it would be worth thinking about how more informal-qualitative forms of data could be generated to complement these, perhaps by listening to discussions by students of their responses in small groups.

Data Reduction

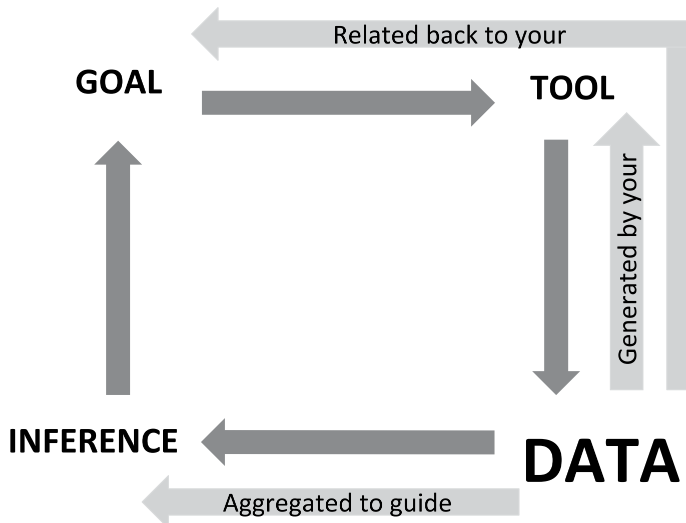
One of the most common things we hear from teachers when we work with them on the Feedback Loop is how overwhelmed they are with data. "What do I do with all this data? I'm swimming in it, and you want me to collect more?" Ironically, now that we've broadened the idea of data, we'd like to talk about the process of data *reduction*. That is, we want to guide you through the process of using the Feedback Loop to help you reduce the overall amount of data you are collecting and looking at daily.

The phrase "data reduction" comes from qualitative social science research, which puts reducing the amount of data you're working with as the first step in moving toward drawing and verifying conclusions. This process has also been called condensation because it refers to "the process of selecting, focusing, simplifying, abstracting, and transforming the data" (Miles and Huberman 1994, p. 12). This needs to be done to make data more manageable, as well as more interpretable relative to your original goals.

If you're like we were before we began using the Feedback Loop, your daily practice involves collecting tons of data. Erin has memories of lugging multiple canvas bags home every night, filled with numerous six-inch tall stacks of student work from her five classes every day. She hauled bags often enough that on teacher appreciation day, when she was getting a free shoulder massage, the therapist immediately identified which shoulder she usually carried the bags on. Zora remembers stacks and stacks of collected homework assignments that taunted her every Sunday night as she frantically tried to catch up and enter grades for weekly progress reports. However, how much of this information was actually useful in adapting our instruction to help students meet our learning goals?

One of the major purposes of the Feedback Loop is to help you be more deliberate about the data you collect. When we talk to teachers who feel overwhelmed by the data they are collecting, we find they are stuck in that lower-right hand corner of the loop. Usually, when we press these teachers to reflect on the other vertexes of the loop, they are not clear on what goal they have in mind, and the tools they use are so long that they generate much more data than necessary. Then, looking forward in the loop, these same teachers struggle to make inferences because they have so much to look at and are not sure where to begin. Figure 4.5 represents the relationship of data to other elements of the Feedback Loop.

FIGURE 4.5 Data in the Feedback Loop; lighter-colored arrows highlight links between data and other elements of the loop



We suggest starting data reduction by going through the following process: Think back to the goal that you had and the tool you used and streamline. If you asked students five questions on a written tool, which of them best aligns with the goal? If you can identify that one question, then you've just reduced your data by 80%.

Sometimes we get a little confused ourselves when talking with teachers about the difference between data and tools. This can be very straightforward for formal sources of data, such as if you design an activity (*tool*) and give it to students to record their written answers (*data*). However, it can get a bit confusing when we're talking about informal forms of data, such as class discussions.

Howard notes that how he would find something is often through information. For example, he could say *how* he would find out what students know is through having them engage in discussions (which he might facilitate), yet the *information* he would look at is the discussions themselves. So, discussions are both how he would find out what students know and the information about what students know. In other words, in-class discussions can contain both the tool and the data.

This might be more clearly seen when looking at something such as a video recording: A teacher could say that how he or she would find out what students know is through making a video of them, while also saying that the information he or she would look at is the video itself. So making a video is *how* the teacher would find out what students know, and it contains the information about *what* students know. In other words, the video can also be both the tool and the data.

Involving Students

Student involvement in the Feedback Loop is perhaps most straightforward when we are talking about data: They are the ones creating the data about what they know and are able to do. If we take a limited view of data, this information is something students generate in one step and you look at in another step. However, we've found that actively engaging students in generating data and listening and responding to the ideas (data) of other students can enrich the feedback loop and generate data in real-time.

In this chapter, we presented the approach of the assessment conversation as a simple and fast method of actively having students share their ideas in real-time (Duschl and Gitomer 1997). If you engage students in conversations like these, over time they can even learn to take the role that teachers traditionally occupy, holding their peers accountable to their ideas and challenging and pushing each other in their thinking (e.g., Engle and Conant 2002).

Another approach to engaging students in selecting data for you is by having them assemble portfolios in which they choose what they think counts as high-quality data of their learning. If you are using a running-record source of student data, such as science notebooks (e.g., Chesboro 2006), students could even identify which pages they felt were the best representation of their work and direct you to look at those pieces of evidence for their learning.

Summary

In this chapter, we discussed the many different forms of data teachers can access in their classroom, from quantitative to qualitative and from formally to informally generated data. Because we can easily be overwhelmed by the amount of information we collect, it is very important to remember how what we want to examine is connected within the Feedback Loop: What is the goal we are trying to get at with our data? How is the tool giving us the data we want to examine? What are the types of inferences we might make from the data? Asking these types of questions can help us be more deliberate about what we collect and reduce the amount needed for the next step—making inferences about what your students know and are able to do. Try using Resource Activity 4.1 (p. 85) to help you think about the data you want to collect and how it fits into your feedback loop.

Is It Heat? Is It Temperature?

Stephan Graham, Arrupe Jesuit High School

My name is Stephan Graham, and I am a science teacher who has worked in urban high schools for the past seventeen years in Chicago, Illinois, and Denver, Colorado. I serve a population of students from underserved and economically disadvantaged communities. The science curriculum I offer these at-promise* students attempts to connect challenging science topics to their everyday experiences and allows me to measure what students are learning at any given time. To that end, the four vertexes of the Feedback Loop resonated with me as an experienced teacher, as I could easily see how I already take these steps to plan and enact classroom activities daily. A good example comes from a recent lesson I taught, which focused on the difference between heat and temperature.

My *goal* for a several-day sequence of lessons was for students to determine the difference between heat and temperature. This set of lessons was part of a unit on thermochemistry, in which students ultimately create a cooking show. This is the third of four units in the chemistry curriculum in the junior year of Arrupe Jesuit, where the topics engage students with ideas that are familiar to them and align closely with the disciplinary core ideas found in the *Next Generation Science Standards* on energy, its conservation, and its transfer. In addition, concepts of heat and temperature encompass common misconceptions that the lab activities address. One common student idea I drew on as a resource is the incorrect idea that objects that feel hot to the touch must be at a higher temperature than objects that do not feel hot to the touch.

I worked with a *tool* that followed the predict-explain-observe-explain format (Figure 4.6, p 82). The tool asked students to predict whether a cube of ice melts more quickly on a metal block or a plastic block. I prompted students to think about two ideas: the difference in conductivity between these two materials and whether they believed that heat flows from hot to cold or cold to hot. Students were familiar with atomic-scale drawings of crystalline versus amorphous substances and their role in explaining thermal conductivity through these materials, but they hadn't yet learned about the direction of heat flow.

* A way of describing at-risk youth that focuses on the belief that all students can succeed.

FIGURE 4.6 The predict-explain-observe-explain tool

Name:

Chemistry: Lab #12—Mass, Temperature, Heat Energy, and Type of Substance

Focus Questions:

1. What is the difference between heat and temperature?
2. How are mass, temperature, heat energy, and the type of substance related?

Research:

1. Which ice cube will melt faster? An ice cube on plastic or an ice cube on metal?

   Prediction:

   Observation:

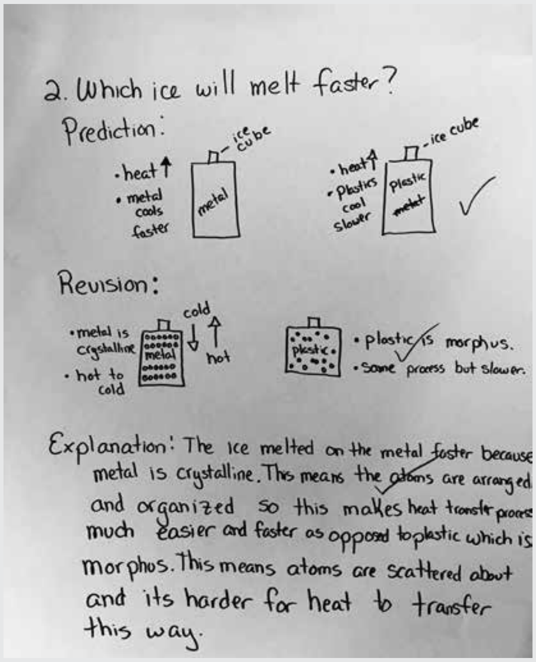
   Explanation:

Then I collected multiple sorts of *data*. I first asked students individually to draw their predictions in their lab notebooks through an initial model. After a few minutes, students conducted the activity themselves, placing cubes of ice on both a metal and a plastic block and subsequently recording their observations. Next, I invited students to get into groups and use a dry-erase board to revise their models on the basis of their observations. Finally, students shared out their data with the rest of the class. Thus, I had four different sources of data: students' preliminary predictions, their initial models, revised models from each group, and the explanations that students offered to the rest of the class.

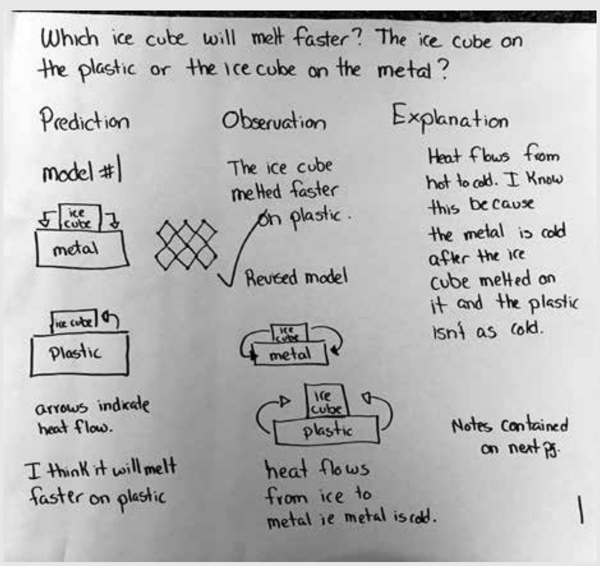
I was able to make a number of *inferences* from these sources of data about whether or not my students met my original learning goal. I was able to infer through their models and explanations that many students knew the difference in conductivity between metals and plastics, but the class as a whole had a more difficult time agreeing on the direction of heat flow. That is, they were not clear about whether heat flows from the block to the ice cube (Figure 4.7a, student A) or from the ice cube to the block (Figure 4.7b, student B). Furthermore, some students questioned if the direction of heat flow changed depending on the material from which the block was made (e.g., student B). As students listened to each other, I asked them to write down what they thought made sense. One student talked about the fact that her ice cube trays at home are made of plastic. Another student shared that for the ice cubes to melt on either the metal or the plastic block, heat must be moving from the block to the ice. A student then noticed that the metal block felt cold to the touch and offered the statement that heat must be moving from his (warm) hand to the (cold) metal block for his hand to feel cold. At this point, students felt confident that the suggestions given by the class helped explain why the ice cube melted more quickly on the metal than on the plastic block.

FIGURE 4.7 Sample student models: (a) student A; (b) student B

a.



b.



After engaging in this process of making inferences from the multiple sources of data and having students reflect on their own learning, I finished the class period with one final tool, a clicker question intended to help me get a sense of how well students had moved toward the correct explanation through the activity:

Which is at a higher temperature inside a car on a hot summer day?

a. The cloth seat covers

b. The metal buckle of the seat belt

c. Both the cloth seat covers and metal buckle of the seat belt are at the same temperature.

The data were not comforting. Students drew on their everyday experiences to answer the question; because the metal feels hot to the touch but the cloth seat cover does not, over 70% of students responded that the metal seat belt buckle would be at a higher temperature. But something interesting then happened. Only when students saw the right answer did they make a connection between the previous ice cube activity and the clicker question. Students were then quick to explain that the heat was flowing from the (warm) metal seat buckle to the (cooler) hand, just as heat flowed from the (warmer) metal block to the (cooler) ice cube. I inferred that this question also gave students an opportunity to see that heat was not the same as temperature. Everything inside the car was at the same temperature, but only the conducting materials efficiently transmitted the heat, thereby making them "feel" hotter.

> Putting a format to the way I informally assess students is affirming. Evaluating students from the start to the end of the lesson and using the data to instruct my next lesson just makes sense. Students should show what they know periodically inside a class period and not only after a summative test.

RESOURCE ACTIVITY 4.1

Data Collection Plan

Before collecting data in your class, we suggest you take a few moments and envision how you will do so.

ASPECTS	CONSIDERATIONS	MY PLAN
Goal	What is your goal?	
Tool	Which tool(s) are you selecting, adapting, or designing?	
Class	Describe the class in which you will generate data.	
Timing	When will the data be collected?	
Categories of data (circle the ones you're collecting)	Qualitative Quantitative Formal Informal	
Instructional strategies	How are students involved in generating data? What efforts are you making to challenge and support all students?	

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THE FEEDBACK LOOP

Using Formative Assessment Data for Science Teaching and Learning

In the introduction to *The Feedback Loop*, the authors write, "We wanted to become better teachers but were overwhelmed with other tasks and uncertain about how to begin examining these areas." What teacher *hasn't* felt this way?

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