Imagine you decide to take a trip with your family to enjoy the beauty of fall in New England. Such a trip requires a significant amount of planning—for example, which highways to take, where to stay, what sites to visit along the way, and how to beat the crowds during peak tourist season.

Effective teaching requires a similar need for planning. Although your teaching goals or objectives may be unique, you still need to consider what you expect from all students (objectives), how you will achieve success with all students (the lesson), and to what degree you were successful (formative and summative assessments). This chapter gives you a map for arriving at high-quality inquiry-based instruction.

If your class is studying energy, for example, you can scour the Internet for activities and lessons on energy (29 million possibilities, the last time I checked), implement the lesson, and then create a grade for each student to put into your grade book. Or you could use some of those activities to systematically devise a plan that ties today's lesson with students' prior experiences and progress in a manner that challenges student thinking while building conceptual understanding. This second option—the focus of this chapter—has the greater chance of improving student achievement among all learners.

The Need for an Instructional Framework

Most teachers realize that they must incorporate a myriad of instructional approaches into their classes to effectively reach all students. However, most teachers also get little guidance on how to successfully assimilate the best practices in the classroom. In addition, a teacher's beliefs plus mandates dictated by the department, school, and district also frame the specific instructional approach for a lesson or unit. Attending to these various and typically competing demands often results in a piecemeal approach to adopting and implementing various instructional initiatives.

If teachers are to adopt inquiry-based instruction as a significant instructional approach, they need a framework to support their efforts. Such a framework must be coherent enough to combine the many things that we know about good instruction and also dynamic enough to adapt to the various instructional settings found in classrooms around the nation. The 4E x 2 (read "4E by 2") Instructional Model, shown in Figure 3.1, unites three major components of learning that have each separately been shown to improve student learning:
Inquiry-based instruction, with four phases (Engage, Explore, Explain, and Extend) Formative assessment Teacher reflective practice

Repeatedly shown to be critical aspects of instruction, formative assessment and reflective practice are explicitly incorporated into each stage of inquiry in the 4E x 2 model (Atkin & Karplus, 1962; Bybee et al., 2006; Marshall, Horton, & Smart, 2009). The resulting synergy of best practices improves teacher effectiveness as well as teacher efficiency. Let’s explore the importance of formative assessment and teacher reflective practice in more depth.

**Formative Assessment: Continually Checking In with Students**

Formative assessment encompasses both the data that you collect from students during instruction and your actions based on your interpretation of these data. Why is formative assessment so critical? Because rather than waiting to help struggling students until it is too late (e.g., at the end of a chapter, the unit, or a long lesson), you can use formative assessment to make informed decisions at each step in the instructional process. In other words, you determine whether students have grasped the material and are ready to move on, or whether they need some type of review or remediation. An important reminder: formative assessment is only effective when teachers intentionally act on the data that they gather from students in order to improve instruction. When formative assessments become an integral component of instruction, student achievement increases (Black & Wiliam, 1998; Marzano, 2006).
TIP: Formative Assessment

Think about the degree to which your instructional practice is guided by formative assessments. Is it occasional, almost by accident when it happens? Or is it central to your daily interactions with students? How do you use the student data from formative assessments in your instruction? One idea that will be revisited later is to check in with all students at least two to three times each class period using high-value formative assessments.

Chapters 4 and 5 present lessons with descriptions of high-value formative assessments, but here I will quickly distinguish between high-value and low-value formative assessments. Low-value formative assessments (e.g., "Please raise your hand if you got 3.25 for exercise 3") do not offer meaningful information about student success or learning. They only measure the surface understanding—was the answer correct? A high-value formative assessment might include students discussing in small groups their specific approaches to solving the most challenging homework exercise. If they didn’t come to a solution, then what questions do they still have that need to be addressed? The teacher would chat with the small groups to see where confusion, understanding, and misconceptions arose. These interactions and the class discussion that follows would provide excellent data for the teacher to know where he needs to tweak or even completely restructure instruction to maximize conceptual understanding. Granted, more low-value formative assessments can be asked in a class period, but to what end? They rarely, if ever, improve instruction or learning.

Teacher Reflective Practice—Now Where?

You have facilitated lessons that have succeeded as well as some that have flopped. Are your successful days due to chance or intentionality? Could you recreate that success (or avoid the flop) on an upcoming lesson?

Teachers must reflect often and deeply on their practice if they are to improve instruction; without such reflective practice, teachers will not grow. Reflective practice involves looking back and evaluating the degree of success of the instruction, classroom interactions, and learning that occurred (Shepardson & Britsch, 2001; Wilson & Clarke, 2004). The National Board for Professional Teaching Standards (NBPTS) bases certification largely on the demonstrated abilities of teachers to reflect deeply and critically over their own practice (NBPTS, 1994, 2000, 2006).

A teacher’s reflective practice couples nicely with the formative assessments she conducts in the classroom. Furthermore, formative assessment and reflective practice provide a guide for improved teacher intentionality and deeper student self-awareness. When students become more self-aware of their learning (often referred to as metacognition), they are better able to ask questions and seek solutions for points that are unclear or confusing—which in turn results in fewer blank stares or "I don't know" statements from students. Instead, students become better able to articulate their strengths and weaknesses as a learner (e.g., "I understand what the problem is asking, but I’m confused about the steps involved in the calculation").

The 4E x 2 Instructional Model

Figure 3.1 (p. 30) shows how the three major learning components entailed in the model interrelate. Although all four components of inquiry—Engage, Explore, Explain, and Extend—may not necessarily be present in a given lesson, students must have an opportunity to explore the major concepts and then engage in the Explain phase for high-quality inquiry to occur.

Teachers often ask me, "How and when do I provide my notes, lecture, and practice materials
for students?" After students have had an opportunity to explore an idea—say, motion or force
in a science class—it is appropriate to provide notes or a lecture. In switching the order from
Explain-Explore to Explore-Explain, you and the students will quickly realize a difference: notes
or a lecture becomes a summary of what has been learned rather than the central aspect to
learning. Furthermore, after students have had the Explore-Explain experience, they can
practice problems related to the concept. Textbook or worksheet problem sets now have
meaning and value related to the explored concepts.

TIP: 4E x 2 Overview

It is easy to just read through each of the 4E components without taking time to
process what it means for your classroom, so after reading each "E" discussion,
pause and answer the following questions (just replace the word Engage with the
proper E component for each stage—Explore, Explain, Extend):

1. What are the major components of Engage?
2. What are examples of specific questions that you would ask during the
   Engage portion of learning?
3. Describe assessments that you can use or have used to assess student
   formative understanding during the Engage phase.
4. How could you tweak a past or future lesson to include an Engage
   component?

Here is a closer look at the sequence of phases that provides an opportunity for
students to explore a concept before we explain it.

Engage

Most of the teachers I work with at first equate Engage strictly with motivation. Engaging the
learner through a hook, mind capture, or perturbation does effectively initiate the learning
process, but engaging students in inquiry-based learning is more involved than just considering
student motivation. In the model, the Engage phase of inquiry includes all of the following
aspects:

- Probing prior knowledge,
- Identifying alternatives or misconceptions,
- Providing motivation and interest-inducing stimuli, and
- Developing scientific questioning (fundamental to both science and math classes).

Teacher intentionality is critical for determining the degree that each aspect is emphasized in a
given lesson. For instance, if the lesson or unit is inherently highly motivating, then you might
best spend your time focusing on revealing students' prior knowledge or misconceptions.

Effective questioning is critical during all phases of inquiry-based learning. Effective questions
to guide teacher facilitation during the four aspects of the Engage phase include the following
questions.

- What do you know about _____?
- What have you seen like this?
- What have you heard about _____ that you aren't sure is true?
- What would you like to investigate regarding _____?
TIP: Engage and Your Teaching

In an effort to link Engage to your teaching, write two or more questions that represent aspects associated with the Engage phase of instruction (e.g., your student's prior knowledge, motivation, and misconceptions).

Intentional, effective questioning is necessary, but not sufficient on its own, to determine if students are ready to proceed to the Explore phase, need a quick review, or need remediation before they can investigate the topic further. Formative assessments can provide content-rich scenarios to check your students' understanding and help to decide when to move on in the unit. Formative assessments for the Engage phase might include a discrepant event (i.e., a surprising or startling science demonstration that powerfully piques students' curiosity), a pre-test to gauge misconceptions, formative probes (Keeley, Eberle, & Farrin, 2005), or KWHL charts (van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001). A KWHL chart is a graphic organizer that facilitates learning by having students answer the following questions:

1. What do I know?
2. What do I want to know?
3. How do I find out?
4. What have I learned?

The more commonly known KWL chart leaves out a fundamental step for science and mathematics education that asks students to articulate how the investigation and learning will take place—for example, designing a procedure in science or a solution path in mathematics.

Integrating formative assessments into the Engage phase of the inquiry framework gives you a robust model for involving students in the three primary learning outcomes for inquiry-based teaching: conceptual understanding, the ability to perform scientific inquiry or mathematical reasoning, and an understanding about inquiry (NRC, 2000). Such assessments also require students to think metacognitively—thus making them aware of their own thinking. This way of thinking helps you become more intentional about your practice and encourage students to become invested in their own learning. In time, this process will help raise the achievement of all students—especially those who are low performing (Black & Wiliam, 1998; NRC, 2000).

When teachers reflect on what has occurred during the Engage stage, they gain valuable information that informs their decisions for the next steps of instructional practice. For instance, by asking yourself, "What did my students' prior knowledge tell me about their readiness to learn?" you are challenged to address specific student needs before plowing through more material. It may become evident that a group of students or even the whole class needs some remediation before proceeding. Another option is for you to address a deficit area (e.g., interpreting a graph, understanding energy conversions) as the lesson proceeds but before it is completed. Regardless of which path you choose, you now are making decisions based on data, with the intention of doing whatever is best to improve your students' learning. This approach is in sharp contrast to simply covering material and then finding out at the end of the unit that 60 percent or more of the class failed to understand the fundamental concept being studied—a frustrating outcome for the teacher and students alike. Instead, reflective practice allows teaching to be specific and targeted to students' needs.

Explore

Once you and your class have successfully navigated the Engage stage, you can lead students into the Explore phase. Note, however, that sometimes you might omit the Engage stage. For instance, if a previous lesson in the unit uncovered the students' prior knowledge, or if the
goals of the Engage and Explore phases can be collapsed into one instructional activity, then you may begin a lesson with Explore. Regardless of whether it is the first or second component of the lesson, Explore is a necessary and vital component of all successful inquiry learning experiences. The key aspects that define Explore include actively involving students in one or more of the following activities: predicting, designing, testing, collecting, and reasoning (Achieve, 2013; NGA Center & CCSSO, 2010; National Research Council, 2012).

**TIP: Explore**

Effective questions that help guide students through the Explore phase include the following:

- What if ... ?
- How can you best study this question or problem?
- What happens when ... ?
- What information do you need to collect?
- Why did you choose your method to study the question or problem?
- Pause now to write at least two more questions that you might ask during this phase of instruction.

Like their roles in the Engage phase, formative assessment and reflective practice are essential for keeping students directed along a meaningful learning path. The assessments can be contextualized into knowledge- or process-centered domains that focus on the individual, small groups, or whole class. Furthermore, formative assessment and reflective practice become meaningfully intertwined when individual responses are united with small- and large-group discussions. A common example is the think-pair-share learning strategy (Lyman, 1981).

Often teachers limit themselves to a fairly passive observational role when assessing student progress during Explore. Although it may be beneficial to let students wade in the muck at times, you may want to assume a more active role by providing guided prompts to encourage individuals or groups to think more deeply about the investigation at hand. For instance, you could ask groups of students to describe the procedure that they intend to follow, and then have them tell you how this approach will help answer the study question. Doing so encourages students to slow down and think about how they interact with the content and what their thought processes are. In addition, having students assess their own progress in real time gives you critical information to guide intentional instruction (Tobias & Everson, 2000) and excellent opportunities to deliver differentiated instruction (Tomlinson, 2003).

**TIP: Rethinking Your Lessons**

Think of two investigations for which your students could devise their own procedure or approach, even if they need a scaffold. With what concepts would this approach be advantageous, and what concepts would require a different strategy?

Reflective practice during the Explore phase may begin by reviewing individual student entries in science or math journals or by considering students’ proficiency in responding to their completion of the H portion of the KWHL chart (“How do I effectively study this question or
problem?”). For example, if you learn that data collection seems problematic for your science class, then you might initiate a brief discussion with small groups that focuses on how to gather data in meaningful ways. Such interactions with students emphasize assessment for learning instead of assessment of learning. Note that students play a pivotal role in teacher reflection. In the Explore phase, for example, the teacher should reflect on questions such as “How successful were students in setting up a scientific study? How meaningful were the data that they collected? How well are students able to justify and defend their approach?”

At this point, I hope you see that formative assessment and reflective practice have considerable overlap. In fact, when formative assessment and reflective practice merge, instruction is intentional and purposeful. More important, students are continually updated on their progress in relation to their goals (Marzano, 2006; Stiggins, 2005; Tobias & Everson, 2000).

Uniting inquiry-based instruction, formative assessment, and reflective practice during the Explore phase intentionally encourages deeper understanding. All three components are central throughout the instructional process, and the students and teacher no longer have to wait until the end of the investigation before knowing whether students truly “get it” (Black & Wiliam, 1998; Wiggins & McTighe, 2005).

**Explain**

As dynamic as the 4E x 2 model is, its framework is predicated on the Explore phase preceding the Explain phase. This order minimizes teacher-centered, confirmatory learning, which is often superficial. Instead, an Explore-before-Explain approach demands a student-centered learning environment. During the Explain phase, students begin to make sense of how their prior knowledge and alternative conceptions from the Engage phase align with findings from the Explore phase. This sense making occurs when students begin to communicate results and evidence (NRC, 2012). However, if explanation precedes exploration—which is typical in instruction that is not inquiry-based—students are thrust into passive learning situations that rarely challenge them to confront misconceptions or gaps in prior knowledge. So, when Explore precedes Explain, inquiry and content can be combined in highly engaging ways that help students reshape their previous conceptions to align with their new learning (Carin, Bass, & Contant, 2005).

During Explore, process skills are emphasized as students grapple with ideas. Then content becomes central during the Explain phase as the process skills are used to support higher-order thinking such as interpreting, justifying, and analyzing. In this Explore-before-Explain model, students from diverse backgrounds and with diverse abilities now have shared experiences as a basis for their claims and ideas. Other prior experiences that students bring to class enrich the learning, too, but learning is accessible to all students because the data collected and observations made were experienced by everyone in class. At the core of the Explain phase—and inquiry learning in general—students are involved in a recursive cycle between evidence and explanations. Ideally, the practices (or process skills) and content become embedded in the investigation.
TIP: Explain

Central aspects of the Explain phase include (1) interpreting data and findings; (2) providing evidence for claims; (3) communicating findings (written, oral, using technology); and (4) providing alternative explanations for findings. Effective questions you can pose during this phase include the following:

- What pattern(s) did you notice?
- What evidence do you have for your claims?
- How can you best explain or show your findings?
- What are some other explanations for your findings?

What additional questions could you use during the Explain phase?

Assessments for the Explain phase include lab reports, presentations, and discussions. These assessments can be formative or summative depending on the implementation. If you allow students to resubmit work or ask them to revise their work based on peer editing, then assessment becomes formative, emphasizing the learning process over the learning product.

Rubrics should be clear in their requirements but also flexible to allow for the unique expression of ideas. The goal is for students to understand concepts that are embedded within scientific or mathematical inquiries, not for them to fill out a worksheet properly. If interpreting data and providing evidence are central to a particular investigation, then students need to justify their claims using the documented data and results.

Improved learning has been noted when both formative assessment and metacognition are used to guide students (Bransford, Brown, & Cocking, 2000; Costa & Kallick, 2000). Metacognitive strategies create time for sense making, when students can reconcile their new knowledge with their prior knowledge. At the same time, the teacher is gathering valuable information to improve instruction. Furthermore, as students become mindful of their own learning, they start to use those strategies that assist their own progress. Graphic organizers such as KWHL charts and POE (predict, observe, explain) cycles (White & Gunstone, 1992) that may have been started during earlier phases can now be completed (e.g., “What have you learned? Explain your results.”). Concept maps can be used in a new way during the Explain phase: during Engage, they highlight knowledge gaps whereas during Explain, they illustrate links among new concepts, prior knowledge, and learned skills.

Reflective practice during the Explain phase entails the teacher considering points such as “How strong are the claims being made by the student? How well are students able to convey knowledge of key concepts? How accurate are their claims?” During the Explain phase, students begin to unite their prior knowledge with their investigation. Although teachers should have a basic expectation for minimum performance for all students, they also should challenge students to exceed this expectation according to their interests and backgrounds—a point in the lesson that offers an excellent opportunity for differentiated instruction.

Teachers often are confused regarding how and where student practice and teacher explanation should occur in inquiry lessons. First, both of these elements are critical to complete sense making and automation of skills, so it is a matter of when, not if. In inquiry where Explore precedes Explain, teachers still will find the need to clarify, explain, and draw the pieces together. Such a discussion fits nicely toward the end of Explain, after students have grappled with ideas. In addition, teachers find that what previously may have been a 40-minute lecture now becomes a 10- to 15-minute review, and students often need more practice with the concept, algorithm, or idea—or what mathematics teachers often refer to as skill automation or computational fluency. Now is the time for this critical practice to occur—after students have
explored the idea and have an understanding of the concept or equation.

**Extend**
The Extend phase plays a critical role in effective inquiry instruction. If learning is not reinforced and then internalized after Explain, when conceptual understanding begins to take hold, then students may quickly revert back to prior knowledge and the understandings (and possibly misconceptions) they had before the investigation. Providing one or more opportunities for students to apply their knowledge in meaningful, authentic contexts during the Extend phase helps students solidify their conceptual understanding and develop a more permanent mental representation.

Misconceptions are hard to revise and must be repeatedly addressed before lasting change occurs (Hestenes, Wells, & Swackhamer, 1992). Now, in the Extend phase, the mental disequilibrium students experienced during Engage and Explore begins to shift as the understanding and knowledge expressed during Explain are applied to both new situations and prior concepts. You can determine the number of Extend activities or the amount of time for this phase by considering the difficulty of the concept(s) being studied, the concept's importance in the curriculum, and the degree of understanding shown by all students.

**TIP: Extend**
During Extend, students are asked to apply, elaborate, transfer, and generalize knowledge to novel situations. Appropriate questions for the Extend phase include the following:
- How do you think _____ applies to _____?
- What would happen if ... ?
- Where can we use this concept in the real world?
- What consequences, benefits, and risks will come with certain decisions?
What other questions can you use with your students in an upcoming lesson?

At this point in the inquiry process, assessments typically are seen only as summative. However, by providing formative assessment during Extend, you can encourage students to think more deeply about their work. For example, you might split students into small teams to perform a new investigation or to solve a new problem that remains focused on the main concepts being studied. Or ask students to reflect in their journals on an area of weakness that you observed during a presentation.

Reflective practice is designed to address explicitly whether the content has been mastered or still needs work. This strategy, of course, can give you valuable information as you decide what to do next and how to improve future instruction. During the Extend phase, students should have an opportunity to deepen their cognition and solidify their knowledge on a given concept. In this stage of inquiry, you want to understand to what degree students are successful in transferring knowledge to new ideas and the quality of understanding that students can demonstrate. Reflective practice in this stage of instruction really is focusing on the degree of conceptual understanding. The importance of the concept to the subject will help you determine the level of proficiency and the depth of understanding to expect from all students.

**Dynamic Variations of the Model**
On first glance of the 4E x 2 model, you may find it logical to proceed sequentially through the phases, having students demonstrate their knowledge and understanding and moving along to
the next concept. Conceptual understanding, however, does not always follow such a linear, straightforward path. Just as there is not one scientific method (Windschitl, 2003), the 4E x 2 model's dynamic structure supports more than one approach. You may opt to vary from the model's progression through Engage, Explore, Explain, and Extend, but your decision should be guided by following whatever path best supports your students' strong conceptual development.

As I stated earlier, the one consistent tip is that Explore should always precede Explain. That said, several variations of the model are possible, each with a clear rationale.

**Variation 1: Multiple Extensions**
Engage-Explore-Explain-\(n\) (Extend) is the default or typical path expressed by the 4E x 2 Instructional Model. The \(n\) denotes that multiple Extend opportunities should be encouraged. The decision for how many, exactly, is based on (1) the depth of student knowledge conveyed thus far; (2) where in the unit or theme the Extend investigation occurs; (3) the relative importance of concepts, standards, and skills to the overall goals for the course; and (4) whether prior content, skills, and ideas that have been studied can be embedded into the essential focus of the investigation. So, if students understand at a significant level and can apply the knowledge to several different situations, then you can confidently move forward to a new concept or idea. If you have introduced a new concept that will be reinforced later by another, related activity, then you may want to opt to minimize the number of Extend opportunities. However, if your students are not likely to see this information again, then employing several Extend opportunities makes sense. Likewise, if several concepts throughout the course overlap with the current concept being studied, then multiple Extend opportunities are useful.

**Variation 2: Multiple Explore-Explain Cycles**
Another variation, in a science or a math class, is to begin with Engage and then lead three consecutive cycles of Explore-Explain before implementing a final Extend. This approach is useful when your class is studying three closely related ideas. For instance, displacement, velocity, and acceleration could be studied in three different investigations before students transfer their prior and current learning (Extend) to motion in general.

**Variation 3: Multiple Explores**
A third variation entails Engage-Explore1-Explore2-Explore3-Explain-Extend. This approach is applicable when students are exploring one scientific question or mathematical idea several ways before they explain their findings. For instance, students could investigate three different plant types before seeking to apply what they studied to a larger ecosystem application. In a math class, students might study the patterns they find by exploring three different linear contexts before they try to explain their findings. Note that in these examples, Engage was used only during the initial iteration because alternative conceptions should be clearly known and continually addressed during subsequent investigations.

**Concluding Thoughts**
The three learning constructs—inquiry-based instruction, formative assessment, and reflective practice—included in the 4E x 2 Instructional Model all have a positive impact on teaching and learning (Black & Wiliam, 1998; Bybee et al., 2006; Tobias & Everson, 2000). Unifying the constructs into one coherent model lets teachers focus their instructional practice on these core fundamentals, improving their practice. While the 4E x 2 model is a dynamic inquiry-based instructional model, it also reminds us of the importance and interrelationship among these three essential learning constructs.

Although the model does not address everything we need to know about effective practice, it provides a meaningful, coherent structure to help teachers plan, implement, and assess their instruction. Teachers using this model may need to devote significant time, at least initially, to lesson planning, but I am confident that the result of deeper, more meaningful learning will pay
dividends in the long run. Also, the time required for planning decreases dramatically as inquiry-based instruction becomes more familiar. A dynamic web tool provides standards-based lessons and a template to help teachers create new lessons. Chapter 4 and 5 also describe several examples of lessons and units that incorporate the model in science and mathematics settings.