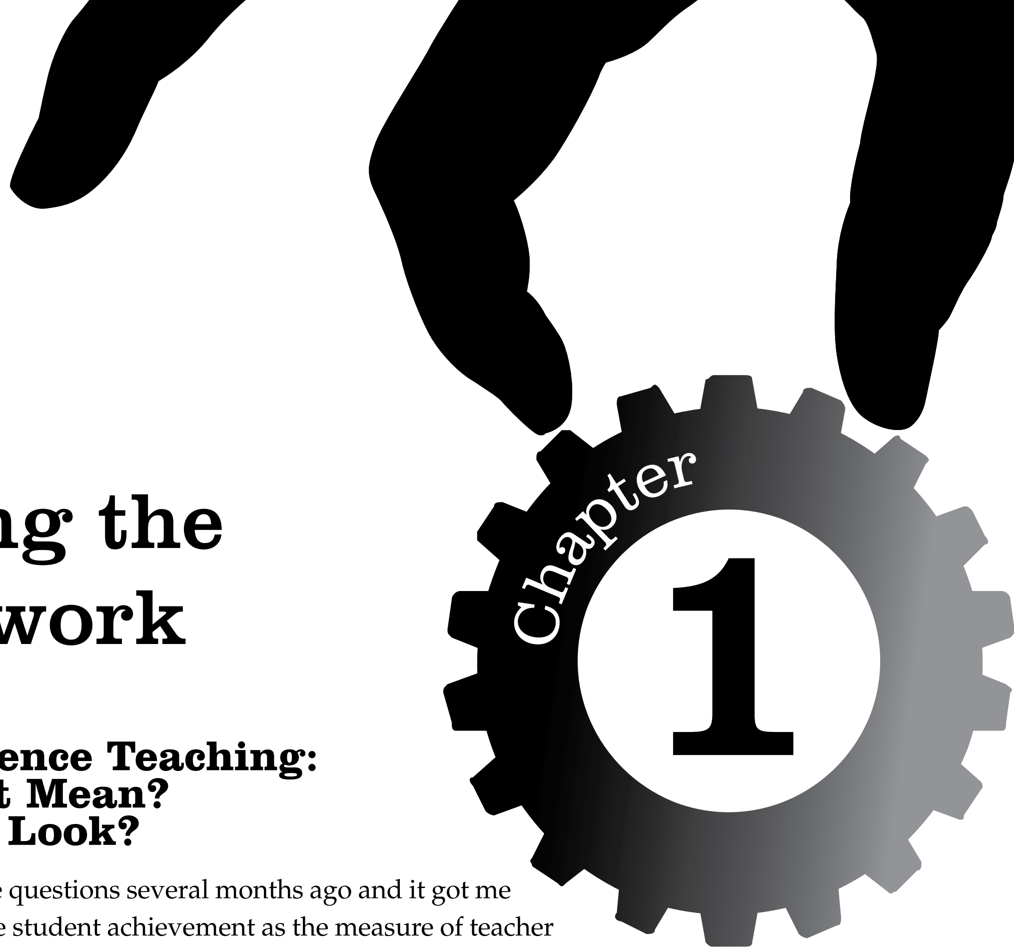

Building the Framework

Effective Science Teaching: What Does It Mean? How Does It Look?

A friend asked me these questions several months ago and it got me thinking. Should we use student achievement as the measure of teacher effectiveness? If improved student achievement is one indicator of effectiveness, we can look at the question of teacher effectiveness with this lens and consider inputs to teachers and outputs as determined by student measures that include engagement, conceptual understanding, and even increased achievement. If we consider science teacher capabilities as part of the inputs, then we need to include teachers' understanding of science concepts and their understanding of when and how to teach the concepts—their pedagogical content knowledge (Shulman 1987). To be more effective as teachers, we need to participate in professional development that increases our content understanding and our ability to decide when and how to present the content to students. But having content knowledge and pedagogical content knowledge is only part of what it means to be an effective teacher.

If we consider teacher effectiveness from the perspective of supporting student learning, then to be effective, teachers need to know instructional strategies that help students learn. In other words, we need pedagogical knowledge. Pedagogical knowledge also includes knowing how to provide learning opportunities that meet the individual needs of students, place the learner at the center of instruction, and facilitate learning opportunities that develop students' conceptual understanding. Since *learner-centered* means different things to different teachers, we use the term to refer to classroom environments that include the existing knowledge, skills, attitudes, and beliefs that our students bring with them. Learner-centered instruction occurs in classrooms that emphasize opportunities for students to construct their own meanings. Instruction begins with what students think and know and bridges their ideas to the subject matter we present (Bransford, Brown, and Cocking 2000).

What Does Research Say About Effective Science Instruction?

If you were to ask science teachers or teachers of elementary school science what effective teaching looks like, the answers would clearly depend upon a variety of factors such as how long they have been teaching, their understanding of learning theory, their ability to understand and apply recent brain research, their content and pedagogical content knowledge, the coaching and mentoring that they received during and after their teacher preparation work, the professional development that they receive, and the professional collaboration and conversations that are part of their day-to-day teaching. This is not a comprehensive list by any means, but it speaks to some of the different influences on teachers' conceptions of effective science teaching and their levels of preparation to design and provide effective teaching and subsequent learning for their students.

When reviewing the research base around effective science teaching there are several resources that provide guidance and insights that can be used to answer the questions "What does effective teaching mean?" and "How does it look?" As mentioned previously, the National Science Education Standards (NRC 1996) provide a framework for what effective science teachers know and do. *Looking Inside the Classroom* (Weiss et al. 2003), a National Science Foundation study, provides additional insights about effective science teaching. According to the study, the goal of all instruction should be to develop students' conceptual understanding. As a result, teachers need to provide students with opportunities to learn the content and be clear about the learning goals for each lesson (specific concepts being addressed). In addition, researchers conducting this study found that lessons judged to be of low quality often lacked meaningful opportunities for discussions or student sense-making and instead consisted of activities for activities' sake, with no clear learning target. As a result of their findings, the observers in the study concluded that "teachers need a vision of effective instruction to guide the design and implementation of their lessons" (p. xiii). It also was clear from the study that teacher content knowledge alone is not sufficient to prepare teachers to provide high quality instruction. A clear understanding of effective instructional practices (pedagogical knowledge) and pedagogical-content knowledge are also needed.

In other words, to adequately develop student understanding of science concepts, we have to go beyond a general understanding of effective instructional strategies and have an in-depth knowledge of the content and common research-based student misconceptions. With that understanding, we need to know when and how to introduce and develop the concepts in class to address students' prior conceptions. We must plan our instruction to engage students beyond a superficial level by using a variety of representations and instructional strategies which make sense to the learner and take into account individual learner needs (Shulman 1986, 1987). We must understand students' scientific thinking and be able to generate effective representations that result in student learning. This cannot happen unless we are prepared with both content and pedagogy and take the time to assess for student thinking.

Figure 1.1 (p. 4) provides lists of the characteristics of effective science lessons that the researchers looked for in the classrooms involved in the *Looking Inside the Classroom* study. The characteristics of effective lessons, along with the research findings, add to our understanding of what it means to offer effective science instruction.

Effective teaching also means assessing what students know as instruction occurs and taking that information into account to adjust instruction. This focus on formative assessment processes in science classrooms is consistent with the research on how students learn science (Minstrell 1989; Donovan and Bransford 2005). Findings from the meta-analysis on how students learn science emphasized the following important principles of learning:

- Assess for prior student understanding of the science concepts.
- Actively involve students in the learning process.
- Help students be more metacognitive so that they can acknowledge the science concepts they understand, the goals for their learning, and the criteria for determining achievement of the learning goals.
- ensure that learning is interactive and include effective classroom discussions.

In a recent publication titled, "Effective Science Instruction," Banilower and colleagues (2008) provide a summary of studies on science learning and suggest an instructional model based on that research. They identify five features of effective science instruction. The first feature is motivating students since students are unlikely to learn without some level of motivation. Second, it is important to elicit students' prior knowledge to find out what their ideas are about the topics or concepts being studied. We know that students have ideas of their own about how the natural world works and some of their ideas will make it difficult for them to learn new ideas. Third, to engage students intellectually with the content, we need to link learning activities to the learning targets. Fourth, effective science instruction helps students think scientifically. This means students are able to critique claims using evidence. Finally, effective science instruction includes opportunities

Figure 1.1
Characteristics of Effective Science Lessons

Quality of Lesson Design	Quality of Noninteractive/Dialogic (NI/D)
❏ Resources available contribute to accomplishing the purpose of the instruction. ❏ Reflects careful planning and organization. ❏ Strategies and activities reflect attention to students' preparedness and prior experience. ❏ Strategies and activities reflect attention to issues of access, equity, and diversity. ❏ Incorporates tasks, roles, and interactions consistent with investigative science. ❏ Encourages collaboration among students. ❏ Provides adequate time and structure for sense-making. ❏ Provides adequate time and structure for wrap-up.	❏ Teacher appears confident in ability to teach science. ❏ Teacher's classroom management enhances quality of lesson. ❏ Pace is appropriate for developmental levels/needs of students. ❏ Teacher is able to adjust instruction according to level of students' understanding. ❏ Instructional strategies are consistent with investigative science. ❏ Teacher's questioning enhances development of students' understanding/problem solving.
Quality of Science Content	**Quality of Classroom Culture**
❏ Content is significant and worthwhile. ❏ Content information is accurate. ❏ Content is appropriate for developmental levels of students. ❏ Teacher displays understanding of concepts. ❏ Elements of abstraction are included when important. ❏ Students are intellectually engaged with important ideas. ❏ Appropriate connections are made to other areas. ❏ Subject is portrayed as dynamic body of knowledge. ❏ Degree of sense-making is appropriate for this lesson.	❏ Climate of respect for students' ideas, questions, and contributions is evident. ❏ Active participation of all is encouraged and valued. ❏ Interactions reflect working relationship between teacher and students. ❏ Interactions reflect working relationships among students. ❏ Climate encourages students to generate ideas and questions. ❏ Intellectual rigor, constructive criticism, and challenging of ideas are evident.

Adapted from Weiss, I. R., J. D. Pasley, P. S. Smith, E. Banilower, D. Heck. 2003. *Looking inside the classroom: A study of K–12 mathematics and science education in the United States*. Chapel Hill, NC: Horizon Research Inc.

for students to make sense of what they are learning by comparing their ideas to those presented by the teacher.

Another significant element of effective teaching comes from the research on formative assessment. Formative assessment provides ways for teachers to focus instruction on student learning. Incorporating formative assessments as part of teacher practices results in teaching and learning that supports an environment focused on learning for all, as Black and colleagues note,

> formative assessment is a process, one in which information about learning is evoked and then used to modify the teaching and learning activities in which teachers and students are engaged.... Feedback can only serve learning if it involves both the evoking of evidence and a response to that evidence by using it in some way to improve the learning. (2003, p.122)

The recent work on learning progressions as part of a formative assessment process provides additional guidance for effective teaching (Heritage 2007). Learning progressions can be created by districts to address coherence across the K–12 curriculum. For our purposes, we are referring to the sequencing of learning targets within a unit of study that leads to student mastery of the big ideas and key concepts. When teachers identify the learning goals (learning targets) in a learning progression and identify criteria for successfully meeting the goals, they can determine student achievement gaps. If students perceive the learning gap as too large, they also perceive the goal as unattainable. If students perceive the gap as too small, they might believe that closing it is not worth their effort (Sadler 1989). Clearly, effective teaching means identifying the "just right" gap for students.

Building a classroom environment that is conducive to learning is essential. Even when teachers clearly understand their content, and design and implement high-quality lessons, teaching will not be effective if the classroom environment does not provide a safe place for students to learn (Marzano 1997). Marzano's work, and that of others (Haertel, Walberg, and Haertel 1981; Bransford, Brown, and Cocking 2000), underscores the idea that effective teaching includes building an environment that is conducive to learning. Teachers' belief systems (how to teach and student accountability) greatly impact their abilities to create an environment where they can work collaboratively with students. That's why it is important to address teacher beliefs, even though it is challenging to do so. Fortunately, research-based strategies are available to help with this task.

As noted previously, effective science teaching develops students' understanding. A recent research-based publication from the National Research Council (NRC), titled *Taking Science to School* (2007), reminds us that in general, students have the capacity to develop understanding of science concepts, but they lack opportunities to do so. This report is not talking about special needs students but the majority of our students who are not achieving in science because they are not provided with sufficient learning experiences. To be effective, science teaching must, first and foremost, provide students with opportunities to learn important concepts. A next logical step is to use research-based instructional strategies to engage students with learning in ways that support development of conceptual understanding (Marzano 2003).

What Do We Know About the Barriers to Effective Instruction?

As science teachers, we have our own ideas about what constitutes effective science teaching. We use a variety of strategies to meet our students' needs and from experience select those that work best for us and our students. It doesn't take very many years of teaching to realize that, even with a clear idea of what effective science teaching is, you will face a variety of challenges that will keep you from being effective with each of your students. Some of these barriers to effective teaching are difficult to address, even when we know what is needed. We may be at a loss for ways to deal with some of the other challenges because we never imagined having to face them.

At a recent teacher workshop, I asked a group of science teachers to identify their current challenges and issues. Their concerns ranged from a lack of resources to a change in students' preparation (e.g., little instruction in science at the elementary levels and a lack of time to teach all of the standards and prepare students for large-scale state assessments). Figure 1.2 provides a visual representation of some of their concerns.

With the No Child Left Behind legislation, there has been a shift in education to a strong system of accountability for schools and districts. This is now a focus area for individual teachers as well. We are now being asked by administrators to be accountable for the learning of all of our students. This shift poses a huge challenge—teachers must find effective ways to differentiate instruction to meet the needs of each student and address gaps in learning. Obviously, many factors influence student achievement. Research, such as that reported in *What Works in Schools* (Marzano 2003), provides guidance about the factors over which schools and teachers have some control, and suggests actions that schools and teachers can take to make a positive difference in student achievement.

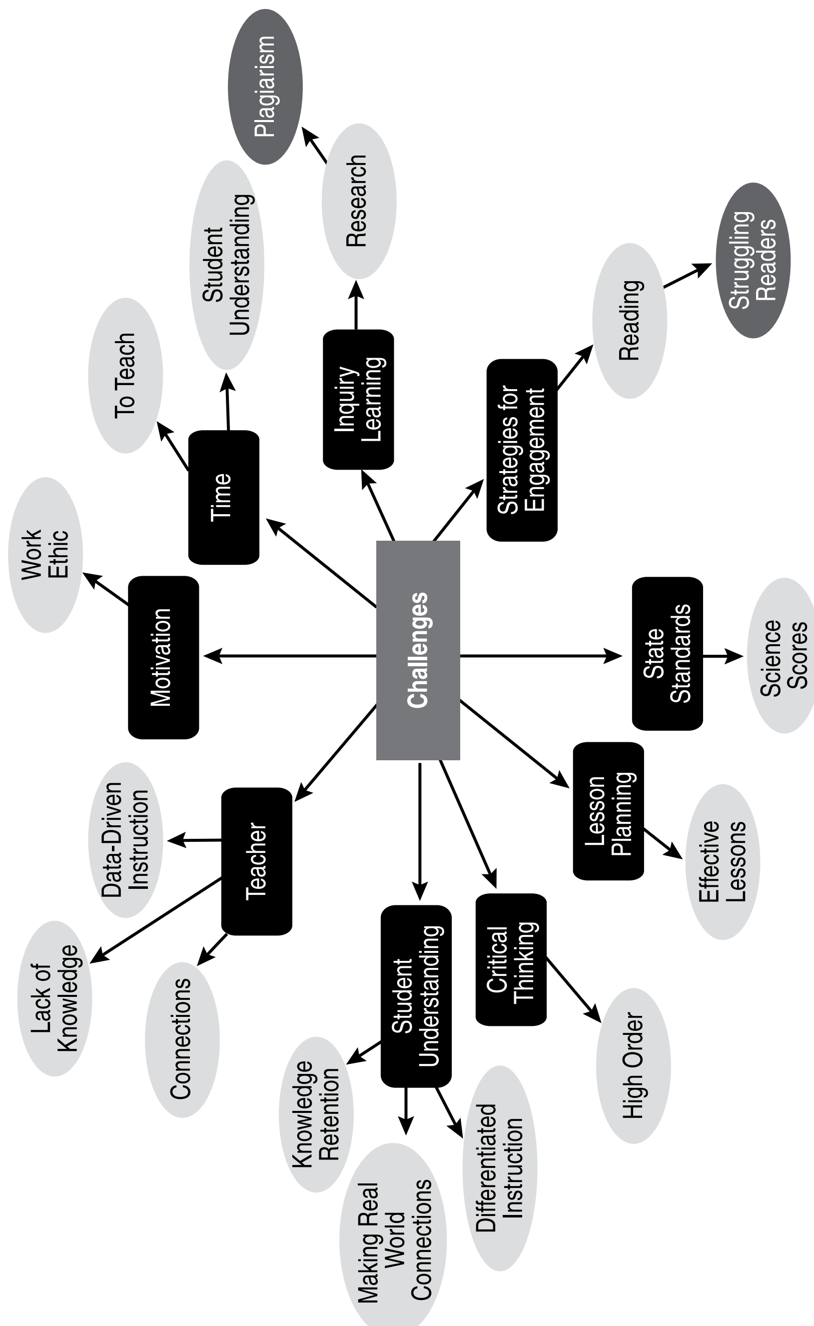

Figure 1.2
Challenges Concept Map

Table 1.1
Influences on Student Learning

 **School**	1. Guaranteed & Viable Curriculum 2. Challenging Goals & Effective Feedback 3. Parent & Community Involvement 4. Safe & Orderly Environment 5. Collegiality & Professionalism
 **Classroom**	6. Instructional Strategies 7. Classroom Management 8. Classroom Curriculum Design
 **Student**	9. Home Environment 10. Learned Intelligence/Background Knowledge 11. Motivation

Adapted from *What Works in Schools: Translating Research into Action,* by R. J. Marzano. Alexandria: VA, ASCD.

Table 1.1 summaries the 11 influences that need to be addressed in effective schools at the school level, classroom level, and student level. Although schools and teachers do not control a student's home life, this research emphasizes that there are actions schools and teachers can take to leverage parents' influence on their children's education. Also on the plus side, we can do something in classrooms to increase students' background knowledge and to motivate them.

Why Did We Develop the Content-Understanding-Environment Framework?

For the past five years, more and more research-based information has been published with clear implications for science teachers. We recognize that it is difficult for teachers to keep up with all of the research reports and revise their teaching to reflect the recommendations from research. To assist teachers with this task, we developed the Content-Understanding-Environment (C-U-E) framework. This framework incorporates key findings from research and is easy to use and remember. Further, current professional development for science teachers usually focuses on only one aspect of teaching and learning, which makes it difficult for teachers to formulate a "big picture" of effective science teaching. The C-U-E framework presents the research in a coherent format that creates a vision of effective science instruction. We acknowledge that the framework does not reflect an exhaustive review of research, but it does include a variety of research from science education and general education and is organized in a way that allows you to readily add new research findings to the ones featured in the book. As a result, the framework is a tool that can serve you well for years to come.

Our goal was to use research findings—those summarized previously in this chapter and other selected research—to create an instructional framework that would be easy for teachers to remember and include recommendations that could be implemented by any teacher. These recommendations are not restricted to K–12 teachers; they can be used by teachers in higher education and, specifically, in teacher preparation programs.

The Content-Understanding-Environment framework is designed to improve science teachers' abilities to deliver effective instruction to diverse student learners. Its effectiveness is due in large part to two qualities. First, all recommended strategies are founded upon a research base with positive links to improved student achievement. Second, the three-part framework helps teachers discern where improvements to their instructional practice are needed and how to take actions that are within their control. This book is based on the premises that delivering 100% effective science lessons is a lifetime professional quest, and immediate and steady improvements can be made by teachers at all stages of their careers.

Before we explain the framework further, we encourage you to reflect on your own teaching practices. To help you do that, we include a self-assessment tool that will prompt you to think about the strategies you currently use to support students' acquisition of significant content, develop student understanding, and create a climate conducive to learning. Figure 1.3, Figure 1.4, and Figure 1.5 encourage you to capture where you are at this moment. There are also places on the documents for you to identify areas you would like to work on or learn more about.

Figure 1.3
Content

Unit of Study/Course/Grade Level
Self-Assessment Rate the following statements using this scale: Not at all 1 2 3 4 5 To a high degree **To what degree do the lessons in my units** __ contain science content that is significant and worthwhile __ contain science content appropriate for the developmental levels of the students __ engage students intellectually with important ideas relevant to the unit's essential understandings __ portray science as a dynamic body of knowledge continually enriched by conjecture, investigation, analysis, and/or proof/justification __ allow for developmentally appropriate sense-making of the science content __ align assessments with the targeted benchmarks __ allow students a variety of ways to demonstrate their knowledge __ promote a context for formative assessments with the purpose of adjusting instruction __ utilize rubrics that help students understand the criteria for quality work __ allow for teacher feedback with the purpose of providing students guidance for improving their performance and clarifying their understanding
My Goals for Improving Instruction Related to Content and Assessment
My Focus During the Book Related to Content and Assessment

Figure 1.4
Understanding

Unit of Study/Course/Grade Level
Self-Assessment Rate the following statements using this scale: Not at all 1 2 3 4 5 To a high degree **To what degree do I feel comfortable** __ adjusting my own questioning and pacing given the outline of lessons in my unit of study **To what degree do the lessons in my unit of study** __ indicate opportunity for quality questioning __ provide adequate time and structure for wrap-up __ provide strategies and activities that reflect attention to students' preparedness and prior experience __ provide opportunity for students to question, reflect, and challenge ideas __ provide adequate time and structure for "sense-making" __ portray a dynamic body of knowledge continually enriched by conjecture, investigation analysis, and/or proof/justification __ provide opportunities for interactions among students that reflect collegial working relationships
My Goals for Improving Instruction Related to Student Understanding
My Focus During the Book Related to Student Understanding

Figure 1.5
Environment

Unit of Study/Course/Grade Level

Self-Assessment
Rate the following statements using this scale:

Not at all				To a high degree
1	2	3	4	5

To what degree do the lessons in my unit of study develop and value

- __ active participation of all
- __ a climate of respect for students' ideas, questions, and contributions
- __ a collaborative approach to learning among the students
- __ ______________________________

To what degree do I actively plan instruction to

- __ encourage and allow for critical, creative, and self-regulated thinking
- __ help students develop positive attitudes and perceptions about classroom tasks and climate
- __ provide timely feedback
- __ provide appropriate recognition
- __ reinforce effort
- __ ______________________________

To what degree do I actively plan instruction to

- __ intellectual rigor
- __ constructive criticism and the challenging of ideas
- __ ______________________________

My Goals for Improving Instruction Related to Environment

My Focus During the Convention related to Environment

The C-U-E Framework

The three elements of content, understanding, and environment are equally essential to improving student learning. A weakness in any one will undermine the effectiveness of the other two. We designate **Content** as the first element of the framework to underscore the idea that designing effective science lessons can only occur when we are clear about the big conceptual understandings and key concepts that will be included in the unit. Identifying the significant, worthwhile content also helps us begin thinking about how to sequence lessons as part of a coherent science unit and a coherent science program. We should think first about content at the course of study or grade level and then at the individual unit of study level. Creating that big picture and identifying the big ideas within a course or grade level are necessary steps before going to the smaller grain size of individual lessons.

Teachers have expressed two primary concerns with regard to content: insufficient time for students to develop conceptual understanding and too much content to cover to prepare students for statewide assessments. Aligning the science curriculum, instruction, and assessments to state and district standards is yet another challenge teachers face. To address time and coverage issues, we need tools and clear procedures to identify all of the content embedded in standards and benchmarks. This "unpacking" of standards and benchmarks helps us ensure that we focus instruction on the important learning objectives. Using lesson and unit templates helps us address alignment issues.

Since our focus is clearly on designing effective science lessons with effective science instruction to deliver those lessons, we also talk about some of the features of ineffective practices at the same time we are recommending effective strategies. Some of these ineffective practices are obvious, such as teaching lessons as if students were empty containers to be filled with science knowledge that we tell them, sometimes over and over again. We also want to guard against treating students as passive learners—learning is something students have to *do* themselves. In the remaining sections of this chapter, we introduce the recommended strategies for each component of the framework. Chapters 2, 3, and 4 provide details and tools related to the recommended strategies.

Identifying Important Content

When we talk about identifying important content, we mean starting unit planning and then lesson planning with clarity about the knowledge students should acquire—the information and ideas they should understand and the skills and processes they should be able to perform. Planning also includes identifying the criteria for successful demonstration of learning and deciding how students will demonstrate the required content knowledge. Once the big ideas and key concepts are clearly identified, we can identify specific learning targets as we plan activities that are sharply focused on helping students achieve conceptual understanding and procedural fluency. Intellectually engaging students with the content means that we need to include relevant, emerging content (e.g., plasma state of matter, genetic engineering, nanoscale science and technology) that captures the interests of our students and motivates them to learn. The specific strategies recommended for addressing the content element of the framework are included in Table 1.2 on identifying the important content. The focusing question "Why am I doing this?" asks teachers to reflect on the lesson they are about to teach and to think about the important learning target for that lesson. If a clear learning goal can't be articulated and the answer is "I don't know," then it is time to revise the unit or lesson and work on getting the learning target identified! We do not have time to waste in class, and doing an activity for activity's sake will not support student achievement.

Table 1.2
Identifying Important Content

<table>
<tr><td>Strategy 1: Identifying Big Ideas and Key Concepts
Identify "big ideas," key concepts, knowledge, and skills that describe what the students will understand.</td><td rowspan="6">Why am I doing this?

What are the important concepts and scientific ideas included in the lesson?</td></tr>
<tr><td>Strategy 2: Unburdening the Curriculum
Prune extraneous subtopics, technical vocabulary, and wasteful repetition.</td></tr>
<tr><td>Strategy 3: Engaging Students With Content
Create essential questions that engage students with the content.</td></tr>
<tr><td>Strategy 4: Identifying Preconceptions and Prior Knowledge
Identify common preconceptions and prior student knowledge.</td></tr>
<tr><td>Strategy 5: Developing Assessments: How Do You Know That They Learned?
Develop assessments that correlate to the conceptual understanding and related knowledge and skills.</td></tr>
<tr><td>Strategy 6: Sequencing the Learning Targets Into a Progression
Clarify and sequence the learning targets into progressions to focus instruction on building conceptual understanding. Align learning activities with learning targets.</td></tr>
</table>

Developing Student Understanding

Student learning is much better understood today as a result of important research findings over the past 15 years. We know from this research that making lessons more engaging, helping students make meaning and connections among science concepts, and developing each student's ability to learn are all part of developing student understanding.

One significant finding from research is that students come to us with prior knowledge and have ideas of their own to explain the natural world around them. If we do not elicit those ideas and confront the conceptions that are contrary to science knowledge, our students will continue to believe their own misconceptions. Classroom discussion that gets students to think about their thinking is an important strategy for helping them make sense of science concepts. Classroom discussions that promote sense-making are fueled by higher-order questions. Such questions also help students engage intellectually with ideas—a necessary ingredient for students to truly understand science concepts. Intellectual engagement is supported in classrooms that are inquiry-based. In these classrooms, students learn how to develop explanations based on evidence that has been critiqued and

Table 1.3
Developing Student Understanding

<table>
<tr><td>Strategy 1: Engaging Students in Science Inquiry
Engage students in science inquiry to develop understanding of science concepts and the nature of science.</td><td rowspan="6">Who's working harder?

A learner-centered classroom is necessary to develop conceptual student understanding.</td></tr>
<tr><td>Strategy 2: Implementing Formative Assessments
Make use of formative assessments to gather feedback on student progress toward understanding.</td></tr>
<tr><td>Strategy 3: Addressing Preconceptions and Prior Knowledge
Build on prior knowledge and address preconceptions.</td></tr>
<tr><td>Strategy 4: Providing Wrap-Up and Sense-Making Opportunities
Provide daily opportunities for wrap-up that support student sense-making.</td></tr>
<tr><td>Strategy 5: Planning for Collaborative Science Discourse
Develop student understanding through collaborative science discourse.</td></tr>
<tr><td>Strategy 6: Providing Opportunities for Practice, Review, and Revision
Teach concepts in depth by allowing students to continually refine their understanding through practice, review, and revision.</td></tr>
</table>

discussed in the classroom. The specific strategies recommended for developing student understanding are provided in Table 1.3 (p. 15).

Creating a Positive Learning Environment

Interactions, routines, and informal feedback that occur every day in the classroom can undermine or enhance learning. Research on learning environments and reflection on decades of my own and other teachers' experiences have yielded very specific advice on practices that support learning. The strategies included in this part of the framework address how to motivate students, support students in taking responsibility for their learning, and develop positive working relationships with and among students.

Elementary teachers often are expert at creating positive classroom climates. They know what kinds of reinforcement and feedback students need. In elementary school, students usually want to please their parents and teachers and are intrinsically motivated to learn science. When students reach middle school and high school, they often are more interested in listening to and pleasing their friends. As a result, secondary teachers often find it challenging to motivate their students. Fortunately, there are some clear recommendations about how to engage these students collaboratively to create a positive classroom climate.

Table 1.4
Creating a Positive Learning Environment

Strategy 1: Believing All Students Can Learn Show through your actions that you believe all students have the ability to learn.	**What's really important?** **How do I create a positive learning environment?**
Strategy 2: Thinking Scientifically Teach students to think scientifically.	
Strategy 3: Developing Positive Attitudes and Motivation Develop positive student attitudes and motivation to learn science.	
Strategy 4: Providing Feedback Give timely and criterion-referenced feedback.	
Strategy 5: Reinforcing Progress and Effort Keep students focused on learning by reinforcing progress and effort.	
Strategy 6: Teaching Students to be Metacognitive Involve students in thinking about their ideas and assessing their own progress.	

From a science perspective, we need to help students think scientifically, which includes taking risks in class by sharing their explanations and ideas about scientific concepts and phenomena. They must be able to share their ideas without fear of being ridiculed by their peers. Helping them act and think like scientists provides the structure for classroom discussions where it is safe for them to take such risks. The specific strategies recommended for creating a positive learning environment are included in Table 1.4. Remember, if we do not have a positive classroom environment, all of our efforts to provide instruction that addresses important content and to develop student understanding will likely not be effective.

Tools for Using the Framework to Design Lessons

To support your work with lesson revision and improvement, this chapter includes two "tools." The first tool is a lesson design template that includes abbreviated versions of the strategies included in the framework. This tool can be used as a "guiding document" for designing lessons. In addition to the tool for designing new lessons, we provide another template that can be used for revising existing lessons. This second lesson design template can also be used with existing activities, such as those provided in textbook-based materials; it asks you to be explicit about how you will address the C-U-E components. Some of the components of the lesson design framework are featured in Figure 1.6. This provides a quick reflection tool to help you determine what revisions are needed to improve the existing activity.

Figure 1.7 (p. 18) is a second tool to evaluate an existing lesson or activity that once again asks you to focus on the key characteristics of content, understanding, and positive classroom environment. This tool could be used by teachers who teach the same course or grade level to prompt discussions about the important learning targets, strategies that could be used to support student understanding, and ways to provide a supportive learning environment for all students.

Figure 1.6
Lesson Design Framework

1. **Content—Identifying Important Content**
   a. Identify key concepts and lesson objectives.
   b. Identify common preconceptions (misconceptions) and prior knowledge.
   c. Identify knowledge (facts and vocabulary) and skills.

2. **Understanding—Developing Student Understanding**
   a. Use inquiry-based activities that engage students.
   b. Implement formative/summative assessments to determine if students are learning (application).
   c. Provide sense-making and wrap-up activities (open-ended questions).
   d. Provide time for collaborative science discourse (discussion of multiple points of view and sharing of ideas).

3. **Environment—Creating a Positive Learning Environment**
   a. Include opportunities for students to work and think like scientists—reasoning, gathering data, using evidence-based thinking, communicating results.
   b. Reinforce progress and effort.
   c. Plan for criterion-referenced feedback.
   d. Provide multiple opportunities to learn.
   e. Ask students to assess their own progress.

Figure 1.7
Key Characteristics of Content, Understanding, and Positive Classroom Environment

Lesson: ______________________________
Evaluator: ______________________________ **Date:** __________

1. Make notes of the strengths and weaknesses of this lesson.
2. Use your notes to prepare a summary and specific recommendations for improvement of the lesson design.
3. Keep in mind that our goal is to improve student understanding of important content.

1. **Big idea, key concepts, knowledge and skills** are described in terms of student understanding ➔ are accurate ➔ don't reinforce misconceptions
2. **Summative assessment** provides evidence of learning ➔ has to relate back to key concept ➔ students can demonstrate high cognitive ability when demonstrating conceptual understanding
3. **Essential questions or activities** engage students in the content and motivate them to learn ➔ may be a discrepant event ➔ should be age appropriate
4. **Students' prior knowledge** is acknowledged and built upon ➔ background info on the concept for teachers ➔ what are the prerequisite student learning's ➔ how do we know what the students know (drawing, prediction, response to essential question…) ➔ what are the common preconceptions
5. **Formative assessments** measure progress toward student understanding and inform instruction ➔ include a variety of opportunities ➔ give example and invite teachers to create their own

Figure 1.7 (cont.)
Lesson Design Framework

Lesson: ______________________________
Evaluator: ______________________ **Date:** __________

6. Activities provide students with opportunities to **make sense of key concepts** ➔ wrap-up supports student sense-making ➔ summary, oral or written ➔ quality questioning by teacher or re-engaging with essential question ➔ probing questions or problems ➔ analogies, visual representations
7. Students are involved in **collaborative science discourse** ➔ is a community of learners being developed? ➔ are there questions that encourage collaborative discourse? ➔ are student ideas encouraged?
8. Students engage in **thinking scientifically** ➔ hypothesizing/inferring ➔ reasoning based on evidence ➔ critique and defend answers ➔ gives priority to evidence

Mid-continent Research for Education and Learning. 2005. *Classroom instruction that works: Facilitator's manual.* Aurora, CO: McREL.

Many districts are currently adopting and implementing kit-based instruction for elementary science. It is not always clear what key concepts are being taught during the kit-based lessons and students often get focused on facts and vocabulary rather than on understanding the science ideas. This tool will help you move beyond a focus on the activities of the science kit to a focus on the important ideas that students should learn as a result of the activities.

In Summary

Becoming a good science teacher doesn't just happen; it develops as a result of a variety of experiences over time. It is a result of continuous reflection about our practice that incorporates lessons learned. In the beginning, our college preparation provides theory, practice, and role-modeling by our professors. Student teaching provides some of our first mentoring and hands-on experiences. As novice teachers we observe and mimic the practices of our more experienced colleagues, and benefit from the advice and mentoring of the principal, fellow teachers, and—for the lucky few—professional development designed specifically for us as new science teachers. We then begin to collect resources—books on recommended topics, textbooks and materials, professional development experiences, and a mental checklist or a journal of what works and what doesn't work. We also learn from feedback about the quality of our practice. This feedback comes from supervisor evaluations, the students' test performance, and student and parent comments. All of these experiences contribute to our instructional skill, but as you'll learn throughout this book, there are specific actions we can take to further enhance the quality of our instruction and the effectiveness of our lessons.

During this journey from new teacher to professional science educator, how do we know if we are doing a quality job? What is the standard for effective science teaching and how good is good enough? How well are we meeting the NSES Teaching Standards (NRC 1996)? Is there a "state of the art" level of teaching that can be achieved? How do we know what we don't know—but should? And if research tells us what we should do to improve teaching and learning, how can we incorporate those findings into our teaching practices? All are good questions without simple answers.

Partial answers can be found in standards documents. For example, the National Science Education Standards describe professional teaching standards. These standards provide descriptions of what a professional science teacher should know and be able to do. The NSES document provides information that teachers can use to determine a level of science literacy that teachers must have, not just to prepare an informed citizenry, but as the baseline for teacher content knowledge.

Research provides additional guidance about effective science teaching, although that guidance is limited with regard to some aspects of teaching. The information and tools provided in this book reflect the standards for science teaching and the results of research on effective science instruction. Thus, this book can help you add to your understanding of effective science teaching so that you can reflect on your own practice and determine areas where you can use the information presented to increase your effectiveness.

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