Hard-to-Teach BIOLOGY CONCEPTS

Designing Instruction Aligned to the *NGSS*

By Susan Koba and
Anne Tweed

Hawker Brownlow
EDUCATION

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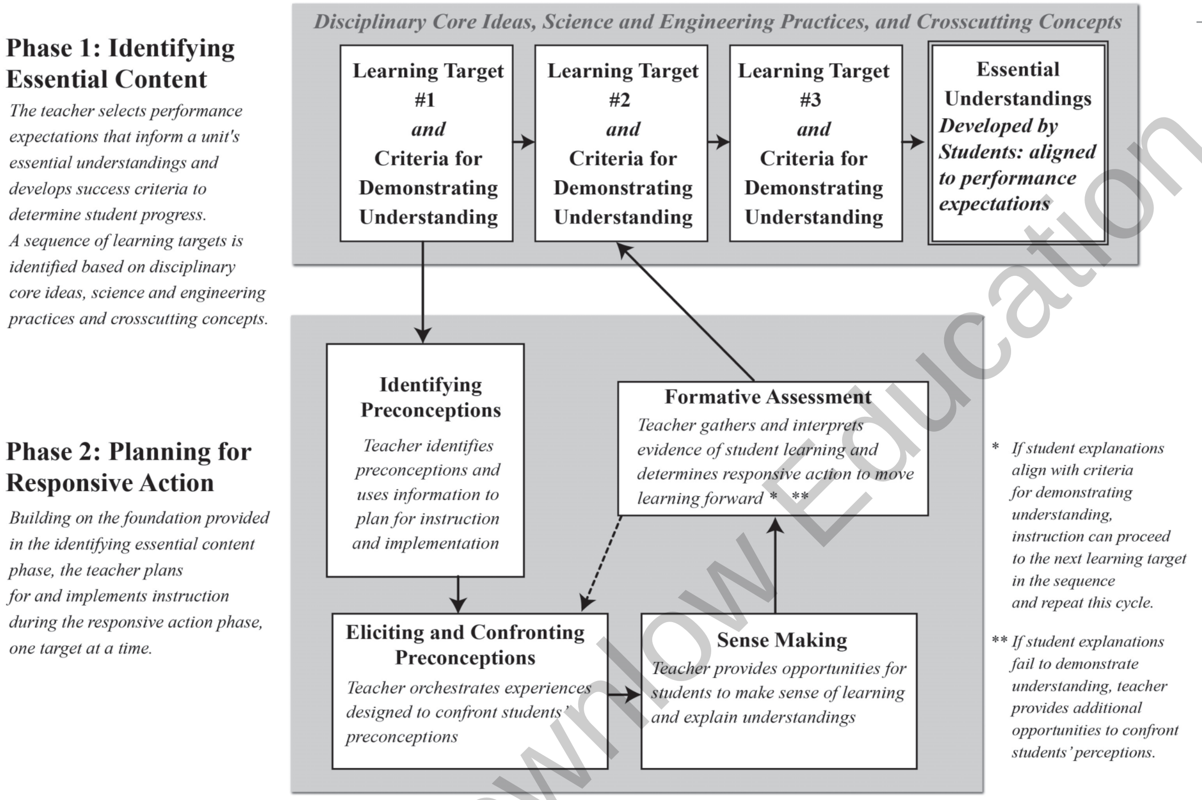


Chapter 1

The Instructional Planning Framework: Addressing Conceptual Change

"Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom."

—Donovan, Bransford, and Pellegrino 1999, p. 10

As biology teachers, we know that certain foundational biology concepts are challenging for our students. And these same students depend on us to teach, assess, and provide feedback to them so that they can understand these concepts. Teachers also know that worldwide shifts resulting in societal, economic, and technological changes shape the skills and understanding required in the future (Bransford, Brown, and Cocking 1999; Bureau of Labor Statistics 2000). With the release of *A Framework for K–12 Science Education* (NRC 2012) and the *Next Generation Science Standards* (NGSS Lead States 2013), science teachers are focused on standards and on identifying what students should know and be able to do in core subjects. The *Next Generation Science Standards* are based on the *Framework* document. The 2012 document provides an explanation of the conceptual shifts included in the visionary approach to science and engineering education designed to engage students with science and engineering practices and apply crosscutting concepts in ways that deepen conceptual understanding of the disciplinary core ideas. The *Framework* emphasizes the integrated nature of the knowledge and practices that should be incorperated in the K–12 learning experiences. Many states reviewed their standards documents and are aligning the performance expectations with *NGSS* and the *Framework*. Other states are including an emphasis on the science and engineering practices with their existing state science standards. Whether your state has adopted *NGSS* or is reviewing the document, we must consider the additional emphasis on advancing STEM learning and the new emphasis on science practices that is central to the *NGSS*. These new directions in science mean that teachers must maintain the classroom focus on learning important concepts and science ideas rather than on rote fact-based learning. This change is particularly significant in biology because of the difficulty that students often have with abstract biological ideas. The Instructional Planning Framework (Figure 1.1, p. 7) initially introduced in the first edition of this book, incorporates research findings and implications for biology teachers in regard to the four hard-to-teach biology concepts (abstract biological ideas). The selected topics arise from the four major disciplinary core ideas in life science defined in the *Framework* and include: proteins and genes, cellular respiration, ecosystems and human impacts, and inheritance and natural selection.

Why Are There Hard-to-Teach Biology Concepts?

As we discussed in the introduction, learning biology is challenging for many students. Students often report that learning biology is like learning a foreign language—that mastering the vocabulary alone is a struggle. This is not surprising since much of the new vocabulary terms represent key biology ideas. Some students are quick to give up and will say that they just don't understand science and they were never any good at it anyway. What can we do to help students with unfamiliar terminology and motivate students who have a mindset that they are not capable of learning biology? How can we engage our students to meet their needs as well as our own? Research-based strategies such as those described in this book offer answers to these important questions.

According to *Teaching With the Brain in Mind*, "Since what is challenging for one student may not be challenging for another … [teachers must provide] more variety in the strategies used to engage learners better" (Jensen 1998, p. 39). As you think about the differences among your students, we're sure that it is obvious that all students do not face the same challenges. What makes certain biology concepts more challenging for some students? In some instances, it is the content itself that cannot be studied directly. So students say that the ideas are just too conceptual and abstract and they can't visualize what is happening.

To further complicate matters, biological concepts frequently require understanding chemistry ideas. As a result, students' preconceptions (those ideas that arise prior to instruction) may include incomplete foundational knowledge that causes them to struggle to understand complex biological concepts. Our approach here is not only to engage students intellectually with the ideas in ways that get them to think about their thinking but also to provide strategies that will increase student motivation to learn and bring about conceptual change. Table 1.1 (p. 6) organizes these ideas and reminds us that our students may have difficulty for a variety of reasons, so reflecting on student needs is where we should start.

Introducing the Instructional Planning Framework

We draw from the research base that supports a conceptual change framework. For our purposes, we understand *conceptual change* to be a process where students access their own thinking, and as needed, alter their existing understanding to generate scientific explanations for the science phenomena being studied. Change in students' preconceptions can occur if teachers use a conceptual change process that addresses the following conditions:

- Students must be aware of their personal conceptual understandings.
- Students must become dissatisfied with their existing views through the introduction of new evidence.
- New conceptions (scientific viewpoints) must appear somewhat plausible.

Table 1.1

Reasons Why Biology Concepts Are Hard to Teach and Learn

Concepts are abstract.	Students can't visualize or directly study some biological concepts. In their attempts to learn from models and representations, misconceptions occur.
Biological systems are complex.	When studying biological systems, they may be complex and composed of integrated components that each need to be understood separately before putting them together. These often include multiple levels of organizations (e.g., protein synthesis and protein functions, flow of matter and energy in ecosystems, and so on).
Students come with limited prior knowledge.	Foundational knowledge may not have been taught so it wasn't learned and/or appropriate learning experiences were not provided in elementary and middle school classrooms.
Students struggle to understand content representations.	Students may struggle to decode/read models and representations of the learning (e.g., diagrams; physical, graphical and mathematical models; and so on).
Preconceptions and misconceptions are persistent among students.	Students may prefer their explanations and ideas to the science ideas. Also some concepts don't make sense to students so their misconceptions are difficult to change.

- New conceptions must be more attractive in order to replace previous conceptions. (Strike and Posner 1985)

Students develop their own ideas about and explanations for many of our hard-to-teach biology concepts. Their learning is an additive, not a replacement, process and the experiences that teachers provide must be incorporated into their existing conceptions as students restructure their knowledge (Chi 1992: diSessa 2006; diSessa, Gillespie and Esterly 2004; Slotta and Chi 2006; Smith, diSessa and Roschelle 1993). Students' early and sometimes naïve preconceptions may contain faulty reasoning that they developed during previous classes or from their own observations. Sometimes misunderstandings arise spontaneously during learning, and sometimes students hold more than one preconception about a topic. Ultimately, students must reconstruct their ideas and revise their mental models and conceptual frameworks. Revealing student thinking and adding to their ideas is an essential part of our instructional framework.

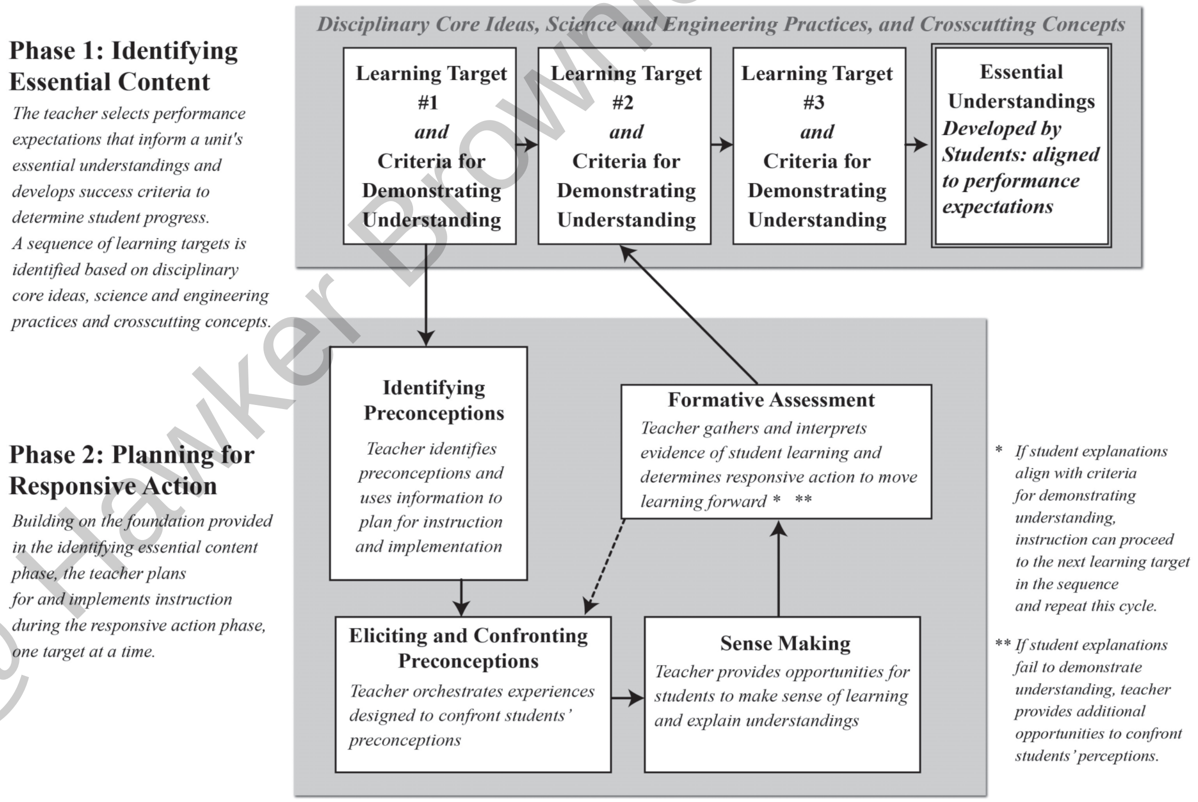
From the research, simply providing our students with the current concept explanation does not work (Chinn and Brewer 2001). The research around conceptual change shows that there are a variety of processes students can use to restructure their knowledge. Some studies have identified the importance of linking to students' prior knowledge as a foundation for adding new ideas, particularly when shifting from non-scientifically based ideas to understanding aligned with current science knowledge (Clark 2000, 2006). We recommend a conceptual change approach to learning and instruction, which shows strong evidence of effectiveness when teaching biology concepts that are difficult for students.

In this chapter, we elaborate on the steps of our research-based Instructional Planning Framework. Figure 1.1 provides a diagrammatic representation of our framework. Using this framework and the research cited throughout the book, you can select strategies to support development of student conceptual understanding.

From the book *Taking Science to School,* we know that there are four areas of proficiency that link the content and practices of science. With the new emphasis on science and engi-

Figure 1.1

Instructional Planning Framework



neering practices found in the *NGSS* and linking them to the disciplinary core ideas and the crosscutting concepts, the second edition of our book will discuss approaches that you can take to plan your curriculum lessons in ways that actively incorporate the practices of science. As you start thinking about the planning process, review the following student competencies that influenced the *Framework* and subsequent *NGSS* documents. The student proficiencies for science include:

- Know, use, and interpret scientific explanations of the natural world;
- Generate and evaluate scientific evidence and explanations;
- Understand the nature and development of scientific knowledge; and
- Participate productively in scientific practices and discourse. (Duschl, Schweingruber and Shouse 2007, p. 2)

In Chapter 2 we will describe the process represented by the Instructional Planning Framework and describe how it aligns with and incorporates the components found in the *NGSS* and the *Framework*. Chapter 3 provides instructional tools that support specific instructional approaches that have been shown to address preconceptions.

Instructional Planning Framework

The Instructional Planning Framework has two phases: Phase 1: *Identifying Essential Content* and Phase 2: *Planning for Responsive Action*. We will start with Phase 1.

Phase 1. Identifying Essential Content

Figure 1.1 represents the stages found in Phase 1 and 2. The framework acts as a logic model diagram. Refer to the top portion of Figure 1.1. This is the *Identifying Essential Content* section of the framework. During this phase, we first clarify the disciplinary core ideas (DCIs) from the *NGSS* or from your state standards—that is, the essential understandings we want students to develop, as well as the knowledge and skills to be taught and learned in order to develop these understandings. We want to also identify the crosscutting concepts (CCs) and science and engineering practices (SEPs) that logically link to the core ideas. We are then able to identify the steps in the learning sequence (the learning targets) needed to build student understanding. Finally, it is critical to provide the criteria for demonstrating conceptual understanding by students so that they can know what successful performance looks like. Performance Expectations (PEs) can be found for each foundation box in the *NGSS* and this is where the developers suggest we focus our attention—on student learning outcomes. To measure progress to the desired outcome, we create checkpoints for the students and provide feedback so that they know how to improve. The final steps in Phase 1 remind us to determine appropriate connections to the Nature of Science and identify metacognition goals to include in the teaching and learning experiences.

Phase 2. Planning for Responsive Action

The stages included in Phase 2 are similar to those included in our framework in the first edition. The following descriptions provide an overview of the important aspects of the planning and implementation that occur when teachers engage in responsive action needed to improve student learning.

1. Research common student misconceptions.

This step is designed to help you study the research-based ideas on student misconceptions so you can outline instruction focused on the conceptual target. Operationally then, the first part of the *Planning for Responsive Action* phase is to identify misconceptions, including common, research-identified misconceptions that your students might bring with them. This is essential as a foundation for planning instruction as we move forward with the framework steps.

2. Identify student preconceptions.

We recognize that, in the ideal, teachers should elicit their students' existing ideas (both preconceptions and research-based misconceptions) and use these ideas to plan instruction. Here we want to emphasize the importance of planning experiences and selecting strategies that allow teachers to identify your students' initial ideas.

3. Elicit and confront preconceptions.

We begin to implement instruction by eliciting our students' preconceptions and discussing those preconceptions with our students. Although this step may require you to make some modifications to your initial plan, it should serve you reasonably well because now your plan uses research-identified misconceptions and preconceptions[1] as well as those revealed by your students. Once you know what conceptual understandings your students already have related to the concepts, you can use the tools in Chapter 3 to select strategies that address the conceptual change process.

4. Use sense-making strategies to address preconceptions.

This step in the process is at the core of our framework. Provide opportunities for your students to make sense of the ideas they learn because it is unlikely that they will draw the appropriate conclusions on their own. Select strategies that engage students through questioning, discussions, and other methods so that students can make connections between their ideas and what they are meant to learn. Later, you will ask students to think about their initial ideas, relate them to their current learning, and then determine how their thinking has changed.

5. Formatively assess student learning and determine responsive actions.

To complete the framework, student learning must match the criteria for developing student conceptual understanding. To determine student progress toward the learning goal, you can