Author Page Keeley continues to provide K–12 teachers with her highly usable and popular formula for uncovering and addressing the preconceptions that students bring to the classroom—the formative assessment probe—in this first book devoted exclusively to life science in her Uncovering Student Ideas in Science series.

In this volume, Keeley addresses the topics of life and its diversity; structure and function; life processes and needs of living things; ecosystems and change; reproduction, life cycles, and heredity; and human biology. Using the probes as diagnostic tools for identifying and analyzing students' preconceptions, teachers can move students from where they are in their current thinking to where they need to be to achieve scientific understanding. At the same time, use of the probes deepens the teacher's understanding of the subject matter, suggests instructional implications, and expands assessment literacy. Using the student-learning data gained through the probes to inform teaching and learning is what makes the probes formative.

Each probe is supported by extensive Teacher Notes, which provide background information on the purpose of the probes, related concepts, explanations of the life science ideas being taught, related ideas in the national science standards, research on typical student misconceptions in life science, and suggestions for instruction and assessment.

Very well written ... direct, straightforward, and uncluttered.
—A. Daniel Johnson, PhD, Senior Lecturer and Kirby Faculty Fellow, Department of Biology, Wake Forest University
Mrs. Jimenez browsed through the book Uncovering Student Ideas in Life Science (actually, this book!) in search of a probe to use before planning her sequence of instruction on the life processes of plants. She decided to use the friendly-talk probe “Light and Dark” (p. 63) to find out what preconceptions her

*A friendly-talk probe is a question set in the context of a group of friends talking about their ideas. The answer choices use the names of the friends instead of, for example, A, B, C, D. Students often find this form of question much more engaging than a standard multiple-choice question. The friendly-talk probes in this book are #3, 5, 9, 10, 11, 12, 13, 15, 16, 17, 18, 20, 21, and 23.
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high school biology students had about photosynthesis and plant respiration.

Prior to selecting the probe, Mrs. Jimenez had examined the middle school curriculum in her school district to identify the key ideas related to photosynthesis and cellular respiration that her students had been introduced to in the seventh grade. Then she read the Teacher Notes for “Light and Dark” and learned that students sometimes believe that photosynthesis and respiration are opposite processes. Because animal and plant processes are often taught separately, some students may form the erroneous “opposites” belief that respiration is an animal process and photosynthesis is a plant process. Even students who recognize that plants respire continue to use the “rule of opposites” in believing that photosynthesis happens only in the daytime and respiration happens only at night (i.e., that with plants photosynthesis takes place in the light and respiration occurs in the dark). She also read that the terms light reaction and dark reaction—terms commonly used by science teachers—may also contribute to students’ misconceptions. She decided that “Light and Dark” would be a good probe to use for uncovering some of these areas of confusion. She then planned her instruction accordingly so that students would learn to distinguish between the two processes by comparing their similarities and differences.

Mrs. Jimenez has used formative assessment probes and FACTs (formative assessment classroom techniques) described in another one of her resources, Science Formative Assessment: 75 Practical Strategies for Linking Assessment, Instruction, and Learning (Keeley 2008), quite a bit over the last few years. She really likes the way the techniques engage all students and encourage them to be aware of not only their own ideas and ways of thinking but also those of their peers. Since using the probes and various FACTs, she has seen her students become more confident in their thinking and more open to sharing their ideas, regardless of whether their ideas are right or wrong. She feels her classroom has evolved into a “thinking classroom”—a place where her students continually revisit their ideas and work together to discard explanations whose implausibility becomes obvious to them in light of new scientific understandings.

Mrs. Jimenez likes to visually display the variety of student responses to a probe so that all students can see what others in the class think. She doesn’t have a set of electronic personal response units (also called clickers) that can be used to display student responses, but that is not a problem. She uses low-tech sticky notes to build what is called a Sticky Bars Chart (Keeley 2008). She gives each student a probe handout and a sticky note. Each student writes his or her response to the probe on the sticky note (e.g., a, b, or c). The notes are then collected and posted as a bar graph, showing the numbers of responses for each answer choice. The students really enjoy using this technique because it allows them to share their answers anonymously, see the variety of responses held by class members, and realize that not everyone knows the right answer initially.

Mrs. Jimenez recently attended a science formative assessment workshop. The workshop presenter shared an interesting adaptation of the sticky bars technique, developed by a high school teacher in Washington State, using the “Giant Sequoia Tree” probe from Uncovering Student Ideas in Science, Vol. 2 (Keeley, Eberle, and Tugel 2007). Instead of using sticky bars only at the beginning of the unit, the teacher uses them at the beginning, midway, and at the end so that students can see how the class collectively modified their ideas as they progressed through the unit.

Mrs. Jimenez was intrigued by the idea of revisiting the probe after students had gained more information and experiences in the lab, so she decided to try that adaption of
the technique. She set up a chart titled “Light and Dark—Let’s Keep Thinking!” At the bottom of the chart, she wrote the students’ names from the friendly-talk probe “Light and Dark” (Janet, Calvin, Mika, Turner, and Sophie). On Monday morning, Mrs. Jimenez announced that the topic of their new unit was photosynthesis and respiration. She shared her learning goals and the essential question: “How are the processes of photosynthesis and respiration alike and different?” She explained that before they began reading about, discussing, and investigating the topic through various reading assignments, labs, and computer activities, they were going to find out what their ideas were right now about photosynthesis and respiration.

She gave each student a copy of the probe handout “Light and Dark” (p. 63 in this book) and a green sticky note. She asked her students to read the probe and then write down on the green sticky note the response that best matched their current thinking (in this case, the response of Janet, Calvin, Mika, Turner, or Sophie). She collected the sticky notes and with the help of a couple of students, made a bar graph on the chart she had previously prepared (see Figure 1). In the upper right-hand corner, she posted a sticky note with the number 1. The number would remind the class that they were on their first round of responding to the probe.

Of the 20 students in the class, only three students chose the “best” response (Mika’s): “Photosynthesis occurs when it is light; respiration occurs both when it is light and when it is dark.” Of course, at this time the students wanted Mrs. Jimenez to tell them the right answer! Some students were sure that the right answer must be Calvin’s because the majority of students selected that response. (Calvin’s response was, “Photosynthesis occurs when it is light; respiration occurs when it is dark.”) Mrs. Jimenez remembered how important it is for the students to “hang out in ambiguity” for a while and keep thinking. She told them that over the next several days they would be learning more about the processes of photosynthesis and respiration and would revisit the probe to see if and how their ideas had changed. In the meantime, she asked students to write an explanation for their answers on the probe handouts. She collected these and after school read the students’ explanations.

She was surprised to find several misconceptions that might be traced back to conceptual misunderstandings some students might have developed during middle school that went unnoticed by their teachers. For example, a large number of students selected Calvin’s response and explained that photosynthesis and respiration are opposite processes—so, if one must occur in the light, then the other must occur in the dark because they are opposite processes. Mrs. Jimenez wondered if students constructed this rule because they know that plants take in carbon dioxide and give off oxygen during photosynthesis and take in oxygen and give off carbon dioxide during respiration. Perhaps
they thought that if one opposite rule applies then other opposite rules apply as well.

She also noted that three of her students chose Sophie’s response, believing that only animals carry out the process of respiration. This was not really a surprise to Mrs. Jimenez because she had read the Teacher Notes before distributing the probe handouts, which had alerted her to this common misconception. After giving a great deal of thought to the students’ responses, Mrs. Jimenez began to plan her unit so that her instruction would address her students’ ideas.

Fast forward five days later. After a series of online activities, labs, readings, and discussions, Mrs. Jimenez announced that they would revisit the “Light and Dark” probe. She returned the original handouts to the students and asked them to decide whether they still agreed with their initial answers or whether their ideas had changed. She pointed to the class’s Sticky Bar Chart and explained that today she would give each student a new sticky note of a different color (blue) to record the responses that best matched their thinking now.

She said that if their answers today were the same as their original answers, they should elaborate on their initial explanations or explain why their thinking had not changed. If they changed their answers, they should provide new, revised explanations. She passed out the blue sticky notes and then collected them after everyone had responded. She created a double bar graph, placing the blue bars next to the green bars (see Figure 2, where the darker bars are the blue bars). She placed a blue sticky note, labeled #2 under the #1 note to indicate that the blue stickies represented the second time they answered the probe.

The students had a lively discussion about the differences in their responses to the probe before they started their unit and their responses midway into the unit. Several of the students mentioned the “light reactions” and “dark reactions” of photosynthesis described in their text, even though Mrs. Jimenez had been careful not to use those terms (which describe two parts of the photosynthetic reaction—one that is light dependent, one that is not light dependent). She made a note that she needed to further address the “dark reaction” by referring to it as the Calvin cycle, explaining how light is not necessary for this phase, yet making sure that students understand that the photosynthetic process as a whole requires light.

After several spirited arguments, the class as a whole decided they could discard Sophie’s answer, and all but one student were ready to discard Calvin’s answer. Mrs. Jimenez made a note that she needed to reinforce the idea that respiration occurs continuously in plants, just as it does in animals. Perhaps if she tied this idea more firmly to the continuous need for energy, her students would be more apt to accept it.

Fast forward to the next week, the end of the unit. Mrs. Jimenez concluded her unit by...
asking the students to reflect on what they had learned. She pointed to the “Light and Dark—Let’s Keep Thinking!” chart and told the class they would have one last chance to reflect on their previous ideas and either change or keep their previous ideas. She again returned their original handouts to them and this time gave each student a pink sticky note, asking them to respond to the probe one more time. She told them to reflect back on all that they had learned and experienced and use their present understandings and experiences as evidence to support their final answers and explanations. She collected the sticky notes, added a third, pink bar to the bar graph for the third and final response, and a number 3 in the upper right-hand corner of the chart (see Figure 3, where the darkest bars are the pink bars).

Wow! She and the class noticed how many students now selected Mika’s answer (the best answer), even though there were still a few students who could not give up their previous conceptions. Mrs. Jimenez asked the students who had chosen Mika as their answer to share their explanations, including why they may have changed their previous answers. They supported their explanations with evidence from the lessons they had experienced. Hearing them, one of the students who had chosen Turner’s answer said, “OK, I get it now. I’m willing to accept Mika’s idea.”

Two of the students were still not convinced. Mrs. Jimenez made note of their reluctance to change their answers, knowing that some students, even after instruction, still cling tenaciously to their original ideas. She also knew that merely correcting them and moving on wouldn’t change their thinking. She planned to bring up these concepts again at an appropriate time. Perhaps then those students would finally be ready to accept the scientific idea. In the meantime Mrs. Jimenez was pleased to see that her instruction resulted in conceptual change for a significant number of students, and, even more important, the students recognized the change as well!

Sometimes the learning bridge is short, sometimes it’s long, but the goal is to move as many students as possible to the other side in the limited school time we have available. Assessment probes are a tremendous tool for constructing that bridge. However, what about the students who don’t make it to the other side? This vignette from Mrs. Jimenez’s class reinforces the fact that teaching difficult ideas is not a one-shot deal. Difficult ideas need to be revisited in different contexts or with different probes whenever the opportunity arises. After all, that’s what good teaching is about—moving students from where they are to where they need to be in order to have a scientific understanding, while recognizing that everyone doesn’t move at the same pace.

This vignette points out the importance of using formative assessment probes to uncover students’ existing ideas and then to use that information to plan targeted instruction. In addition, probes and FACTs can be used to continuously monitor students’ thinking and their progress toward achieving conceptual

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**Figure 3. Sticky Bars Chart: Revisited at End of Unit**

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*Uncovering Student Ideas in Life Science*

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change. As you use the life science probes in this volume, think about the essential ideas you want to target in your curriculum. The probes can help you discover barriers to learning that often remain hidden if they are not deliberately uncovered by the teacher. However, merely uncovering students’ alternative ideas is not enough. Students must be confronted with them and guided through a sense-making process that gives them the new evidence they need to willingly give up or revise their alternative ideas when they realize that these ideas no longer hold explanatory power. With this book, you have the tools to uncover a variety of alternative ideas (as well as correct ones) that your students may have about life science concepts. However, the most important step is deciding on the actions you will take as a teacher to address your students’ ideas. And that is the essence of good science teaching that supports conceptual change!

References