CHAPTER 10

Reading

By providing students with engaging texts, workshop model instruction, explicit training with reading comprehension strategies, and tools for holding thinking, science teachers can enhance students' capacity to understand what they read.

Think Tank

- Why is reading important for scientists?
- What kinds of reading do I ask my students to do in science class?
- How do I support my students in making meaning of what they read?
- How do I know what students learn from their reading?

After a fifteen minute lecture introducing some key terms—ecosystem, producer, consumer, decomposer, carbon cycle, nitrogen cycle, and more—Ms. Benson assigns a reading task for the remainder of class. "Chapter 14: Ecology," she writes on the board, then explains, "When you are done reading, answer questions 1–18 from the end of the chapter. What is not completed in class can be done for homework." Seventh graders dig in their backpacks for thick life science books.

She returns to her desk as the students wordlessly get down to work. The minutes tick by in silence. At the end of class, only a smattering of learners are ready to turn in their assignment; most will come in the next day with their multiple choice answers scrawled onto binder paper.

Daunted by the text, Ursula spends most of the class fake reading—turning pages and spacing out. She is guessing that Tom will email the answers to their group of friends tonight. His cousin was in the class last year, and has given his science folder to

Tom. So Tom has the answers to just about everything ... in science.

Reflection

What will Ursula learn from this reading assignment?

What suggestions would you offer her teacher?

The scenario described above is one example of how students develop their own strategies for survival in classes that require challenging content reading. Reading is difficult, especially for learners whose first language is other than English. Expecting students to read alone with no structure or support leaves many behind. If we hope our students will gain science content knowledge from the texts we offer them, we serve them best by explicitly integrating reading instruction within our science courses; in this chapter, I offer some insight into how.

Most of us expect students to read and understand important scientific information independently in order to achieve our courses' learning goals. An array of books on content-area reading, literacy in science, and science for literacy widely promote the critical relationship between reading instruction and content learning.

Reading science is difficult work, and many students need our support in order to get the most from the texts we offer them. We make the best use of reading for learning when we emphasize understanding and devote our energy to teaching students comprehension strategies—such as questioning, determining importance, and synthesizing—to help them make meaning of texts (Pearson 1983).

The Game of Reading

I myself grew up with the myth that reading was a race. Also, if I looked at every word on each page, that counted, and I had read that book. I did not understand the half of what I read, but I was very fast. I knew how to hunt for answers in a textbook chapter—how to locate boldface words, then copy their definitions. I knew that if the definition was not given in the same sentence as the boldface word, I could always turn to the glossary in the back of the book to get a meaning to write down. I knew that picture captions often contained special clues needed for answering the chapter questions. I was adept at this game called reading.

As a science teacher, I found that my students knew that same game. But when I asked them what a chapter meant to them, or how the new information related to their lives, no one had much to say. I realized that this was because I had not been asking learners to do much more than to play reading as the game I grew up playing, the one where you win by getting done first, with "right" answers on your paper. That game is not about making meaning, it is just about looking at the words. For my own teaching to be effective, for my students to be learning, I realized I had to teach a different reading game, one where you win by understanding ideas.

Enter my friend Jen Wood, a staff developer, who showed me that my students needed a *reason* to read, and something to *do* with what they had read. I played around with these ideas in my science classes for some time, with good results. Next, through my work with the Public Education & Business Coalition, I grew and deepened my own understanding of how we can harness the power of quality reading instruction to maximize science learning. This chapter is a synthesis of what I have learned and what I have taught.

What Is Reading, Really?

Reading is not just looking at words or hunting for answers. Reading is thinking and learning. To understand new information from a text, we need to have our brains hooked in and turned on to what the page before us is saying. In order to get learners playing this game of reading for understanding, we need to

- give students a purpose for their reading,
- select high-interest texts,
- explicitly teach comprehension strategies in conjunction with reading tasks, and
- offer students ways to hold their own thinking while reading.

Initially, these tasks might appear out of the realm of responsibility of a science teacher, but our students need our help. In order for the majority of learners to make sense of the complex written material we set before them, they need specific instruction and support. When we teach students to read—really read—for meaning, we empower them as scientists and learners for life. Let's look at how.

Purpose

Many times, we read a chapter in the text because it is the next chapter, or because it is the chapter about our current unit, or because it is what our partner across the hall is having her kids read. For our students, this may not be sufficient motivation to engage them. We need to dig deeper and develop a specific reason for each reading activity, and to convey that to the group effectively. Reading with purpose motivates students to make meaning of the often challenging scientific texts laid before them.

The purpose can be simple: we are reading this to build our background knowledge in order to write informed hypotheses tomorrow in our lab, or to participate in the discussion, or to develop research questions. Whatever the purpose is, linking the reading activity to other learning experiences helps students understand where they are headed, and motivates them to get on board. Readers need a purpose.

Choosing Texts

Science textbooks will likely always be a pricey staple in our schools. They come in all shapes and sizes, all densities and reading levels, and offer an overview of basic facts considered integral to a certain body of knowledge—earth science, physics, chemistry, and so forth. Since textbooks are designed to cover a broad range of topics within a discipline, they do not have the space to delve into the details and intricacies of each. Textbooks present predigested information, sifted and synthesized for easy access. These books are set up for students playing the old reading game, memorizing and copying. Traditional textbooks are not designed to support our students thinking as scientists engaged in genuine questioning, data gathering, and meaning making. For these reasons, it is important to introduce other reading materials to our students.

Either in addition to or aside from textbooks, we can offer our students reading material from a variety of sources. Consider reading with your classes

- original data, such as research from a *Science Daily* article about Hawaii's Mauna Loa volcano's recent changes;
- scientists' field journals, such as the published works of Charles Darwin;
- writing by scientists about science, such as Barbara Kingsolver's *Small Wonder*;
- newspaper articles about science-related topics found in your local paper or the *New York Times* science section;
- magazine articles from *National Geographic*, *The New Scientist*, *Popular Science*, or similar publications; or
- articles from professional journals such as *Nature*, or even *Lancet*.

While some of these sources may initially appear beyond the reading levels of our students, we can make these texts accessible either by revising the content, better supporting our students in accessing the material, or both.

Appropriate Reading Challenges

My colleague Jeff Cazier teaches science to an amazingly diverse population of students in one of Colorado's largest middle schools. He is adept at finding interesting nonfiction articles on the Internet that directly relate to what his students are studying. He shared with me a strategy for making adult-level reading accessible to his seventh-grade English language learners: after downloading an article, he cuts and pastes the text into an online readability calculator to assess the reading level, then edits the text to shorten sentences and replace difficult vocabulary words. He can then reassess the readability of the revised article until the level presents an appropriate challenge for his students.

One online resource for this sort of revision is www.standards-schmandards.com/exhibits/rix/index.php

Bringing these types of reading material to our students connects our classrooms to the real world. Primary sources are windows into the thinking of professional scientists. Original research documents present scientific data in its raw form. Current events put science learning in context. Magazine pieces present well written, in-depth narratives. These genres can serve to present or illuminate our content in meaningful, real-world ways for learners. Starting with a high-interest text—one well written and linked to current events, or students' lives and interests, or current events—can engage learners in a topic and drive them to want to understand. (See the Resources at the back of the book for some sources of high-interest science articles.) The use of primary and other sources of science reading material reinforces to our students that science is relevant and everywhere.

It is time consuming and frustrating to spend hours late into the night surfing the Internet for just the right article to introduce the next unit—which starts tomorrow. Rather than setting our sights on finding the perfect readings for each unit all semester, we can start small, find a few useful ones each year, and continue to keep our eyes open. Let family and friends know the types of reading material you are looking for, and they may just come across things you could use in your classes. Our students can be excellent researchers as well when we point them in the right direction. Over time, your collection of high-interest science texts will grow, and you will constantly be replenishing your stash.

Reading as Thinking

Once we and students know *why* they are reading and *what* they are reading, we need to help learners with *how* to make the most of their reading experiences. David Pearson (1983) uncovered a distinct set of seven strategies proficient readers use in all disciplines to make meaning while reading.

- *Monitoring for Meaning:* remaining self-aware, conscious of when you understand fully, and when you become confused by the text.
- *Background Knowledge:* connecting new information to what you already know.
- *Questioning:* posing questions before, during, or after reading; looking for answers in the text.
- *Inferring:* drawing conclusions based on your background knowledge plus the new information.
- *Sensory Imagery:* relating to the texts through personal memories of sights, sounds, smells, or other sensory experiences.
- *Determining Importance:* reading with purpose, identifying salient passages and information.
- *Synthesis:* combining new thinking with prior knowledge to deepen understanding.

While the initial research on these comprehension strategies was designed primarily to inform reading instruction, many of these thinking strategies described by Pearson are integral to the work of professional scientists. Figure 10.1 details how.

Pearson's comprehension strategies, then, are familiar territory to scientists. We can teach these strategies to science learners to support them in making meaning while reading new information in a variety of formats—texts, charts, illustrations, graphs, data tables, and so forth—as they study science. When explained, taught, and practiced, the strategies offer students a tangible way to engage in mental conversation with the text as they read. When learners' minds are active during reading, they come to understand what is on the pages much more deeply.

Depending on the text you have selected for your class, one strategy or another may be more or less appropriate to introduce and practice. In my work teaching reading to science learners and teachers, I have found the following strategies to be most broadly useful: background knowledge, questioning, determining importance, inferring, and synthesis.

You may select others to practice with your students as well. As science teachers, though, we must take seriously the responsibility of teaching students to understand complex science texts, even though we are not their English teachers. Otherwise, we leave them adrift and alone, unable to successfully navigate the sea of complexity that science readings can present. This can cripple their future confidence and opportunities as scientists and readers.

Thinking Strategy	How Scientists Use This Strategy
Monitoring for Meaning	• Scientists reflect on the validity of their hypotheses in light of new data. • If their new data don't fit their background knowledge, scientists assess the possibility of errors in the experiment. • Scientists repeat their investigations to ensure that their results are replicable. • Scientists consider how new discoveries impact existing theories.
Background Knowledge	• When planning an investigation, scientists begin with what they know. • Scientists build their background knowledge by reading the publications of other scientists, attending scientific meetings, and participating in peer reviews of their work. • Scientists formulate questions and hypotheses based on their background knowledge. • Scientists draw inferences based on their background knowledge.
Questioning	• Scientific inquiry is the systematic, reasoned process of investigating questions. • Scientists focus each investigation by posing specific, testable questions and designing experiments which can give definitive answers. • Scientists often pose new questions or modify their hypothesis after gathering new data.
Inferring	• Scientists develop hypotheses based on their inferences. • Scientists examine existing and new data and draw inferences to explain their observations.
Sensory Imagery	• Scientists make observations and gather qualitative data using their five senses. • Scientists record their qualitative observations with illustrations.
Determining Importance	• Scientists as researchers maintain their focus on a specific area of inquiry. • Scientists take data and carry out a statistical analysis to determine its significance. • When designing investigations, scientists determine the sequence of the steps to be taken in the process. • Scientists must demonstrate the significance of their research in order to obtain grant funding for their work. • Scientists try to communicate the importance of their work to the larger community and public.
Synthesizing Information	• Scientists analyze and interpret quantitative data using tables, charts, graphs, and diagrams. • Scientists draw conclusions from their data by synthesizing what they learned with what they already knew before an investigation. • When publishing their findings, scientists demonstrate and reference how their research is related to those who published earlier work.

FIG. 10.1 *Thinking Strategies in Science*

More on Comprehension Strategy Instruction

Our colleagues in the language arts department have been working hard for many years to teach these valuable comprehension strategies to readers. There are numerous resources available describing how content area teachers can integrate explicit comprehension strategy instruction to support student achievement. This chapter only provides an overview.

If you are interested in going into greater depth with this important work, I recommend:

Daniels, Harvey, and Steven Zemelman. 2004. *Subjects Matter.* Portsmouth, NH: Heinemann.

Keene, Ellin Oliver, and Susan Zimmermann. 2007. *Mosaic of Thought: The Power of Comprehension Strategy Instruction,* Second Edition. Portsmouth, NH: Heinemann.

Tovani, Cris. 2004. *Do I Really Have to Teach Reading?* Portland, ME: Stenhouse.

We can take the time to weave comprehension strategy instruction into all of our science classes. Students can practice within the context of science reading and science learning, so it is not as though we need to stop science class to do reading instruction. Providing direct instruction about a comprehension strategy before a science reading task makes the students' time doubly useful: students are learning the essential life skill of reading for meaning while also comprehending the science content we are striving to impart.

Workshop Model Comprehension Strategy Instruction

The workshop model, described in Chapter 3, is an essential structure for effective reading instruction in science. Below, we will look at how the "before, during, after" format can be used to teach and practice comprehension strategies as students make meaning of science texts.

Before Reading

Introduce and work on one strategy at a time, and spend plenty of time practicing each. In designing a minilesson introducing or emphasizing a strategy, include the following:

- examples of strategy use in a real-life context,
- an anchor chart,

- a system for documenting thinking, and
- plenty of modeling.

Strategies in Real Life

To start teaching students a new thinking strategy, I like to let learners know that this strategy is something they are already doing proficiently. Just as we are all scientists, we are all meaning-makers as well. So whichever strategy we may be working with, I look to share lots of examples of how that strategy is second nature to most of us.

Questioning, for example, is something adolescents do every day: Which side should I part my hair on? What is the purpose of life? How many calories are in that Yoplait? When will time end? How can I save the Earth? How can I get to sit by him on the bus without making it look like I want to sit by him? And so on. When we use examples from our own and our students' lives to illustrate the thinking strategies in action, we lower students' affective filters and give them confidence that these strategies are innate to their thinking already. Now we are just going to put that already proficient thinking to work in the context of a science reading task.

Anchor Charts

I learned about these from my elementary school teacher colleagues: an anchor chart is like a poster-sized, one-frame cartoon representing the strategy visually. Anchor charts are one tool for introducing and reinforcing thinking strategies.

For example, when explaining inferring, I may draw an anchor chart with a picture of an elephant visited by two blindfolded people. The people are each using their hands to gather information and draw inferences about the elephant. One person has the elephant's trunk around her waist and is grasping it. "It is very warm and friendly," says the bubble above her head. The next person is standing near the elephant's tail as it swats flies. The tail keeps smacking the person in the head. "It is angry and violent," that person is stating.

The observers are each drawing conclusions based on what they are experiencing, and, in this case, they are both wrong and both right at the same time. This is just one way that I could illustrate how inferring is about taking in new information through the lens of your background knowledge to arrive at original conclusions.

An anchor chart hanging in the classroom serves as a visual reminder for students as we discuss and practice a thinking strategy. Sometimes students can come up with their own—even more imaginative—images to represent a thinking strategy, and it is fun to have learners draw original anchor charts to exhibit their understanding of metacognition (see Figure 10.2 and Figure 10.3 to see anchor chart examples).

Once I have introduced a strategy with real-life examples and an anchor chart, I am ready to put it to work in the context of a science learning experience.

During Reading

After explaining and modeling a thinking strategy in several contexts, I need to model how that strategy looks and sounds as I read science.

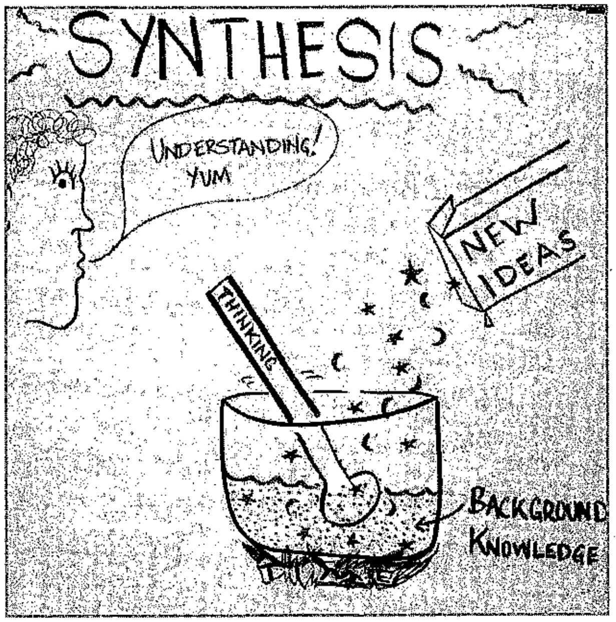


FIG. 10.2 *Anchor Chart Depicting Synthesis*

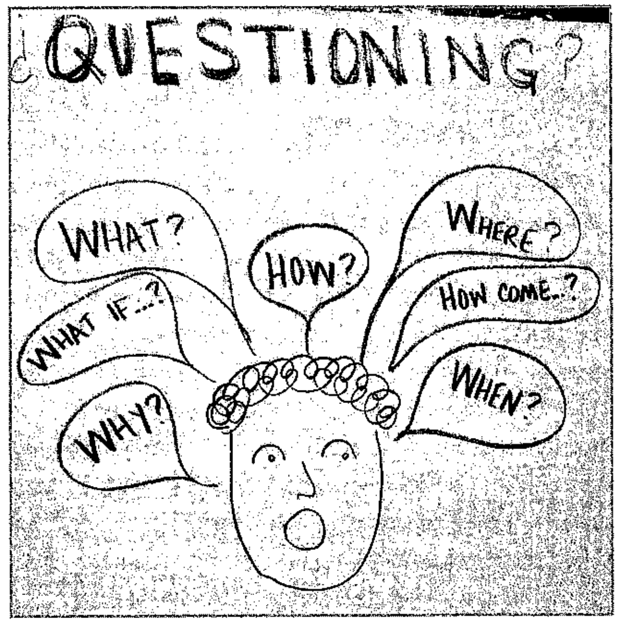


FIG. 10.3 *Anchor Chart Depicting Questioning*

Think-Alouds

Thinking aloud is a wonderful way to model a comprehension strategy. Quite simply, a "think-aloud" means the teacher is reading out loud and stopping to talk about his thinking process and ideas while he reads. For think-alouds to be most effective, several things are needed.

- All students should have copies of the text the teacher is using.
- The teacher's copy of the text is visible to all students, ideally on an overhead projector or document camera.
- The teacher signals that he is reading by looking down at the text, then signals that he is thinking by looking up at the group.
- The teacher records thinking clearly and in good detail, on the text or a separate page.
- The teacher presents several different examples of reading and thinking.

For example, a teacher working with her students to read an article about stem cell research from the *Los Angeles Times* during a genetics unit would prepare by making one copy of the article for each student and also one copy on an overhead transparency (unless she has a document camera—even better). If they are practicing accessing their background knowledge while reading, their teacher would look for specific places in the text where she could highlight what she already knows about the topic. Then, as she stands in front of her students and reads the first paragraph aloud, she will pause and look up as she makes a connection to her background knowledge—a memory of her own thinking process in deciding not to preserve her own children's cord blood, perhaps. On the transparency, she will jot a margin note about her background knowledge, then continue reading.

Sometimes a teacher presents a think-aloud with the first few paragraphs of a text before asking students to read the rest independently. At other times, teachers find it useful to do a think-aloud with a separate text to model the strategy. Either is fine. The main point is that we need to model the thinking and documenting we would like students to do independently.

Anyone who has presented a think-aloud to students knows how challenging it can be for learners to keep quiet. When you start reading aloud a controversial article challenging students' preconceptions about the relationship between space and time, for example, they will be ready to chime in. Learners are having their own ideas while we are reading, and want to share those. This is where a think-together comes in: while the teacher retains leadership of the reading activity, he may read a sentence or two aloud, then ask students to share their thinking on the text. In this way, thinking is shared aloud together, while the teacher continues to document the ideas in the selected format. Most students benefit from observing several think-alouds and participating in a number of think-togethers with each new strategy in order to boost their ability to practice these strategies independently.

When students do begin their independent practice using a comprehension strategy, we need to be on hand conferring and checking for understanding: as students read the article, "Gluttony, Not Laziness, to Blame for Obesity," while practicing determining importance, our first conferring goal may be to check for understanding of the key concepts. Kneeling beside a reader, we may probe for understanding by asking, "What is gluttony? What is laziness? What is obesity? What do you think this article is trying to say? What kinds of evidence do you think the authors will use to make that point? What kinds of important information are you looking for as you read?" A reader's answers to these questions will help a teacher to assess and instruct the individual to ensure that he gets the most from the text.

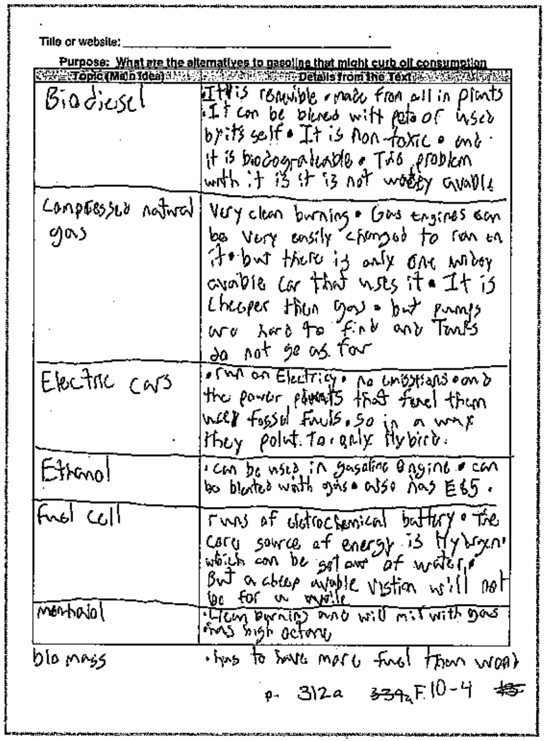
Students need ongoing support and affirmation as they begin this work. Often, in talking with a student, we may find that she understands much more than she wrote down in her notes. At this point, it is important to emphasize the value of documenting thinking (see Chapters 3 and 4 for more details on conferring).

Documenting Thinking

While many proficient readers employ thinking strategies naturally in their own minds while reading, ask learners to document their strategy use in some way while they read. This makes students slow down and really think, rather than skim over the reading material. Some teachers use texts that the students can actually write on or in; others ask students to use sticky notes to record thoughts, or to document their ideas on separate graphic organizers, as in Figure 10.4.

There is no wrong way; the point is that students are using the strategy, thinking while reading, and recording that thinking in a tangible format that can be shared with peers and teachers. In *Subjects Matter*, Daniels and Zemelman present a broad range of excellent strategies for documenting thinking while reading, as does Cris Tovani in Chapter 6 of her 2004 book *Do I Really Have to Teach Reading?*

Once learners understand a strategy and have seen it in action, then turn them loose with a quality text to practice on their own, as one learner did in Figure 10.5. In the end, create time for students to reflect on how the strategy helped them to understand their science reading. This metacognition is one of the most important steps to success.



Title or website:

Purpose: What are the alternatives to gasoline that might curb oil consumption

Topic (Main Idea)	Details from the Text
Biodiesel	It is renewable • made from oil in plants • It can be blend with petro or used by its self • It is non-toxic • and it is biodegradable • The problem with it is it is not widely avable
Compressed natural gas	Very clean burning • Gas engines can be very easily changed to run on it • but there is only one widey avable car that uses it • It is cheeper than gas • but pumps are hard to find and Tanks do not go as far
Electric cars	• run on Electricity • no emissions • and the power plants that fuel them well fossil fuels, so in a way they polut. To only Hybird.
Ethanol	• can be used in gasoline engine • can be blended with gas • also has E85 •
Fuel cell	runs of electrochemical battery • The core source of energy is Hydrogen which can be got out of water, But a cheap avable vistion will not be for a while
methanol	clean burning and will mix with gas has high octane
bio mass	• has to have more fuel than wood

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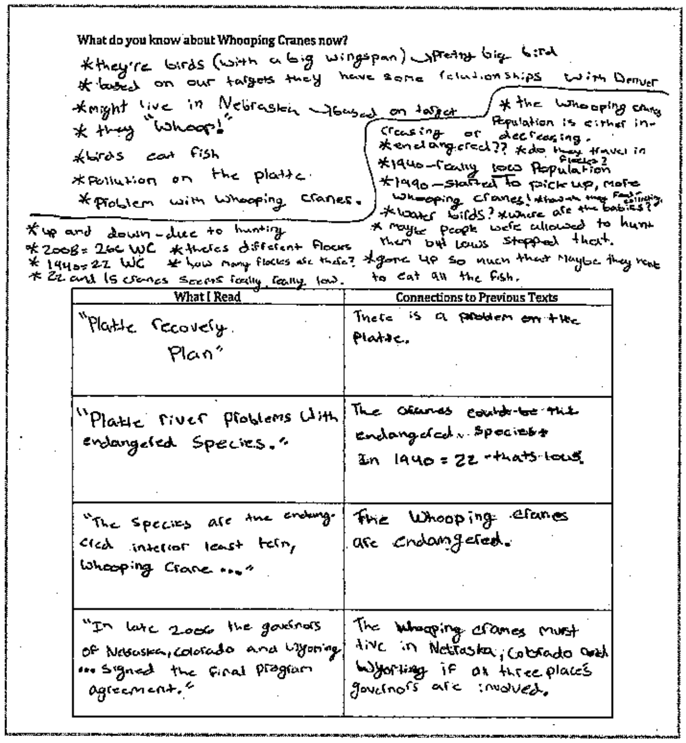
FIG. 10.4 *Students Noted Important Information from a Text as They Investigated Alternatives to Oil*



What do you know about Whooping Cranes now?

What I Read	Connections to Previous Texts
"Platte recovery Plan"	There is a problem on the Platte.
"Platte river problems with endangered species."	The cranes could be the endangered species. In 1940 = 22 - that's low.
"The species are the endangered interior least tern, whooping crane..."	The whooping cranes are endangered.
"In late 2006 the governors of Nebraska, Colorado and Wyoming ... signed the final program agreement."	The whooping cranes must live in Nebraska, Colorado and Wyoming if all three places governors are involved.

FIG. 10.5 *Teacher Scaffolded Students' Thinking as They Made Connections Between This Text, Their Background Knowledge, and Other Readings*

Sample Strategy Instruction

Each teacher must develop for herself a means of conveying these strategies' value. Figure 10.6 presents some examples of how I have defined, explained, and modeled my favorite thinking strategies in the context of science learning. You can build on these to develop your own instructional plans for introducing and teaching these valuable comprehension strategies to support your science learners.

After Reading: Metacognition

Metacognition (or thinking about thinking) is an important part of the learning process. We need to ask students not only to document their thinking while reading, but then to do something with that thinking in order to solidify their understanding. Learners might share their written thinking with a partner, a group, the class; use it as a reference for a paper or test; sort it or sift it or connect it to other learning. In this way, harried students can appreciate the value of actually taking the time to write this stuff down.

For example, after individually reading an article about hybrid cars while practicing questioning, small groups of students could come together and share their questions: "Why are the batteries so big? Other than gasoline, are there other fuels that could power hybrids? What about just plugging them in?" With one another as resources,

Strategy	Background Knowledge
Definition	Using what we already know about a topic to help us make meaning. Drawing connections between the text and our own experiences in life, or with other texts.
Sample Real-Life Experiences	My daughter grew up visiting the ducks at the lake. One of her first words was, "Quack, quack." We went to California and saw seagulls. "Quack, quack!" she shouted with glee.
Anchor Chart	Drawing of a mind filled with information, with threads from the ideas in the mind connecting them to the pages of the text in hand.
Possible Format for Holding Thinking	Two column notes: What I read / What it reminds me of
Possible Use	During a weather unit, introduce background knowledge before reading a National Climactic Data Center article about Hurricane Katrina. Many students will have memories or personal connections to help them understand the magnitude of the storm.

Strategy	Questioning
Definition	Wondering while we read. Asking for the meaning, importance, or relationship between new information. Answers may or may not be found in the text; the point is to be thinking while reading.
Sample Real-Life Experiences	Every morning getting dressed: Does this match? Do these still fit? Where are my black socks? Am I going to be late?
Anchor Chart	A thinker holding up a book with a collection of questions floating above her head: Who? What? Why? Where? When? How?
Possible Format for Holding Thinking	Two columns: questions on the left, answers on the right. Add questions before, during, and after reading. Record answers found in the reading.
Possible Use	During an energy unit, prepare students to research renewable energy sources by brainstorming questions. While students read and work, they search for answers and add new questions.

Strategy	Determining Importance
Definition	Reading with purpose and sifting through the text for the important information that helps us attain that purpose.
Sample Real-Life Experience	"You are the bus driver. You drive downtown and pick up seven people, stop at the train station and pick up one more, drop off three. Head to the airport where you pick up five and drop off four. Who is the bus driver?"
Anchor Chart	A farmer jumping for joy after finding a needle in a haystack.
Possible Format for Holding Thinking	Three column notes: What I read / What it means (in my own words) / Why it is important
Possible Use	During a unit on treatment and prevention of communicable diseases, introduce "determining importance" before giving learners case studies to read and diagnose. This strategy will help student scientists consider what matters most in assessing a patient's needs.

(continues)

FIG. 10.6 *Favorite Thinking Strategies for Science Learning*

Strategy	Inferring
Definition	Putting new information together with background knowledge to draw conclusions of our own.
Sample Real-Life Experience	My husband comes home from work singing, greets the family with big hugs, and is beaming; I infer that he had a terrific day.
Anchor Chart	Picture of a surfer riding waves, watched by three different people, each holding up a colored lens representing their background knowledge. One is thinking this is dangerous, another thinks it looks fun, a third thinks the beach is being invaded by aliens.
Possible Format for Holding Thinking	Two column notes; What I read / What I infer from the text
Possible Use	During a health unit, discuss and practice inferring before reading the data from a report on a clinical trial of a new medication for diabetes. After reading, ask students to infer the meaning of the data.

Strategy	Synthesis
Definition	Thinking about relationships and meaning, combining new ideas with background knowledge to create a web of understanding.
Sample Real-Life Experience	Baking a cake—the flour, eggs, and so forth look and taste totally different from the product you create when you mix it all together and put it in the oven.
Anchor Chart	Picture of a kettle of background knowledge into which new ideas are poured, stirred with the spoon of thinking, cooked on the fire of time to produce a delicious serving of understanding.
Possible Format for Holding Thinking	Concept mapping: List the important concepts from the reading. Create a web representing and explaining the relationships between those concepts.
Possible Use	During a unit on rocketry, introduce synthesis before asking students to read a series of articles about aerodynamics. After reading, ask students to synthesize what the articles, taken together, mean in terms of ideal rocket design.

FIG. 10.6 *Favorite Thinking Strategies for Science Learning (continued)*

they will likely find some answers and be able to narrow their collective questions to a short list of important ones. These could be shared with the class, answered if possible, or held onto until an explanation is found. In this way, students document, rather than gloss over, their confusion as they read; it becomes the fodder for further conversation as the class engages together in a collective project of meaning making.

In addition to wrapping up a reading activity by sharing thinking, it is also important to offer students an opportunity to be metacognitive about how the strategy helped them make meaning of what they read. In other words, we need to ask, "How did the strategy affect your experience as a reader? In what ways was it helpful to read with a purpose? Employ this strategy? Record your thinking? Share your thinking with others? How did this experience enhance your understanding of the text?"

Learning Targets

- Students will understand how density is an example of the big idea, stability.
- Students will understand the concept of density and be able to apply it in problem-solving situations.
- Students will understand that density is a relationship between mass and volume.
- Students will understand how density is relevant in the context of our daily lives.
- Students will become proficient at using the comprehension strategy of background knowledge to aid their comprehension of texts, diagrams, problems, demonstrations, and lab activities.

Day	Activity	Gradual Release of Comprehension Strategy
1	Preassessment	Written preassessment draws out students' background knowledge about density. After individual work time, class shares and charts what we already know.
2–3	Oil slick	Students work in small groups to separate oil from water using an array of tools. Before they start the task, we will brainstorm as a class what strategies might work best.
4–5	*Exxon Valdez* article (Grade 6 reading level)	Teacher introduces the idea of background knowledge with an explanation and anchor chart. Then leads the class in a think-aloud as we read together the magazine article "*Exxon Valdez:* The Big Spill." Teacher encourages students to draw on background knowledge built during yesterday's activity. After reading the article, students draw concept maps explaining and connecting a list of key words relating to density. Metacognition: Ask students how background knowledge gained from the oil slick activity helped them understand text.
6–7	Read Ch. 7 "Density" from physical science text (Grade 7 reading level)	In a think-aloud, teacher models two-column notes about background knowledge and connections as one reads. Students read along in the text, then continue reading and note taking independently.
8	Density column model	Teacher presents a density column and asks students to draw on their background knowledge to explain what they see. Students work individually, then in pairs to develop explanations. Teacher confers. To debrief, teacher leads class discussion emphasizing students' use of prior knowledge to support their explanations.
9–11	Read "Ice Floats, So Do Boats" from *Science Snackbook* (Grade 8 reading level)	Teacher begins lesson by eliciting students' background knowledge about what floating has to do with density. Then, teacher models two column notes about background knowledge again, but only for two paragraphs of the text. Students work in small groups, each group creating two-column notes on an overhead transparency. Groups share their notes about connections and background knowledge at the overhead. Teacher gives feedback to each group, looking for particularly meaningful and helpful connections to highlight. Students write short reflections on how they used background knowledge to boost comprehension and why it is helpful to them.

FIG. 10.7 *Sample Unit Plan: Density (with emphasis on background knowledge)* *(continues)*

When students have time to stop and see the value, how a strategy slowed them down and helped them to experience success as learners, they are more likely to hang onto the strategy, put it to good use the next day or week in the context of a course.

Assessment

After a reading experience, there are two important things to assess, content and process.

- Do students understand the content of the reading?
- Are students proficient with the comprehension strategy we have been practicing?

To answer the first question about what sense students are making of the text, we can look to a variety of quick assessment tools including conferring, exit tickets, quick quizzes, and future tasks that require students to apply knowledge from their reading.

Students' proficiency with the comprehension strategy is assessed through their understanding of the text, but also can be addressed independently. Surveys, interviews, conferring, and written reflections can invite students to consider how the strategy is working for them. Questions might include the following:

- How would you define this strategy in your own words?
- How do you use this strategy in your daily life?
- How do you use the strategy as a reader?
- How does strategy use affect your experience as a reader?
- What do you think you need in order to be a better reader?

When we encourage students to step way back and look at their experience as a learner in these ways, we empower them to find out what works for them and to make changes, to grow as learners.

Putting It All Together

What does this really look like, a thinking strategy layered into a science unit? The sample unit overview in Figure 10.7 illustrates how the comprehension strategy of background knowledge can be integrated throughout a unit on density for an eighth-grade science class.

This sample unit illustrates the importance of introducing and revisiting a thinking strategy over the course of time with a range of material. With practice and reflection, comprehension strategies are a powerful tool to assist learners in reaching our course's science learning goals.

While you may not think of yourself as a reading teacher, integrating direct instruction of comprehension strategies into your science course will directly benefit your students as science learners. They will build skill and confidence in their ability to make meaning of complex science texts. You will find an abundance of reading material now

12–13	Activity: Create a density column	Students work in pairs to create density columns. Prior to distributing materials, teacher will assess each pair's comprehension of the written design parameters.
14	Read "A Famous Bath" from *Handbook to the Universe* (high school reading level)	Teacher elicits students' background knowledge about Archimedes, then briefly models note taking. Students work in pairs to create two-column notes about their background knowledge. Teacher confers with pairs during work time. Pairs report favorite connections to the whole class.
15	The algebra of density	Teacher introduces the equation for density (first seen in the reading Days 6 and 7) and models how students can solve density problems mathematically. Sample problems.
16–18	Density lab	Students weigh and find the volume of various objects, then calculate their densities. Debrief of lab links mathematical understanding of density to conceptual understanding. Students complete written lab reports.
19	Final strategy practice: *New York Times* article on oil spill cleanup technology (adult reading level)	Students read the article independently using two column notes on background knowledge. Teacher confers with students individually about their use of the strategy. Students take turns modeling their thinking by each doing a think-aloud of one paragraph of the text at the overhead. Homework: Write an explanation of background knowledge and how it helps readers comprehend texts.
19	Final assessment: Density problem solving	Students work individually to demonstrate their understanding of density by solving practical and theoretical problems, both hands-on and text based.

FIG. 10.7 *Sample Unit Plan: Density (with emphasis on background knowledge) (continued)*

accessible to help connect classroom learning to the wider world. In order to teach comprehension strategies effectively, you need to

- prepare for reading instruction by selecting high-interest texts and an appropriate comprehension strategy;
- explain, demonstrate, and invite students to practice the strategy; and
- encourage metacognition and awareness of how comprehension strategies enhance investment and understanding.

Here are some questions to help you plan quality workshop model comprehension strategy instruction.

Reading: Teacher Planning Questions

What is my learning goal for this unit?

How will I use reading to support students in achieving that learning goal?

What will students read?

Which comprehension strategy will I teach and practice throughout this unit? Why?

How do I use that thinking strategy in my own life? What examples can I give students as I introduce the thinking strategy?

What are the ways I can ask students to document their thinking while they are reading and practicing this thinking strategy?

How will I assess learners' proficiency with this thinking strategy?

Dobetter Reading

Ms. Dobetter is ready to look at revising how she incorporates reading into her seventh-grade earth science class. In the past, she has relied merely on the textbook for reading material and has expected all of her students to know how to get information from it independently. This year, she is going to look for some high-interest texts and experiment with teaching a comprehension strategy. Let's see how it goes.

What is my learning goal for this unit?

The unit is on plate tectonics. I want students to understand that the surface of the Earth is constantly changing, yet in predictable ways. I want to emphasize the big idea, patterns of change. Learners should understand how plate tectonics affect our lives by way of volcanos, earthquakes, mountain building, and other large-scale geologic phenomena.

How will I use reading to support students in achieving that learning goal?

I usually just use reading to practice vocabulary and build background knowledge for the classroom activities. I also like all of the timelines, charts, and pictures in the textbook. I suppose this time I could have them read the text with a more specific purpose, such as being able to really explain how plate tectonics relate to our lives. I also need to ask learners to do something with what they read—write about it, discuss it, share it so that it really sticks, and is not just like a separate homework task I usually assign that we do not talk about in class.

What will students read?

I usually have them read three chapters in the book—"The History of Plate Tectonics," "The Mechanism of Plate Tectonics," and "Plate Boundaries." They are pretty dry chapters, but with lots of illustrations. Maybe I can spice it up this time by finding a few related articles on the Internet that would pique their interest. I know seventh graders are all pretty curious about natural disasters, so maybe I could kick off the unit with some true newspaper stories about earthquakes and volcanos, then back into the topics from there. I would still like to use the textbook because it contains all of the main ideas and vocabulary, but I think some current event–type stories would bring the unit a bit closer to home for my students. I will look on some of the sources suggested in the Resources list.

Which thinking strategy will I teach and practice throughout this unit? Why?

I have not done comprehension strategy instruction in my science classes before, so I want to start with something that feels comfortable to me. Background knowledge feels like the most straightforward, but I am not sure how much background knowledge or personal experience my kids will have about plate tectonics or even volcanos. So now I am thinking about questioning. Everyone knows how to do that, and that is really what scientific inquiry is all about: questions.

How do I use that thinking strategy in my own life? What examples can I give students as I introduce the comprehension strategy?

I feel like I am constantly asking questions, both as a teacher and a learner. As a teacher, I notice myself asking, "How can I make this unit or activity better? Do my students really understand?" and questions like that. As a learner, I am constantly inquiring, wondering, curious about the world and all things in it: "How can we use wind power to reduce ozone depletion? Who will be our next president? Why does cheese become moldy?" These are real life examples of some of the questions I have thought about just this morning, not to mention the more mundane like, "What should I eat for breakfast? Is it going to rain?"

When I introduce the strategy for reading, I will give examples of how I am often asking questions before, during, or after reading a newspaper article: the title gets me thinking and wondering, facts from the text make me curious, when I am finished reading, I often want to know more. These are some of the examples I can offer.

What are the ways I can ask students to document their thinking while they are reading and practicing this thinking strategy?

Well, questioning should be fairly straightforward to most of my students. I am sure they can come up with a lot of questions as they read, so I have a few different ideas of how to document those. One idea I have is to have students keep a question log and list their questions before and during the unit, then take time at regular intervals to let them check if we have answered any of their questions, and write those answers down. But more specifically, while we read I would like them to use sticky notes to write questions in the textbook; when we read articles, I will let them write directly on the photocopies and record any questions they have. Then we will definitely need to make time to go back and answer them, the ones that we can.

How will I assess learners' proficiency with this thinking strategy?

That is a good question. On the one hand, I can see myself counting the number of questions the students develop, but I don't think that is the only thing. I also want to see the depth of their questions. For example, are they really thinking hard, or just tossing questions out for the sake of questioning. I think we will have to spend some time discussing what makes a "good" question. I can show them Bloom's taxonomy and talk about the kinds of higher-order thinking we should strive for when questioning.

Another thing I am wondering is what about answering the questions, where that fits in, whether I need to expect them to find the answers to everything they ask.

Ms. Dobetter's Constants Checklist

1. *Which feature of inquiry will I emphasize? How?*
With questioning as the comprehension strategy, this unit will be most closely linked to that first essential feature, engaging in scientifically oriented questions. I think most of their questions as they try to understand the text will be scientific.

2. *What is the big idea, and how will I bring it to life?*
Patterns of change will come to life through the reading and other activities of the plate tectonics unit. I need to work hard to keep that big idea alive, though, by referring to it at frequent intervals and asking students to reflect on how their learning applies to it.

3. *Which elements of the workshop model will I employ?*
I will definitely wrap the workshop model around all of my reading instruction.

4. *When and how will I assess students' content understanding and skill proficiency?*
Students will be assessed in a lot of different ways—through conferring, through their small group conversations, and based on their individual written questions and reflections.

5. *How will students build and experience community through this learning?*
We will do a lot of paired conversations and whole group discussions as we practice this strategy. Through these experiences, students will participate in a community striving to make meaning together of new information.

Questioning Plate Tectonics

Introducing Questioning

Before kicking off her plate tectonics unit, Ms. Dobetter decides to orient her students to a new thinking strategy, questioning. "We are all constantly wondering about things—from social to scientific—all the time," she starts. She describes her morning getting ready for school and all the questions she asked herself: "When I got downstairs for breakfast and grabbed for the cereal, there was only Shredded Wheat left, and I wondered, 'What happened to all the Honey Bunches of Oats?' After breakfast, I thought about lunch, 'Will I have time to go out to lunch, or do I need to pack it?' As I decided between my thin fleece jacket and my warm coat, I was asking myself, 'Is it going to be cold today?' Some of my questions were answered—my cousin visiting from Chicago admitted to eating all the good cereal. I realized that I never have time to go out to lunch, so decided to pack one, and then I looked on the Internet and checked the weather.

"As I arrived at school, I wondered about more things: 'Why can't I get here any earlier?' 'What is wrong with the copier?' 'Where shall I take my cousin, who is visiting this week?' Some of those questions are still unanswered. Some are important, some are not, but nonetheless, when I stop and listen to the chatter of my own mind, I realize that I am asking questions all the time."

Ms. Dobetter then asks students to each take out a piece of paper and write down any question—any at all—that they have wondered about since getting up this morning. After several minutes of silent work time, she asks students to each look back over their list and answer which of their questions got answered through the course of the day, which were not yet answered, and which may never be answered. She invites students to share examples of each and records them in three columns on the board:

Questions Answered	Questions Not Yet Answered	Questions Unlikely to Be Answered (Ever)
• What's for breakfast? • Where is my iPod? • Why won't our car start? • How long is my brother going to be in the shower?	• What are we going to do in science today? • Is it going to rain? • When is Ciara's next album coming out?	• Why does she hate me? • Will infinity ever end? • Who stole my cell phone? • If we all stop driving our cars today, can we end global warming?

Ms. Dobetter uses these lists to point out how there are different types of questions, and that we each live with a great deal of uncertainty every day. "Our minds are full of unanswered—or as yet unanswered—questions. Similarly, scientists are also constantly asking questions, and throughout this unit, we—as student scientists—are going to practice our questioning skills." She introduces an anchor chart restating familiar question words, and asks students to notice themselves questioning for the rest of the day.

The second half of the class Ms. Dobetter devotes to preassessment of the unit learning goals. Students create concept maps synthesizing what they know about how the unit's key terms—continental drift, crust, mantle, plate boundaries, magma, and so on—relate to one another.

Practicing

The next day, students enter Ms. Dobetter's darkened room. Her projector shines on the anchor chart listing question words in bright colors: Why? How? Where? What? If? When? She begins class by reminding students that they are all natural questioners, and that today they are going to put those abilities to work as scientists—geologists. Ms. Dobetter has selected a number of slides of geologic events. Before sharing those with students, she explains that for each slide, she would like them to generate as many questions as possible in their notebooks. The show begins: lava oozing underwater, Mt. St. Helens, Mt. Surtsey, Mt. Fuji, Kilauea, Crater Lake . . . Ms. Dobetter pauses at each slide for several minutes to give students time to think and write. The room is awash with questions, none of them as yet answered.

After the slide show, Ms. Dobetter asks the students which of the slides (1–10) they are most interested in discussing. The class votes and selects slide five (Grimsvotn, Iceland), which Ms. Dobetter flashed on the board again for all to see. Then she invites questions, which they shoot rapid-fire as Ms. Dobetter records them on the board. Answering none, she affirms the group's curiosity and invites them back tomorrow for more before the bell rings.

Modeling While Reading

Now that Ms. Dobetter's learners experienced asking questions as they view photographs, she is ready to introduce the comprehension strategy of questioning while reading a text. When the students arrive, she piques their interest by reminding them of the recent tragedy in the news, then passes out the article. She has selected a recent newspaper piece about a cataclysmic earthquake in Mexico City; she flicks a transparency of the article onto the overhead and begins her think aloud. Ms. Dobetter refers to the anchor chart and describes how she will be recording questions in the margin as she reads. She proceeds to do so on the transparency as students follow along on their own page.

After reading three paragraphs and jotting five questions, Ms. Dobetter pauses and asks students to notice what kinds of questions she is asking: they are thoughtful science questions, probing for meaning in the piece. She is *not* asking questions like, "Why do we have to read this?" she points out. Ms. Dobetter asks the students what questions they have about the strategy before they proceed on their own. All seem ready to give it a try, and so she asks learners to read and think in silence.

Learners Use the Thinking Strategy While Reading

As the students work, Ms. Dobetter circulates and confers with them. She pauses to notice questions students are recording in the margins of the page, celebrating insightful ones by reading them aloud to the class. After sufficient work time has passed, Ms. Dobetter calls the students back together and asks them to think about where they would find the answers to their questions: In this text? Where? Students pair up and analyze their questions, sorting them into categories based on how they think each could be answered. Then, by way of closure, she asks each student to write for a few minutes about one of their questions that *was* answered today in their reading. Ms. Dobetter's students leave the room curious, some irritated by how much they still want to know and understand about earthquakes.

The next day, Ms. Dobetter has a story of a different sort of natural disaster caused by geologic forces: the explosion of Mt. St. Helens. While this volcano erupted before her students were born, several of them have heard of the event, and she invites all to join her in a think-together as they begin to read the article, her at the overhead, students with copies at their tables. As she reads aloud, she pauses, asks the students for their questions, and records those on her transparency. This collective activity gives Ms. Dobetter another opportunity to discuss how good questions should represent higher-order thinking:

- *Analysis:* Why did Mt. St. Helens explode, while Mt. Fuji only smolders?
- *Synthesis:* If change takes place in a predictable pattern, what will happen next to Mt. St. Helens?
- *Evaluation:* Why couldn't scientists have prevented this disaster?

After reading the first page together, Ms. Dobetter releases the class to finish the reading independently, continuing to record their questions.

As they get down to work, one girl complains that stopping to write questions is really slowing her down. Ms. Dobetter asks the rest of the group if they agree. Several do. As a remedy, Ms. Dobetter suggests they self-edit: instead of writing every last question—now that they are experienced questioners—record only those that seem most pressing, at least a handful per page. This feels like a reasonable compromise to the naysayers in the group. This article is longer, and few students finish reading it before the lunch bell sounds. Ms. Dobetter asks them to finish reading—and to finish questioning—for homework.

Metacognition

Friday, their fifth day on questioning, Ms. Dobetter decides that it is time to introduce metacognition. She begins class with a "quick write": How is this strategy—questioning—helping me to understand the texts? Students write their answers before sharing them in pairs. Since they have had think time, Ms. Dobetter draws names from her hat and calls on individuals to share their answers:

> "Questioning really slowed me down, but that was because I wanted to know what the article said to see if my questions were being answered."
>
> "I realized that I always do questioning while I read. This time I just had to write the questions down."
>
> "There were a lot of words in the articles that were new to me, and instead of just skipping over them, I made them into questions. I looked some of them up."
>
> "Questioning is just like what scientists do when they are trying to understand something. Questioning while reading these articles made me want to know more about geology."

Ms. Dobetter's geology unit continues: she weaves the questioning strategy into every aspect of their work. Students use questioning while reading from the text, and also when they are pursuing their culminating project analyzing earthquake data from the San Andreas Fault: their task is to predict an earthquake, and so their questions are about which conditions indicate that one is expected. Frequently, Ms. Dobetter pauses to celebrate questions and laud the virtue of this strategy as an important skill for thinking in science—as well as all other content areas.

While not all of her students' questions are answered at the end of the unit, Ms. Dobetter is not disappointed. She managed to get these kids more curious about plate tectonics than any class before them. Their curiosity drove them to learn more than she had ever hoped about volcanos, earthquakes, and other geologic phenomenon. And there is no question about that.

So What?

By explicitly teaching a comprehension strategy within a science unit, Ms. Dobetter built students' thinking skills while helping them make sense of important content. While it did take an investment of time to explain and model questioning at the outset of the unit, that investment paid off. Students were able to use the strategy again and again to engage with visual media, current events articles, and the textbook. Questioning gave students' minds something to focus on while they were taking in new information. The results in terms of student engagement and student learning were noteworthy.

"Yah, but . . ."

- *"I am not the English teacher."*

Anyone teaching in an English speaking country is an English teacher. In fact, research shows that students learn more new words in freshman biology than in a first year foreign language course (Williams 1992). In order to succeed in our classes, students must learn vocabulary and the skills of reading, writing, and thinking like scientists.

For best results, we can ask our English teacher colleagues to share their rubrics, strategies, and other tools so that the students make connections between our classes and see that language skills are imperative for success across the curriculum.

- *"Who has time for strategy instruction; we have to get to the content!"*

While strategy instruction may appear to take time away from science learning in the first analysis, it will actually enhance everything you do in class thereafter. With these tools, they will be better equipped to understand the science content of your course, which will help them to engage more fully as learners, so comprehension strategy instruction is well worth the effort and investment. Thinking strategies are lifelong skills that will serve our students throughout their learning careers. In five or ten years, your pupils may not remember the difference between a strike-slip and oblique-slip faults, but they are likely to remember the value of questioning—and other thinking strategies as tools to keep their minds turned on.