Chapter 2

Literacy and Thinking Tools for Science Teachers

by David Whitehead, University of Waikato

Introduction

Josephine, a third grader, carefully draws two intersecting circles on a piece of paper and labels her Venn diagram "Birds." She then lists, on scrap paper, words that describe Chirpy, her pet parakeet, in one column, and in a separate column, words that describe bald eagles that she identified in a text she is reading. Happy with her lists, Josephine writes the words that describe Chirpy only in one circle, and words that describe bald eagles only in the other circle. Some words describe both birds, so she writes these words in the space where the circles intersect. She then shares her completed Venn diagram with her teacher, who encourages Josephine to talk about similarities and differences between the two birds. Josephine is reminded to add words to her Venn diagram over the next few weeks as she learns more about the two birds. The teacher then models how the completed Venn diagram might be used to write a compare and contrast—structured paragraph.

The next time Josephine reads and makes notes or prepares to write a similarly structured paragraph, she might again use a Venn diagram literacy and thinking tool, which is a tool she can now name, use confidently; and state when it might be used. Wisely, Josephine's teacher designs a science unit assessment item that requires

Josephine to use a Venn diagram tool prior to writing a paragraph. This assessment item will indicate Josephine's understandings of birds and her ability to use this literacy and thinking tool to learn science and think like a scientist.

Literacy and thinking tools, such as Venn diagrams, are construction tools for the mind. Just as carpenters use tools to construct a piece of furniture, literate thinkers learning science can use tools to construct new scientific understandings. Like tools used by a carpenter, some literacy and thinking tools are purpose-built for science education; Josephine used a Venn diagram tool because she wanted to compare her pet bird to a bald eagle. Just as a screwdriver is built to slot into the head of a screw and rotate it, you can use literacy and thinking tools for subject- and text-specific purposes.

Frequently, a carpenter will use two or more tools together—hammer and chisel—to fit a lock-set. Likewise, you can help students achieve sophisticated scientific understanding by using literacy and thinking tools in combination. For example, Josephine may have used a Brainstorm tool (see chapter 9, The Earth Beneath Our Feet) to think about the attributes of birds, and then grouped and labeled those attribute groups, prior to constructing multiple Venn diagrams.

Just as carpenters use a range of screwdrivers depending on the type of screw they want to move, you can help students use a range of more or less sophisticated tools to help them gather information, process, or reflect on what they know. Carpenters also use more or less technologically sophisticated screwdrivers, depending on their technical ability and task demands. Similarly, literacy and thinking tools can be, in a developmental sense, more or less challenging.

In this chapter, we examine some characteristics of literacy and thinking tools (Whitehead, 2001, 2004). A list of these tools, together with the chapters associated with their use, is provided in Table 2:1.

The Wider Context

Consistent with the content, purpose, and developmental dimensions of the International Reading Association and the National Council of Teachers of English (IRA/NCTE) *Standards for the English Language Arts (1996),* the tools described in this chapter provide students with a means of comprehending, interpreting, evaluating, and appreciating scientific texts. They are designed to achieve our intentions as authors of this book to build a scientifically literate society, and to help literate thinkers live in a world shaped by science and technology, through the use of hands-on inquiry-based lessons. Likewise, in terms of the *National Science Education Standards* (1996), these tools are designed to support Standard A: Science as Inquiry, designed to help students develop the abilities necessary to conduct scientific inquiry. Finally, the literacy and thinking tools are designed to fit seamlessly into the 5E framework outlined in chapter 1 and used in subsequent chapters.

The Characteristics of Literacy and Thinking Tools

We begin with the premise that just as carpenters cannot turn a screw into a piece of timber with their fingers, students cannot turn their minds to higher order scientific thinking without the help of tools that give power to their minds. And just as carpenters know when to use a screwdriver, a literate thinker needs to know when to use different types of tools. Of course, tools are not always used for the tasks they were designed for; plenty of people have taken the top off a can of paint with a screwdriver, that is, used it as a lever rather than a screwdriver. Likewise, the creative use of literacy and thinking tools in science is to be encouraged.

The selection of tools described in this chapter is based on a set of seven theoretically embedded criteria. Ideally, literacy and thinking tools should be:

1. Teaching and/or learning focused
2. Text-linked
3. Subject-specific
4. Smart
5. Brain-friendly
6. Developmentally appropriate
7. Assessment-linked

Each of these criteria is described and illustrated below with examples of the tools used in association with the science units outlined in the following chapters (see Table 2:1).

Teaching and/or Learning Focused

The difference between literacy and thinking teaching tools and learning tools is, like the Chinese proverb: "Give a family a fish and they will eat for a day; give them a fishing line and they will eat for a lifetime." Teaching tools are like fish, but learning tools are like fishing lines. For example, you might teach students how to design questions around titles and subheadings prior to reading a science text. And you might model how students can ask these questions while reading to enhance their recall and comprehension. This is a learning tool because it is transferable, and because it equips students with an independent means of inquiry.

Some teaching tools, such as Think-Pair-Share (used in chapter 4 as an introduction to the study of traits) and Summarize-Pair-Share (used in chapter 8 to assist students to understand shadows and form generalizations), allow you to engage students in quality instructional dialogues. However, simplistic teaching

Table 2:1 Links between Selection Criteria, Literacy and Thinking Tools, and Chapter Use

Selection Criteria	Linked Literacy **and Thinking Tools**	**Used** in **Chapter**
Teaching (teacher) focused	*Concept Cartoon* *K-W-H-L* *Summarize-Pair-Share* *Think-Pair-Share*	5 4 *8* 4
Learning (learner) focused	*Question Maker* *Venn Diagram*	4 11
Text-linked	*Concept Frame*	*7*
Subject-specific	*Multi-Flow*	10
Smart	*Brainstorm*	9
Brain-friendly	*Moving Visual Imagery* *Concept Frame* *Short- and Long-Term Consequences*	6, 8 *7* 10
Developmentally appropriate	*Concept Frame*	*7*
Assessment-linked	*Meaning Grid*	11

tools, such as matching a list of scientific words to their definitions, evoke very little in the way of dialogue. In contrast, more complex teaching tools, such as the Concept Cartoon tool (see chapter 5), allow you to evoke high-quality instructional dialogue that will help students explore the scientific hypotheses and theories in their heads.

Thus, a fundamental difference between teaching- and learning-focused tools is that some are, and will always be, literacy and thinking teaching tools, while others are designed as learning tools. Both teaching and learning tools can be designed to achieve deliberate and purposeful outcomes with science text, but only learning tools are designed to help students achieve strategic outcomes with science texts, independently. We, therefore, favor the use of learning tools. Learning tools equip students for lifelong learning.

The Concept Cartoon Teaching Tool

The Concept Cartoon tool (Goodwin, 2000; Naylor & Keogh, 2000) is a cartoon-styled drawing that illustrates students' conceptions, or misconceptions, of science (see Figure 2:1). This tool, used in chapter 5, Birdie Buffet, has a problematic, scientific dimension designed to evoke constructive instructional dialogue. The ideas beginning with BUT... expressed in the Concept Cartoon callouts can come from either a teacher, who understands some common misconceptions students might have about the topic, or from students, with the teacher taking a "back seat." The visual format and minimal written text of the Concept Cartoon tool, together with its potential to help students express diverse and complex scientific viewpoints, make it an effective teaching tool.

To use the Concept Cartoon tool, you will need to initially provide the *Observation* ("Some birds have beaks curved at the end"). Students then provide more observations about birds with curved beaks, such as "they are carnivores" or "they are fish eaters." Finally, as a result of this discussion with you, the class generates a *Big Scientific Idea,* which in Figure 2:1 is: "Birds with curved beaks at the end might starve if rats and mice and fish die out."

This *Big Scientific Idea* is then transferred to a Concept Cartoon, and then your students suggest what might be written in the callouts beginning with BUT. These BUT statements form the basis of discussion around the challenge question "What Do You Think?" printed at the bottom of the Concept Cartoon.

Figure 2:1 A completed Concept Cartoon tool.

Through discussion around your initial science *Observation,* then through the instructional dialogue that enabled students to make the intellectual leap to a *Big Scientific Idea,* you are able to help students talk themselves to meaning—to clarify and elaborate their scientific understandings. Inevitably, this requires that you adopt a more constructive, rather than transmissive, approach to the teaching of science.

Although we are thinking about teaching and learning tools separately, some tools, such as the K-W-H-L tool used in chapter 4, Nurture and Nature, and the Venn Diagram tool used by Josephine, can be introduced as a teaching tool then become a tool learners use independently. The *K* in this tool represents what students Know about a topic; the *W* represents what students Want to learn about a topic; the *H* represents How the students will find information on a topic; and the *L* represents what students have Learned (Ogle, 1986). You can use this tool, initially as a teaching tool with the whole class, but it has the potential to be used, independently, as a learning tool. Like the K-W-H-L, the Question Maker (chapter 4) and Multi-Flow (chapter 10) tools may be used initially as a teaching tool, but are designed to be, primarily, learning tools.

The Question Maker Learning Tool

Perhaps the most significant learning tool you can equip students with is one that empowers them to ask questions. Like the K-W-H-L, the Question Maker tool (see chapter 4) enables students to independently construct questions about any science topic. The Question Maker lets you and your students identify what is not known and what is needed to be known. The tool also provides learners with an independent means of designing research questions that serve as purposes for reading, talking, and writing, as well as initiating or expanding a scientific investigation. To this extent, it is a learning tool rather than a teaching tool. Figure 2:2 outlines how you might help your students use the Question Maker tool with the topic of heredity, which is addressed in chapter 4, Nurture and Nature.

The Multi-Flow Learning Tool

The Multi-Flow tool (see chapter 10, Away We Go!) is also a learning tool because after students gain some mastery with it, they can apply the tool independently while reading, or prior to writing a scientific explanation. The Multi-Flow tool evokes cause-and-effect thinking typical of science. To use a Multi-Flow tool, you might first ask your students to read and discuss a text that explains something and that uses a cause-and-effect text structure. Then, ask your students to list causes and effects relating to the topic and write them in the boxes of the Multi-Flow tool. Finally, the completed tool can be used to structure a written explanation about the topic or a new topic.

Step 1: You state: "The topic is, for example: 'Inheriting Eye Color.'"

Step 2: You ask your students: 'What Level One Questions can we ask about this topic?"

(N.B.: *Level One Questions begin with: What..? When..? Why..? Where..? How..?)*

Level One Questions for this topic might be:

- What color eyes can you inherit?
- Why do some children have brown eyes when their parents don't have brown eyes?

Step 3: You ask your students: "What Level Two Questions can we ask about this topic?"

(N.B.: *Level Two Questions add modifiers to Level One Questions)*

- What if...
- When might
- Why should
- Where could
- How would

Level Two Questions for this topic might be:

- What if we could choose our baby's eye color?
- How would we find out whether it is healthier to have a particular color of eye? Step 4: You

ask students to group their questions around a common theme, and write a single question that covers this group of related questions. These questions are now available to steer the inquiry process.

Students discard questions they choose not to research.

Figure 2:2 A Question Maker learning tool.

Text-Linked

The text-linked criterion acknowledges a relationship between the type of thinking evoked when reading and writing scientific texts, and specific literacy and thinking tools. If a tool evokes the same type of thinking as is required to read, write, or discuss a particular text, then it is probably best used when students read, write, or discuss that type of scientific text. Recall that the Multi-Flow tool (see Figure 2:3) evokes causal thinking—students list the causes and effects associated with the process of erosion. Therefore, it can be used as a catalyst for your students' writing when the purpose of their text is to explain erosion. Given that both the Multi-Flow tool and a written explanation evoke similar types of thinking, they are best used together. (See Appendix A for an annotated writing sample about erosion that is based on the information generated from the Multi-Flow in Figure 2:3.)

You can also gain the benefits of the text-tool link by using the Concept Frame tool (see Figure 2:4) to help students organize information they gather, as well as help them write more descriptive scientific texts. This tool evokes attribute

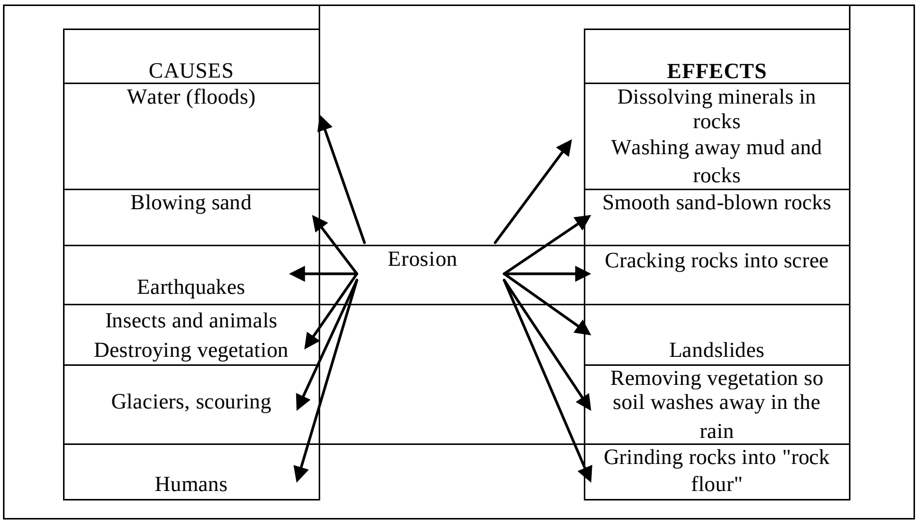

Figure 2:3 A simple Multi-Flow learning tool about erosion.

A bird is... 1. An animal that can fly 2. An avian 3. An animal with feathers	**A bird can...** 1. Fly 2. Squawks 3. Eat grain 4. Glide 5. Eat nectar
Examples of birds are... I. Eagle 2. Hummingbird 3. Parakeet 4. Emu 5. Kiwi	**A bird has a...** 1. Feathers 2. Beak 3. Wings

Figure 2:4 A simple Concept Frame tool about birds.

thinking—students list/describe the attributes of (or things about) an object, event, or idea. Then, they use their lists/descriptions to write about that object (i.e., crystals), event (i.e., respiration), or idea (i.e., evolution). Given that both the Concept Frame tool and descriptive writing evoke similar types of thinking, it makes sense to use them together. Chapter 7, Roll It, uses the Concept Frame tool to help students organize information they gather about force and motion and then write a description to show what they know.

Different parts of the simple Concept Frame illustrated in Figure 2:4 reflect some of the typical features of descriptive writing associated with the activities in chapter 5, Birdie Buffet. One feature, usually found toward the beginning of this type of writing, classifies the topic that the students are asked to describe. You can help students write this part of their text by telling them to use information from the top-left unshaded cell of the Concept Frame. Then, tell them to use information in the other shaded cells to write the body of their text. This information can be written as a simple sentence, or as more complex sentences and paragraphs that reflect deeper understandings. You could use Figure 2:4 together with the short annotated writing sample about birds provided in Appendix B to model this text-tool link when working with the Birdie Buffet unit in chapter 5.

Subject-Specific Criterion

While some literacy and thinking tools, such as Thinking Maps (Hyerle, 1996), suit most subjects, some tools are better suited to science. As we have seen, there is probably more use for a Multi-Flow tool (see Figure 2.3) in science than in most other subjects because cause-and-effect thinking is central to science. This tool is designed to help students understand causal dimensions typical of scientific concepts.

A generic aspect of the subject-specific criterion is that some tools will operate at the word level, to help students decode and comprehend the vocabulary of science, while other tools will help students comprehend whole texts independently. Tools operating at lower levels (i.e., decoding and vocabulary comprehension) tend to be teaching tools, while tools that operate on whole texts tend to be learner tools with a reflective dimension.

Smart Criterion

The literacy and thinking tools described in this chapter are consistent with the teaching and learning, text-linked, and subject-specific criteria. In addition, all the tools can be used to help students read or write, as well as listen or talk, about science. Tools with these complementary characteristics are consistent with the smart criteria. Just as a builder's screwdriver can be used to either screw in or unscrew a fixture, so, too, tools consistent with the "smart" criterion can be used to help students use the receptive and productive modes of spoken language (listening and speaking) and the receptive and productive modes of written language (reading and writing).

The simple Brainstorm tool (see Figure 2:5) used generatively in chapter 9, The Earth Beneath Our Feet, is a smart tool. To use this tool, you will need to first ask your students to construct the "Words about erosion" list as they "receive" (read, listen, or view) information about erosion, and call upon their prior knowledge of the topic. You can then ask them to construct groups and labels for those words as a means of further processing that information, prior to their producing a written or oral text about erosion. Based on Figure 2:5, you might expect students to produce at least a paragraph based on Label One: "Agents of erosion" and at least one paragraph based on Label Two: "Effects of erosion?' The Brainstorm tool is consistent with the smart criterion because students can use it productively (as a prewriting and pretalking tool) and receptively (as a note-taking tool).

Words about Erosion

Water (force)
lee (glaciers)
Freezing
Earthquakes
Sand
Flour
Landslides
Sand blasting
Floods
Wave erosion
Silt
Water (transporting dissolved minerals)
Scoured river banks
Eroded shoreline
Lower hills
Sculptured rocks

Groups and Labels

Label One: Agents of erosion	**Label Two: Effects of erosion**
Ice	Floods
Wind-blown sand	Sculptured rocks
Water (force)	Landslide deposits
Earthquakes	Scoured river banks
Gravity	Eroded shorelines
Water (dissolving)	Silt
	Lower hills
	Flour

Figure 2:5 A simple Brainstorm tool.

Brain-Friendly Criterion

Literacy and thinking tools are consistent with the "brain-friendly" criterion when they align with how the brain learns naturally (Wolfe, 2001). Acknowledging a tool as brain-friendly requires an understanding of how the brain learns. At a general level, we know the brain processes verbal language (words, mathematical and scientific symbols, and formula), and nonverbal language (e.g., images or pictures in the head) in two separate, but connected, neural systems. These systems provide your students with different ways of knowing. For example, the verbal system provides one way of knowing about light waves (stating in a sentence: "Light waves come from the sun"), and the nonverbal system provides another way of knowing about light waves (forming a visual image in their head of light waves coming from the sun) (Farah, 1989; Farah & McClelland, 1991). Moving my arms like a light wave to demonstrate what happens when they reflect off a mirror provides me with a further, kinesthetic way of knowing about light.

Some literacy and thinking tools, such as the Concept Frame tool used in chapter 7, Roll It, are more verbal; others, such as the Moving Imagery tool used in chapter 6, What Matters about the State of Matter, and chapter 8, Light Blockers, are more nonverbal. The Short- and Long-Term Consequences tool used in chapter 10, Away We Go!, evokes both nonverbal responses as students "see" into the future and verbal responses as they represent in words what they "saw." This use of a "dual coding" tool broadens students' perspective for science. This section explains why visual imagery tools are consistent with the brain-friendly criterion.

Moving and Melting Visual imagery Tools

Picture in your head what happens as water turns into steam. Visual imagery (making pictures in your head) and visual imagery thinking (doing something with the pictures you made in your head) are crucial to learning science. This is because explanations of how and why things occur often rely on understanding things unavailable to direct inspection—sometimes because they are hidden, sometimes they are too small to see, and sometimes they would take more than a lifetime to observe. The picture in your head about water turning into steam requires you to make a "melting" image rather than a "still" image, like a photograph, because you are imagining matter changing state.

Now try this one: Picture in your head how a T-rex that died in a swamp slowly turned into a fossil! This requires you to see bone transforming into stone—again, you need a "melting" image because you are picturing a change of state. Likewise, in the absence of direct experience, your students need to rely on visual imagery to understand what might be happening to magma full of gas as it blasts out of a volcano (see chapter 9, The Earth Beneath Our Feet), or what is happening between two surfaces as force is absorbed (see chapter 7, Roll It). In chapter 8, Light

Blockers, students are invited to make moving visual images to help them clarify and elaborate their observations of shadows and the absorption and reflection of light. They are also invited to write about and sketch their images. In chapter 6, What Matters About the State of Matter, you can invite students to make moving visual images to help them understand gases, liquids, and solids at the molecular level. By drawing what they image, students begin to both understand things hidden from direct inspection and synthesize and comprehend what they can "see." So reading and writing science—indeed, understanding science—is not exclusively verbal; students of science also form meaningful visual images (Sadoski & Paivio, 2001).

Imagery-based literacy and thinking tools are consistent with the brain-friendly criterion because they activate specific areas of the brain that allow us to make images, move and melt images, and inspect images. For example, we know the area at the rear of the brain, that allows us to see with our eyes, also works when we "see" images in the brain. It is an area crucial for both visual perception and visual imagery (Kosslyn, Ganis, & Thompson, 2001). This rear area of the brain works in concert with areas on the left side of the brain, which make visual images meaningful, and areas on the right side of the brain that allow us to think about the extent of our images. Further, a "motor area" on the left side of the brain allows us to rotate our images (Tomasino, Borroni, Isaj a, Rumiati, & Farah, 2005). All of these areas work under the direction of the front part of the brain that acts like an executive decision maker.

Visual imagery tools are consistent with the brain-friendly criterion because we know that our "picture-in-the-head" knowledge is stored in the brain close to the areas that work when we see or handle objects directly (Martin, Haxby, Lalonde, Wiggs, & Ungerleider, 1995). Thus, direct concrete experience is an essential prerequisite for the use of Visual Imagery tools. Direct experience provides students with the raw materials for imagery thinking.

There is an important difference between making visual images and using them. When you ask students to use images to help them understand science, they engage in visual imagery thinking. Use implies thinking, and use implies doing things with our visual images—moving them or moving our point of view in relation to an image, or melting them, zooming in, and scanning across them. For example, picture in your head what happens at the surface of the water in a boiling jug, now zoom in for a close-up view, and then position yourself just under the surface of the water. Changing perspective—doing something with our images—offers insight into this scientific process.

In a practical sense, during a science lesson, you might ask students to make a still image (a picture in their head that does not move) of an object or event central to a lesson (the beak of a bird, light hitting an opaque object, the contact between a toy car and sandpaper). Then, you might ask students to engage in imagery thinking, to make their images move, to "see" the bird using the beak, to "see" the light hitting the object, and to "see" under the toy car as it rolls across the sandpaper. When you ask students to share the things they "saw," you move from using a nonverbal system in the brain to using a verbal system. And in doing so, you give your students the opportunity to express, and further clarify, what they know. When you ask students to make their images move, to explain what's happening from a different position (e.g., from inside the flower as the hummingbird feeds), you give them an opportunity to gain further understanding. As a lesson closure, you can even ask students whether their moving images affected their understanding of an object or event; whether the use of this literacy and thinking tool helped them learn science.

The justification for using brain-friendly literacy and thinking tools is that they are consistent with the criterion that states tools should reflect the way the brain learns naturally. The application of this criteria leads to deeper learning in science and to the design and selection of better literacy and thinking tools.

Developmentally Appropriate

You may have already noted that some of the literacy and thinking tools associated with the science units in this book have been designated as simple or complex. The design of tools at these two levels is consistent with the developmentally appropriate criterion. Multi-leveled tools are essential for differentiated instruction. The two levels are designed to align with students' intellectual development and experience. Simple tools are probably best suited to students in Grades 1-4, or those students using literacy and thinking tools for the first time. Complex tools are designed for students in Grade 5 and beyond, or for gifted students who will probably begin to use a range of tools in combination. What these two developmentally appropriate levels do not assume is that grade level should absolutely determine which tools students use. If students in Grade 3 are developmentally ready, they should use a complex, rather than a simple, tool.

Initially, you might use both simple and complex tools as "teacher" rather than "learner" tools. So, although developmentally appropriate tools provide challenge levels designed to guide science teachers in their planning, the levels should never deny students opportunities to think.

The two developmentally appropriate levels also reflect beliefs about students' attention spans and the types of text-related intellectual tasks they encounter in science classrooms. For example, you can use a tool such as a simple Concept Frame (see Figure 2:6) as a text-linked prewriting tool in a matter of minutes. This tool enables you to assess and record prior learning by collaborating with students as they use each sector of the completed frame to write or dictate simple sentences beginning with "A bird can.... A bird has.... A bird is...An example of a bird is..." This is an achievable challenge well within the capabilities of most Grade 1-4 students that can be completed with a minimum of teacher intervention (Chapman, 1999).

What we already know about birds

A bird is...	A bird can...
• An animal that can fly • An avian • An animal with feathers	• Fly • Chirp • Eat grain • Eat meat
Examples of birds are... • Eagle • Crow • Sparrow	**A bird has...** • Feathers • Claws • Wings • Curved beak

My sentence about birds.

An eagle is an example of a bird that has a curved beak and claws and that eats meat.

Figure 2:6 A simple Concept Frame tool about birds.

In contrast, students may find the complex Concept Frame tool (see Figure 2:7) slightly more challenging. Successful use of this tool requires persistence and a degree of independent learning behavior. This complex tool requires students to further attend to what they know by ordering information in each sector of the Concept Frame. This order will be reflected in the structure of their writing. They might also decide that some information doesn't align with what they want to write, and signal this with an X beside the word (see Figure 2:7).

A complex Concept Frame also requires students to generate additional ideas using the *Examples* words (see right-hand bottom sector in Figure 2:7) to construct questions. Based on this figure, you would direct students to begin with the name of a bird listed in the *Examples* sector, such as "eagle,' and add a sector header word ("is," "are," "can," or "has") to "eagle" to construct their question. For example, "An eagle is...?'; or "Eagles can...?", or "An eagle has...?" You would then record the words that answer the question in the appropriate sector of the Concept Frame. For example, "Eagles can... catch rabbits" so you would record the words "catch rabbits" in the "can" sector of the Concept Frame (see point 6, "Catch rabbits" under "Can" in Figure 2:7). A complex *Concept* Frame additionally requires students to group information. Figure 2:7 illustrates how you might help students make groups for "bad" things birds *can* do, and for *examples* of birds that are "meat eaters" and "grain eaters."

Is.../is a...		Are...
Order Belongs to a group 3. Animals that fly 2. An avian 1. Animal with feathers X. A noisy thing	BIRDS	*Order Things about them* 2. Pets 1. Expensive to keep X Colorful 3. Meat eaters 4. *Threatened*

Can	Has.../has a.../have...	Examples
Order Actions Groups 4. Chirp 2 Fly 1. Eat grain 5. Spread bird flu } Bad 3. Dirty windows } Bad 6. *Catch rabbits*	*Order Things they hare* 1. Feathers 2. Claws 3. Wings 4. Curved beaks 6. Stubby beaks	*Order Groups* 2. Eagle } Meat eaters 1. Crow } Meat eaters 3. Sparrow } Grain eaters 4. Chaffinch } Grain eaters

Figure 2:7 A complex Concept Frame tool about birds.

In addition to increasing demand on students' attention, the two developmentally appropriate levels increase intellectual demand on students. For example, a simple Concept Frame provides students with just four cues that assist them to gather and record information. In terms of Bloom's taxonomy (Bloom, 1956), this evokes little more than recall and understanding. In contrast, a complex Concept Frame requires students to work with five sectors and to further process information in each sector. In terms of Bloom's taxonomy, this requires students to analyze and synthesize information. In taxonomic terms, literacy and thinking tools consistent with the developmentally appropriate criterion evoke higher order thinking.

Assessment-Linked

A final criterion is that, ideally, literacy and thinking tools associated with science programs can be used as assessment tools. The forms of assessment you use in science have a powerful influence on the kinds of learning your students do and the kinds of teaching your students encounter. In a high-stakes testing environment, teachers tend, quite naturally, to teach to content-focused testable standards. In a high-stakes testing environment, the measures used are usually norm-linked and summative rather than diagnostic and formative (Calkins, Montgomery, Santman, & Falk, 1998). The assessment of prior knowledge and the growth of students' understanding assessed using formative measures tend to play second fiddle. Literacy and thinking tools consistent with the assessment-linked criterion can be used for both formative and summative purposes.

The Formative Assessment of Scientific Knowledge

A Meaning Grid tool (see Figure 2:8) is ideal as a formative, science assessment tool because you can use it on several occasions during a series of lessons to measure students' growth in content knowledge. This tool is gradually introduced throughout chapter 11, The Earth in the Solar System. To use the grid as an assessment tool, you will first need to draw a grid with the objects or events you wish to assess listed across the top (see igneous, sedimentary, and metamorphic rocks in Figure 2:8). Then, together with your students, you will need to list two or more descriptors of each rock type down the left-side column of the grid (see "Made when hot rock cools").

Figure 2:8 illustrates that, part way through a study about rocks, students were unsure of some facts (see the question marks), and in some cases, just plain didn't know (see the blank sections of the grid). There is also a possibility that what they think they know (as indicated by dots, crosses, and checks) might be wrong, and that eventually, your intervention will be required.

The tool can also be used flexibly as a summative assessment measure. For example, you might provide students with the types of rocks listed across the top of the grid and descriptors of those rocks listed down the left side of the grid. The assessment would simply involve students using√, x, or • to indicate their understanding. A more rigorous assessment would involve students providing their own descriptors down the left side of the grid and then completing the grid with √, x, or • and adding summary statements beside and below the grid.

Testing Like We Teach

As the preceding description illustrates, there is nothing inherently wrong with the assessment of content knowledge, as long as you simultaneously assess *how* you taught the science. This presupposes that some of the assessment items in a science unit test are constructed in such a way that students recognize and treat them as familiar and representative of the actual learning experience—of how they learnt the science. Thus, the challenge signaled by the inclusion of literacy and thinking tools described in this book is for you to test both the science curriculum content together with students' ability to apply the literacy and thinking tools used to teach the content. In effect, this form of assessment is providing a measure of content knowledge *and* students' ability to inquire.

For example, you can use the Concept Frame tool illustrated in Figure 2:9 in association with the unit, The Earth Beneath our Feet (see chapter 9), to help students learn about rocks as an inquiry tool. This tool can also be used as a pretest item to gauge students' prior knowledge of the topic, as well as a summative post-test

Key:

✓-= We are sure

X= We are sure they are not

• = Some are/do and some are/do not

? = We are not sure

Blank square = We don't know yet

	Igneous rocks	Sedimentary rocks	Metamorphic rocks	Comment
Made when hot rock cools	✓	X	?	
Made from broken _pieces of rock		•	X	
Made when igneous, sedimentary, and metamorphic rocks are changed by heat and pressure	?	X	✓	
Lots of tiny crystals	✓	?	X	Most metamorphic rocks seem to be fine grained.
Contains fossils	X	•	•	
Often have shiny surfaces		X	✓	
Generally dark in color	✓		•	Rocks come in all different colors.
Often in lavers				
Used in carving	?		?	We need to Lind out which rocks you can carve.
Basalt	✓	X		
Granite	✓	X	X	
Sandstone				
Limestone		?		
Marble			?	
Slate				

Comment

We think that some metamorphic and sedimentary rocks may contain fossils.

Figure 2:8 A Simple Meaning Grid tool used as a formative assessment tool.

item. Again, using this tool provides you with an opportunity to "test as you teach," to assess not only what you taught (about rocks), but also how you taught it. That's smart teaching, and that is the kind of assessment one would expect to see if literacy and thinking tools were used as an integral part of a science curriculum.

Conclusion

The use of literacy and thinking tools that are consistent with the criteria outlined above, and when used as an integral component of your science program, should be prized and valued. Their application leads to attractive scientific destinations. And the journey toward these understandings is, itself, extremely satisfying and motivating for both you and your students alike.

Instruction: Define the meaning of a rock as accurately as you can by completing the Concept Frame.

A rock is... 1 2 3	A rock can... 1 2 3
Examples of rock are... 1 2 3	A rock has... 1 2 3

Figure 2:9 A Simple Concept Frame **tool used as a pre- and postassessment.**