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CHAPTER 14

Integration of Literacy and Science

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OVERVIEW OF RESEARCH

The ability to engage effectively with texts across content areas is increasingly viewed as central to advanced literacy in the 21st century (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). As is becoming more widely recognized, reading, writing, and talk are shaped in part by the texts and contexts in which they are situated, such that reading in the scientific disciplines calls for different sets of skills and stances than, for example, reading literary texts does. Moreover, whereas science educators traditionally regarded reading and writing as separate from learning and participation in science, literacy is increasingly viewed as authentic and integral to science learning.

A growing body of instructional research provides insight into the characteristics of effective approaches to literacy and science integration. In particular, this research supports the efficacy of approaches that help students acquire strategies to understand and write science texts and tie the literacy practices of science to science inquiry. The approaches to literacy–science integration described in this chapter have demonstrated wide-ranging benefits for students' learning in science and literacy, and for students' engagement and motivation in both domains.

Helping Students Acquire Strategies to Understand and Write Science Texts

For many decades, reading was widely viewed as a set of general skills that could be applied to nearly any text and nearly any purpose. The underlying assumption was that students who were taught to read on literary texts would later simply transfer their reading skills to content-area texts (Shanahan & Shanahan, 2008). This view has been

challenged recently by evidence that a focus on "basic" reading skills has failed to prepare adolescents for the demands of content-area reading. In addition, many educators now recognize that reading differs in important ways, depending on the nature of texts and the disciplinary practices in which reading is situated. (For more about helping students learn to read and write specific genres of text, see Duke & Watanabe, Chapter 13, this volume.)

Several recent reports on reading and adolescent literacy have called for attention to text- and discipline-specific reading and writing instruction (e.g., Alliance for Excellent Education, 2010; Heller & Greenleaf, 2007; RAND Reading Study Group, 2002). These reports emphasize that literacy instruction should continue beyond the elementary years and support students in developing the kinds of literacy skills that foster involvement in disciplinary learning and participation (Alliance for Excellent Education, 2010; Heller & Greenleaf, 2007). The reports emphasize that each discipline involves different kinds of texts, different approaches to reading, and different purposes for reading (Heller & Greenleaf, 2007).

The authors of some key adolescent literacy reports express concern that the emphasis on generic reading skills and strategies might lead students to believe that they can approach every text in the same way, when the texts that students encounter in history are different from those they encounter in chemistry (Carnegie Council on Advancing Adolescent Literacy, 2009; Heller & Greenleaf, 2007). For example, although texts differ across different disciplines in science, students are more likely to encounter reports, procedural texts, and explanations in the sciences than in other content areas (Fang, 2012), and each of these text genres is associated with different features. Lee and Spratley (2010) note that scientific reports often include features such as abstracts, headings, and diagrams, which can support understanding if students are taught to use them. Experts in adolescent literacy note that students can be supported in navigating the complexities of the texts they will encounter in science by being taught to use these features and to do the following:

- Make sense of technical vocabulary and complicated syntax, such as long noun phrases.
- Make sense of visual elements, such as diagrams, drawings, photographs, and maps.
- Use textual structures, such as cause-and-effect and sequential structures, to understand text.
- Search text to find information related to their purpose for reading.
- Read key parts of texts with exactitude—for example, noting even small differences in research results (England, Huber, Nesbit, Rogers, & Webb, 2007; Fang, 2012; Heller & Greenleaf, 2007; Lee & Spratley, 2010).

Although the most obvious difference in reading as students move into different disciplinary contexts concerns the nature of the texts, reading in the disciplines involves the use of more sophisticated and specialized skills. Shanahan and Shanahan (2008) examined the reading processes of disciplinary experts as they read and thought about texts in their areas. The researchers found that the experts in each discipline approached texts differently and leveraged a different set of reading strategies. For example, whereas historians attended to possible sources of bias, mathematicians

engaged in close examination and rereading to ensure that they understood the contribution of each word to the meaning. Shanahan and Shanahan suggested that differences in the reading practices of disciplinary experts are related to the values, norms, and methods of scholarship within each discipline. That is because historical scholarship involves arguments about the interpretation of source documents and historical events, and because such scholarship risks selective analysis and biased interpretation, historians read for authors' perspectives. Readers of history must evaluate the arguments being made by the authors and the authors' interpretations of sources that underlie the arguments. Because chemists use experimentation to develop knowledge in their field, they read the reports of others' experiments with a careful eye to the quality of the instruments, data collection procedures, and analyses that produced the particular results. The recent adolescent literacy reports have also pointed out strategies and stances that scientists take toward texts. For example, Lee and Spratley (2010) point out that in the context of reading scientific reports, students need to be able to pose questions about these aspects:

- The functions of investigations.
- The appropriateness of the data collection and its analysis in relation to the questions and conclusions.
- The tradeoffs of the research design in terms of what we can learn from the research.
- The links between and among data, findings, previous research, and existing theory.
- Potential sources of bias that might have influenced the findings.

Moreover, students of science need to be able to look across texts in order to make sense of conflicting claims and in order to synthesize knowledge (McMahon & McCormack, 1998).

Several research studies have demonstrated the power of teaching students strategies to help them read and write science texts. One effective, research-based approach is that of the Reading Apprenticeship (RA) program (e.g., Greenleaf et al., 2011). The RA model is focused around the *metacognitive conversation,* in which teachers model and discuss how to read science texts, why people read science texts in these ways, and the content of the texts. Although teachers use well-known comprehension routines in RA, such as reciprocal teaching (Palincsar & Brown, 1984) and ReQuest (Manzo, 1969), they also use the metacognitive conversations to model and guide students explicitly in using an array of comprehension tools to understand and reason about science texts. For example, teachers might talk about how they pull apart difficult sentences, where they find information about unknown words, and how they take notes from a content-area text. In metacognitive conversations, teachers provide explicit support for science reading by making visible the processes of reading and comprehending complex texts.

Research on RA has demonstrated many positive outcomes for students. In one recent study, high school students in RA classrooms made greater gains on the state standardized test scores in English language arts, reading comprehension, and biology than students in comparable classrooms (Greenleaf et al., 2011). In addition, students in RA classrooms reported that that they were receiving more support for reading in science.

The Science Writing Heuristic (SWH) is an approach to engaging students in written and oral argumentation in order to support their learning from laboratory experiences in science (Hand & Keys, 1999). The SWH includes a student writing form that student use over the course of their laboratory experiences. The form, which is designed to scaffold students' writing and reasoning about their inquiries, includes the following questions (Hand, 2008, p. 6):

Questions: What are my questions?
Test and Collect Data/Observation: What did I do? What did I see?
Claims: What can I claim?
Evidence: How do I know? Why am I making these claims?
Reading: How do my ideas compare with others?
Reflection: How have my ideas changed?

The SWH also includes a template for teachers to use in designing laboratory activities and facilitating group discussions. The template lays out a series of instructional steps, including pre- and postassessments using concept mapping, prelaboratory activities (such as posing questions and brainstorming), laboratory activities, and several phases of negotiating understandings through writing and discussion.

In two separate studies (Hand, Wallace, & Yang, 2004; Hohenshell & Hand, 2006), SWH researchers found that 7th-, 9th-, and 10th-grade biology students using the SWH made greater gains in their conceptual understanding of cell biology than students in a control group who participated in traditional to laboratory activities across 7–8 weeks of instruction. In addition, 5th-, 7th-, and 10th-grade students using the SWH improved in their ability to make written arguments regarding their biology lab experiences over time.

Integrating literacy and science with a focus on reading and writing strategies has been shown to support literacy development for English language learners (ELLs). Lee, Mahotiere, Salinas, Penfield, and Maerten-Rivera (2009) worked with third-grade teachers to improve their students' science writing, with a particular focus on supporting the ELL students in their classrooms. In the professional development, teachers learned to use science instruction to teach literacy strategies, such as activation of prior knowledge, comprehension of science texts, and language functions in science, with a special focus on science writing. Teachers also learned to support ELL students' learning in science through the use of linguistic scaffolds (e.g., pacing, repetition, and rephrasing), the use of students' home language to provide access to science terms and concepts, and the incorporation of students' cultural experiences into science instruction. The teachers were provided with curriculum units that included language supports for ELLs in science, such as hands-on investigations and use of *realia* (i.e., visual images and artifacts, such as photographs and objects). In each of three years, the intervention had positive impacts on ELL students' writing gains. It is particularly notable that the ELL students made gains comparable to those of non-ELL students. In a related study, Lee, Maerten-Rivera, Penfield, LeRoy, and Secada (2008) reported that third-grade students whose teachers participated in the professional development intervention improved their science achievement scores. Importantly, the growth scores for students identified as ELLs were not different from those of students who had exited ELL status or had never been ELLs.

Tying the Literacy Practices of Science to Science Inquiry

Although there are many ways to define *inquiry* as it relates to science teaching and learning (Anderson, 2007; Minner, Levy, & Century, 2010; National Research Council [NRC], 2011), the defining characteristics of science inquiry for the purposes of this discussion of science and literacy learning are that students (1) actively engage in exploring scientifically oriented questions, (2) gather evidence in the interest of answering those questions, and (3) engage in firsthand or hands-on activities that allow them more concrete experiences with scientific phenomena (or models) and allow them to gather evidence in a firsthand way. Reading and writing are important tools of science inquiry, but they are too often used in place of students' involvement in firsthand investigations. There is a long history of division between textbook-based approaches to science learning and inquiry-based approaches to science learning, but research has increasingly demonstrated that a combined approach not only better supports students' science learning, but also supports students' reading and writing of science texts.

The most obvious reason to tie students' reading and writing to science inquiry is that combining these activities is a more accurate representation of science as a discipline and more supportive of students' learning in science. However, there is also substantial evidence that linking reading about science with doing science is powerful for children's literacy development. There are several possible explanations for these effects.

First, reading in the interest of answering compelling scientific questions—particularly when combined with hand-on experiences—offers the kind of reason for reading that has been shown to promote more active engagement with texts. Firsthand experiences and ongoing investigations can make the difficult task of pulling apart content-area texts more purposeful (Romance & Vitale, 1992). In the context of ongoing investigations, the goal of reading is not just getting from the beginning to the end of a particular text; the goal is understanding something that is connected to students' experiences in the classroom and the world. Science investigations offer opportunities to engage students in reading with the goal of understanding the material well enough to use it for other purposes, such as making an argument or applying a concept in some way. As such, when students are engaged in ongoing investigations, teachers and students tend to focus on deep understanding, rather than on the details of a particular text, and it turns out that a focus on deep understanding supports students' growth in reading comprehension (Knapp, 1995; Purcell-Gates, Duke, & Martineau, 2007; Taylor, Pearson, Peterson, & Rodriguez, 2003; Taylor, Peterson, Pearson, & Rodriguez, 2002). Purcell-Gates and colleagues (2007) examined the impact of authenticity of literacy activities involving the reading and writing of science text genres on second- and third-grade students' growth in reading and writing the genres. Purcell-Gates and colleagues defined *authentic activity* in the study as reading and writing the science text genres for purposes other than learning to read and write them (e.g., reading for information or writing to communicate information to someone who wants it). The researchers found that authenticity was strongly related to growth in students' abilities to read and write the text genres. Guthrie and colleagues (2004) provide one possible explanation for the impact of authenticity (or application) on comprehension: They note that the goal of understanding a conceptual theme provides a purpose for using comprehensions strategies, thus building students' skill with the strategies.

Relatedly, firsthand experiences in science support motivation to read. Reading motivation is an important outcome of reading instruction and a mediator of growth in reading comprehension (e.g., Wigfield et al., 2008). Several studies have demonstrated that hands-on experiences in science support sustained motivation and gains in reading comprehension. For example, Guthrie, Wigfield, and colleagues (2006) found that the number of stimulating (hands-on) activities that teachers used related to reading in science predicted third-grade students' growth in reading comprehension through the mechanism of motivation; that is, the stimulating tasks increased students' motivation to read, and motivation to read supported students' growth in reading comprehension. In a related study, Guthrie, Hoa, Wigfield, Tonks, and Perencevich (2006) studied the results of involving third-grade students in a reading program designed to increase their situated interest in reading (i.e., their enjoyment of reading particular texts in particular situations) by involving the students in observational and hands-on activities in science and then providing an abundance of related, interesting texts for students to choose to read. The researchers found that students who participated in the program not only increased their situated interest, but also increased their general motivation to read over 3 months.

Finally, firsthand experiences can build the knowledge that supports students' comprehension of text—both immediately and in the future. We have known for decades that having knowledge about a topic supports reading comprehension (Alexander, Kulikowich, & Schulze, 1994; McNamara, Kintsch, Songer, & Kintsch, 1996; Tierney & Cunningham, 1984). Readers who have more knowledge can more easily assimilate new information and can better distinguish between important and peripheral information (Stahl, Hare, Sinatra, & Gregory, 1991). As such, building a wide base of knowledge about the natural world is likely to support students' reading development as they move through school and beyond. It also appears that a developing bank of knowledge supports students in learning and use of reading strategies and in overall reading comprehension (Guthrie & Ozgungor, 2002; Taboada, Tonke, Wigfield, & Guthrie, 2009).

Several programs of instructional research have demonstrated the efficacy of approaches that bind reading and writing to inquiry experiences in science. Romance and Vitale (1992, 2001) have designed an integrated science–literacy program at the elementary level that involves students in hands-on science activities, reading comprehension instruction, concept mapping, and writing with the goal of supporting students' deep conceptual understanding in science. The program, In-Depth Expanded Applications of Science (IDEAS), involves teachers in developing concept maps of key science concepts and then planning a range of science and literacy experiences to engage students in different aspects of the concepts.

The reading comprehension program includes three components:

1. Text analysis, in which students are taught to use their prior knowledge for reading and to build new knowledge while reading.
2. Concept mapping, in which teachers guide students to pull apart and map ideas encountered during reading.
3. Writing summaries based on the concept maps.

These three activities not only help students make sense of the science concepts in the texts they read, but also help them to understand how these texts are organized.

In addition, because reading is linked to students' involvement in multiple hands-on inquiry experiences, students learn to bridge text and experiences in ways that are authentic to science. In a series of research studies, this approach has resulted in wide-ranging positive impacts for the students. Notably, students in grades 1–5 in classrooms that used this approach demonstrated greater gains on the Iowa Tests of Basic Skills Reading and Science subtests than students in classrooms that did not use this approach (Romance & Vitale, 1992, 2001; Vitale & Romance, 2010).

Concept-Oriented Reading Instruction (CORI) is an integrated science–literacy program based on a model of reading engagement that includes the following five practices (e.g., Guthrie et al., 2004):

1. Using content goals for reading instruction.
2. Affording choices and control to students.
3. Providing hands-on activities.
4. Using interesting texts for instruction.
5. Organizing collaboration for learning from text.

The program also involves students in assembling portfolios that include records of questions and reading inferences, summaries of text passages, illustrations, charts, and even physical models (Guthrie, McRae, & Klauda, 2007; Swan, 2003). Student use the portfolios to write books related to the themes of the units.

In the Guthrie and colleagues (2004) study, third-grade students in CORI classrooms were taught reading comprehension strategies, such as activating background knowledge, questioning, searching for information and summarizing, as they learned about a conceptual science theme (ecology). The students read texts of various genres related to the theme, and they participated in firsthand experiences, including observations of different habitats and an experiment with aquatic insects. The teachers made explicit connections between the texts and students' firsthand experiences. For example, the students took a habitat walk in their school yard and then compared their walk with a nature walk described in a trade book. Embedding strategy instruction in a knowledge-rich context full of firsthand experiences had a powerful influence on students' acquisition of the strategies. These students showed greater growth on a composite assessment of reading strategy use than did students who received more traditional strategy instruction.

The same framework has been implemented with students at other grade levels, with similar results. In a study of fourth-grade students, CORI was compared with cognitive strategies instruction and traditional instruction. Following 12 weeks of instruction, students in the CORI classrooms outperformed students in the other classrooms on measures of reading engagement, reading comprehension, multiple-text comprehension, and use of reading strategies. Guthrie and colleagues (2009) found positive results for fifth graders involved in CORI on measures of word recognition speed, reading comprehension, and ecology knowledge. Moreover, they found that the CORI instruction was equally effective for lower- and higher-achieving readers.

Seeds of Science/Roots of Reading (Seeds/Roots) is a curriculum-based integrated science–literacy program. Seeds/Roots is premised on the idea that both science and literacy development benefit from integration that focuses on shared and complementary skills, but that leads with science conceptual development and involvement in inquiry.

The curriculum units engage students in reading, writing, discussing, and using firsthand experiences to develop understandings about science concepts, the nature of science, and the process of inquiry. One of the main principles underlying the Seeds/Roots model is that texts can and should be used in various roles to support students' inquiries. To this end, students read texts that model the inquiry processes that they will use in their own investigations; they search handbooks for information that they can leverage as they investigate; and they read books that situate their classroom-based inquiries in the wider natural world. Students are instructed in issues related to science text genres and science reading and writing strategies as they use literacy to support their involvement in ongoing investigations.

In a study of second- and third-grade students learning about the shoreline ecosystem and the forest floor ecosystem, students who used the integrated Seeds/Roots units made greater gains in science understanding, science vocabulary, and science reading comprehension (in one of the two units) than did students who participated in an inquiry-based science unit involving firsthand experiences, but little reading and writing (Wang & Herman, 2005). In a study of third- and fourth-grade students studying light energy and light interactions, students using the Seeds/Roots integrated unit outperformed students in classes using their regular science materials (also on the topic of light) and literacy materials on measures of science writing, science understanding, and science vocabulary (Cervetti, Barber, Dorph, Pearson, & Goldschmidt, 2012).

SUMMARY OF BIG IDEAS FROM RESEARCH

The research on literacy–science integration is summarized in Table 14.1. This research supports the following big ideas:

- Effective teachers provide instruction that supports students' use of science literacy practices.
- Effective teachers help students develop the range of distinctive reading processes and stances toward text in science that characterize reading in the disciplines of science.
- Effective teachers tie the literacy practices of science to science inquiry.

EXAMPLES OF EFFECTIVE PRACTICES

Helping Secondary Students Acquire Strategies to Understand and Write Science Texts

High school science teacher Will Brown is working to apprentice his ethnically and linguistically diverse urban students into the literacy practices of science (Greenleaf, Brown, & Litman, 2004; Litman & Greenleaf, 2008). Will has been part of the RA project for several years and has learned to use metacognitive conversations to help his students make sense of science texts. In addition to engaging students in many firsthand investigations in chemistry, Will routinely gathers his chemistry students together to discuss their thinking, problem solving, and challenges as they make sense of their reading. In these conversations and in his in-the-moment interactions with students, Will thinks

TABLE 14.1. Positive Outcomes in Experimental and Quasi-Experimental Research Studies of Science and Literacy Integration

Citation	Grade(s)	Reading and vocabulary	Writing	Science knowledge	Motivation/ engagement
Cervetti, Barber, Dorph, Pearson, & Goldschmidt (2012)	4	Vocabulary	Writing (use of evidence, introduction, clarity, science content, and use of science vocabulary)	Science understanding	
Fang & Wei (2010)	6–8	Reading vocabulary and comprehension		Science knowledge Science grade	
Greenleaf et al. (2011)	8–10	English language arts Reading comprehension		Biology knowledge	
Guthrie, Anderson, Alao, & Rinehart (1999)	3, 5	Strategy use in a text search activity (grade 3) Comprehension of narrative texts Conceptual learning from text			
Guthrie et al. (2004)	3	Passage-reading comprehension Reading strategy use (a composite of activating background knowledge, searching for information to answer questions, and organizing information) Multiple-text reading comprehension Reading comprehension			Intrinsic motivation to read Extrinsic motivation to read Reading motivation

(*continued*)

TABLE 14.1. *(continued)*

Citation	Grade(s)	Reading and vocabulary	Writing	Science knowledge	Motivation/ engagement
Guthrie et al. (2009)	5	Reading comprehension Word recognition speed		Knowledge of ecology	
Guzzetti & Bang (2011)	11–12			Chemistry knowledge and scientific skills	Attitudes toward science
Hand, Wallace, & Yang (2004)	7			Science conceptual understanding	
Hohenshell & Hand (2006)	9–10			Science conceptual understanding	
Lee, Mahotiere, Salinas, Penfield, & Maerten-Rivera (2009)	3		Ability to explain science concepts in writing English proficiency in writing		
Lee, Maerten-Rivera, Penfield, LeRoy, & Secada (2008)	3			Science concepts and science inquiry	
Romance & Vitale (1992)	4	Reading		Science achievement	Attitudes toward learning science and reading Self-confidence in science
Romance & Vitale (2001)	2–5	Reading		Science achievement	Attitudes toward learning science and reading Self-confidence in science and reading

(continued)

TABLE 14.1. (continued)

Citation	Grade(s)	Reading and vocabulary	Writing	Science knowledge	Motivation/ engagement
Vitale & Romance (2010)	1–2	Reading		Science achievement	
Wang & Herman (2005)	2–3	Science reading comprehension Science vocabulary		Science understanding	
Wigfield et al. (2008)	4	Reading strategy use (a composite of activating background knowledge and posing questions) Multiple-text reading comprehension Reading comprehension Reading engagement			

aloud about his own comprehension processes, making visible often-hidden problem-solving processes. Will invites students to see what it means to comprehend the texts, and helps them to acquire the strategies that proficient readers use to deal with the comprehension challenges encountered in complex science texts.

During one class period, the students watch Will think through a difficult passage and discuss the comprehension strategies that help him overcome the difficulty. Students listen as Will describes how first figuring out the meaning of boldfaced words in the science textbook can help them make sense of a difficult sentence or paragraph. He explains his strategy:

> "It can still be hard even when they give you the definitions of the key words. The words around the key words can be words you don't know. . . . Start with the word in bold or italics and the sentence it is in. Try to understand that one sentence, work very hard on it, and then look around it in the paragraph. Put most of your energy into understanding the boldfaced words."

Because words are often stumbling blocks for students in understanding school texts, including the science textbook, Will often focuses his metacognitive conversations on building students' knowledge about and interest in words. Will occasionally starts a class period by asking students to talk about "interesting" words they have learned recently. Sometimes this leads to a group problem-solving session, as it does

one morning when Veronica shares the word *substantially*—explaining that she encountered it while reading the science textbook on the previous day, but does not know what it means. Veronica's classmates first try the strategy of looking for a familiar word in the unfamiliar word, but this leads them to *substance*, which does not seem to help. Will guides the students in using other strategies for figuring out the word, such as using the context to substitute a synonym. Veronica suggests *partially* as a synonym, and Will rereads the passage aloud, substituting the *partially* for *substantially*, to see whether it makes sense in context: "A fundamental property of acids and bases is that an acid and a base always react to 'neutralize' one another. That is, the products of the reaction do not have acidic or basic properties (or they are *partially* reduced compared to the reactant acid and base)." Will asks students whether they think *partially* and *substantially* mean similar things, but the class is divided. Will calls the students' attention to the phrase *that is*, and asks, "What does *that is* mean to you? What is it telling you?" Will asks Darren to reread the sentence, but stops Darren after the phrase *do not have*. Will asks, "How much is *do not have*? How does *partially reduced* compare to *do not have*?" Will points out the parentheses following *do not have acidic or basic properties*, and helps students see that *substantially reduced* must have a similar meaning to *do not have*. Karen suggests that *completely reduced* would fit.

Will's students gradually come to see that replicable strategies and determination are the keys of science comprehension. And they become more comfortable in sharing their own reading processes. Students discuss what's easy for them in texts and what's confusing, and they share their own strategies for overcoming comprehension challenges. Metacognitive conversations make individual reading and thinking processes part of the community of Will's classroom.

Will has worked hard to establish the kind of environment in which these kinds of conversations can take place. He has talked to his students since the beginning of the year about the purpose of the conversations, and he has guided students to explore their current ideas and feelings about reading in science. Throughout, Will has communicated excitement about figuring things out through firsthand inquiry and reading. Will has found that metacognitive conversations invite greater engagement in his classes and help students take on more productive roles as readers and learners.

Helping Elementary Students Acquire Strategies to Understand and Write Science Texts in Service of Inquiry

Lorna Ratliff is planning a science unit for her class around the second-grade standards related to changes in matter. Lorna has participated in the Science IDEAS professional development workshop over the last few years, and is using the IDEAS model to develop the unit.

Lorna begins by selecting a core concept to serve as an entry point into the unit. Lorna selects the concept of evaporation because she knows that many of her students will have had everyday experiences with this concept, such as watching when water is heated in a pot on the stove and disappears into the air as it turns into an invisible gas (water vapor), or noticing how water in a cup slowly disappears if it is left open for a day or two.

Following the IDEAS model, Lorna selects the concept of evaporation from the "Changes in Matter" concept map that the professional development facilitators

provided in the IDEAS workshop (see Figure 14.1). Lorna learned in the IDEAS workshop that it is important to begin planning with a concept map of the key ideas, so that unit development is coherent, is guided by the structure of the concepts in the discipline (Romance & Vitale, 2010), and aligns with the NRC's new K–12 science framework (NRC, 2011).

Lorna uses sticky notes to add to or replace some ideas from the concept map, based on her objectives and her students' existing knowledge of changes in matter. Lorna knows that she will rebuild this concept map with her students as they move through the unit, and she will have students use the map as the basis for written explanations of evaporation.

Once she has a concept map that represents the core ideas in the unit, Lorna begins to plan instructional experiences. She decides that she will begin with a demonstration to invite students to puzzle about evaporation. At the beginning of the school day, she will introduce the unit and ask students to discuss what they already know

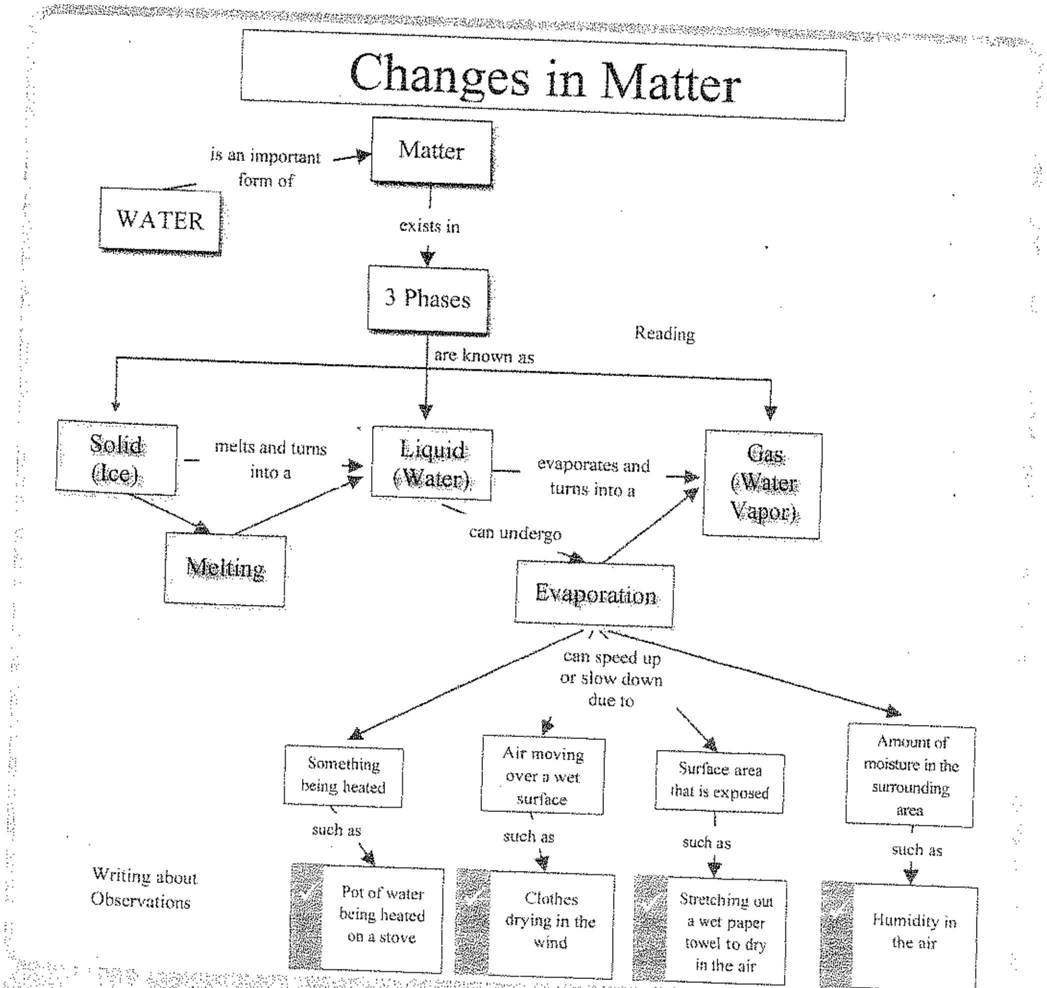


FIGURE 14.1. Science IDEAS "Changes in Matter" concept map.

about phases of matter. She knows that they are familiar with solids, liquids, and gases, but she doesn't think they understand a lot about how matter changes between these phases. Following the discussion, Lorna will dampen a thin rag and place it outside. She will ask students to make predictions about what will happen. Later in the day, they will revisit the rag and set up two additional firsthand experiences with evaporation.

As Lorna proceeds in planning the unit, she refers often to her concept map, annotating it with references to activities that address each concept cluster on the map. She includes reading experiences, which she can also use to reinforce students' understandings of informational text features. She also includes writing experiences to help students record their observations and make sense of the key ideas in the unit.

Lorna's objective is to ensure that the students understand that water changes phases because of specific factors, such as heat and surface area. She carefully lays out a series of science and literacy experiences that together form a journey to help students grasp these important concepts. She also makes preliminary plans to use students' experiences with reading and writing in the unit to help them acquire strategies for comprehending and writing science texts. She also knows that she can use the concept map as a blueprint to guide expository writing.

Tying the Literacy Practices of Science to Science Inquiry

Over the last 2 weeks, the students in Michael Medina's third-grade class have been engaged in an ongoing inquiry about soil as a habitat for plants and animals. They started the inquiry by building and observing two tabletop terrariums (see Figure 14.2). They built the terrariums in clear plastic containers by adding soil and other earth materials. Then they planted alfalfa seeds and observed the first sprouts. Michael told the students that the terrariums are models of a forest floor habitat. The students have been learning about habitats and know that they are preparing to add earthworms to the terrariums.

The students are excited on the day that Michael brings the earthworms. They observe the earthworms' body parts and how the earthworms move. They write their observations and make drawings of the worms. Michael asks them to write predictions about what will happen when they add the earthworms to the terrariums. What will the earthworms do? Some students think that the earthworms will eat the leaves in the terrariums and grow bigger. Others think that the earthworms will go underground. Finally, the students add earthworms to the terrariums.

The next day, the students observe the terrariums again, but the earthworms have disappeared. They look for evidence about where the earthworms might be. One student notices holes in the soil and suggests that the earthworms are under the soil. The other students agree that this must be the case. Michael asks how the earthworms can survive underground. He wonders aloud what the earthworms do down there. What do they eat? How do they move? The students join in with questions and wonderings about the activities of the earthworms underground.

Michael tells the students that he has a book about different forest floor animals that might help them answer their questions about the earthworms. The students join their reading partners and begin to read. Michael knows that the students can read this book with their partners, because they possess a powerful combination of curiosity and

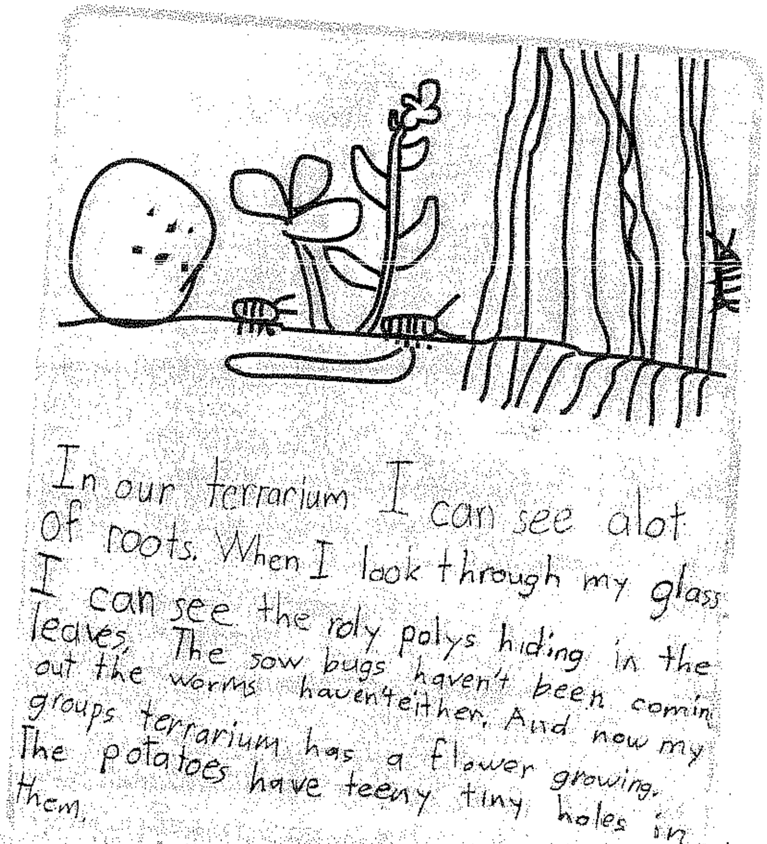


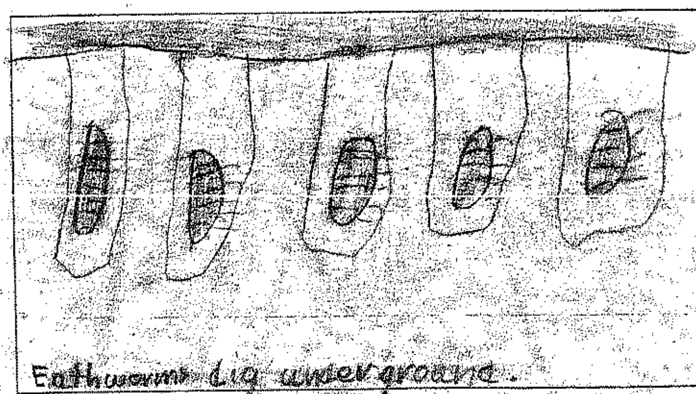
FIGURE 14.2. A student's observation of her group's desktop terrarium.

relevant knowledge from their work in the habitat unit so far. They have encountered almost all of the challenging vocabulary in the book already, and they know how to use the glossary to look up words they don't recognize. In addition, Michael has been teaching students strategies for reading informational texts since they entered his classroom. Students use the reading to answer their observation-driven questions about the behavior of earthworms. Later they will pose questions about different aspects of life on and under the soil, answering the questions through firsthand investigations and reading (see Figure 14.3).

Planning for Integration of Literacy and Science

All of the teachers just described foreground science learning in their integration of literacy and science; they use both literacy activities and inquiry as the tools of conceptual development. Pratt and Pratt (2004) suggest that "the commonality between the science and reading comprehension goals should be obvious; both place the understanding of subject matter content as the ultimate outcome" (p. 396). The good news is that literacy benefits from this authentic supporting role, particularly when teachers provide explicit guidance about strategies and purposes of science reading and writing.

Directions. Write the question that you will write about in the space labeled "My Question." Then write about your question. Illustrate about your writing in the space provided.



My Question: What adaptatoins help eathworms survivous de decomposers?

Eathworms have adaptation to help them survive as decomposers. Eathworms dig underground. They have a mouth to eat dead things also it puts nutrients in the soil. Intestines that help them poop out nutrients.

FIGURE 14.3. One student's writing about the inquiry question "What adaptations help earthworms survive as decomposers?"

Perhaps the easiest way to begin enacting science–literacy integration is to use existing curriculum materials. Increasingly, there are curriculum materials available through publishers and online that support the integration of literacy and science instruction. However, it is also possible to design these experiences in your classroom. You might begin with a science unit that uses mainly firsthand experiences and look for authentic opportunities to infuse reading and writing. You might gather a set of thematically related science trade texts, or even a science textbook, and imagine where firsthand experiences could be used to support students' understandings of the science concepts. Or you might engage in the ambitious work of developing a fully fleshed out, integrated unit of instruction.

- Map out the science goals and the literacy goals that you are setting for students. The science goals should include attention to science concepts, science inquiry

skills, and understandings about the nature of science. The literacy skills might include using the structural features of informational text genres (e.g., headings, glossaries); making sense of the visual features that often appear in these texts; reading for information across different texts; recording observations and taking notes; or using comprehension strategies that support students' comprehension of science text, such as goal setting, summarizing, and questioning.

- Gather sets of books that relate to your science goals. These may include everything from books about the science concepts you want to address to books about the lives of scientists to news articles that connect the science to everyday life. Try to select texts that provide the kinds of information and experiences that would be difficult to recreate in the classroom, such as experiences in distant places (under the ocean, in space) and experiences with things that are difficult to observe (molecules, internal body systems).
- Develop firsthand experiences that invite students to explore the concepts you are studying and to develop their inquiry skills.

Guzzetti (2009) describes an example of this approach: a chemistry teacher's implementation of a forensics unit she implemented with her high school class. While the teacher, Sharon, wanted to capitalize on the students' interests in forensics and to support their development of important science concepts (such as the difference between physical and chemical evidence), her main goals related to students' development of inquiry skills, such as the ability to evaluate evidence and to draw conclusions from this evidence. Sharon also wanted them to develop science literacy skills, including the ability to read a range of science texts for evidence and to communicate scientifically. Across the 3-week unit, the students read from a wide range of texts that Sharon had gathered. The students read about crime scene evidence in teacher-constructed cases. They also read forensics procedures and reference documents, news articles, (fictional) police reports, and sections from forensics textbooks. These readings supported the students' ability to solve the crime scene cases. In addition, the students used a variety of forensic processes, such as fingerprinting, blood spatter analysis, chromatography, and chemical analysis, to explore physical and chemical evidence "found" at the fictional crime scenes.

LOOKING FORWARD

Although the programs of research discussed in this chapter provide strong evidence for the efficacy of instructional approaches that integrate literacy and science, the following efforts will be needed in order to make instruction in disciplinary literacies a reality in U.S. classrooms:

- Broader development of materials and approaches that provide opportunity for students' authentic engagement in reading and writing (Purcell-Gates, Duke, & Martineau, 2007), particularly as part of inquiry-oriented content-area instruction (RAND Reading Study Group, 2002).
- Improvements in the quality and accessibility of content-rich texts across the K–12 spectrum (Pearson, Moje, & Greenleaf, 2010). Although science texts for

young readers are changing, typical science textbooks are dense and disengaging (Lee & Spratley, 2010; Schleppegrell, 2004), and teachers still struggle to find good text for inexperienced science readers (Eisner, 1987; Lee & Spratley, 2010; NRC, 1990; Schleppegrell, 2004). In addition, most science texts present facts, but fail to help students understand the nature and processes of scientific inquiry (Cervetti & Barber, 2008).

- Changes in the structure of the elementary school day to allow more time for rich engagement with content-area learning. Undoubtedly, the biggest obstacle to the adoption of integrated approaches to science and literacy is the general status of science teaching at the elementary level. Surveys of elementary teachers over the last decade have indicated that the pressures of standards and testing have driven many teachers to forgo science instruction entirely, and that those who do teach science tend to devote only 1–2 hours per week to its instruction (Dorph et al., 2007; Fulp, 2002; McMurrer, 2008).
- The development of assessments to help us track students' progress in applying literacy skills in the interest of inquiring and learning in the content areas. As long as multiple-choice tests constitute the primary metric for measuring student learning in science and literacy, it will be difficult to advocate for the approaches described in this chapter.
- Professional development opportunities and changes in initial teacher preparation to soften the boundaries between literacy instruction and content-area instruction (Pearson et al., 2010).
- Research to help us better understand and capitalize upon complementarities between science and literacy at different points in students' development, including better understanding of how literacy skills are similar and different across the disciplines of science, and the relationship of these myriad skills to our goals for students' science and literacy development across the K–12 spectrum.
- Research to help us better understand the nature of the relationships among inquiry, knowledge development, reading motivation, and reading comprehension skill.

QUESTIONS FOR REFLECTION

1. To what extent do I support students in understanding that science texts call for different approaches to reading than literary texts do? How do I ensure that students have strategies to make sense of challenging, content-rich informational texts?

2. To what extent do I make explicit for students the differences among the texts that we read across different content areas?

3. To what extent do I help students make sense of the visual elements of science texts, such as diagrams, tables, and graphs?

4. To what extent do I help my students develop the understanding that science involves reading, writing, talking, and doing—all in the interest of reaching a better understanding of the natural world?