5

Text in Hands-On Science

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Over the past several years, we have been engaged in a curriculum development and research project focused on the integration of science and literacy. Our approach to integration ties reading, writing, and speaking to science inquiry in order to build students' scientific skills and understandings and to give context and purpose to students' experiences with nonfiction reading and writing. This paper describes one aspect of our work—the development of science texts and their use in inquiry-based science curriculum. While we position science skills and understandings as essential ends of our work, we also set out to explicitly target literacy learning goals. Toward those dual objectives, we have been searching for the "sweet spot" between text and experience, where the use of text supports students in conducting scientific investigations and making sense of scientific ideas, and science investigations and ideas support students' development of academic vocabularies and world knowledge, their facility with content-rich text, and their comprehension of nonfiction materials.

SCIENCE TEXT IN THE ELEMENTARY CLASSROOM

Over the last decade, researchers have documented a genre imbalance in early-reading instruction (e.g., Duke, 2000). This work has resulted in a heightened awareness that students' early-literacy instruction is dominated by fictional texts, while, as Palmer and Stewart (2005) point out, "simply put, we live in an expository world" (p. 426). That is, most of the reading students do in schools is of nonfiction materials, and adults, likewise, do most of their out-of-school reading with nonfiction materials (McKee & Ogle, 2005). However, when it comes to school instruction, students have few experiences with informational text (Duke, 2000).

Arguments for the importance of including nonfiction and informational text in literacy instruction at the primary level have been presented elsewhere (e.g., Duke & Bennett-Armistead, 2003). One compelling rationale concerns students' preparedness for content-area learning, which inevitably involves students in learning from nonfiction texts. The assumption that text is text—that students will easily transfer generic reading skills from fictional literature to other genres of text—has been called into question as research has documented that students across grade levels struggle with reading and understanding nonfiction text (McGee, 1982; Meyer, Brandt, & Bluth, 1980). This research suggests that, if we want students to use nonfiction text effectively, they must be taught how. According to the 2002 Rand report, *Reading for Understanding*, teachers need to directly instruct students on how to navigate and extract information from text (RAND, 2002). In addition, the failure to include more content-rich texts in elementary reading instruction is seen by some as a missed opportunity to develop powerful world knowledge that can support students' later reading comprehension (Walsh, 2003).

At the same time that literacy educators have come to recognize the importance of nonfiction text genres, science educators have started to revisit the relationship of text to science learning. There is no dispute that inquiry-based science, or science that involves students in hands-on experiences and investigations, is the accepted standard for elementary science instruction (American Association for the Advancement of Science [AAAS, 1993]; National Research Council [NRC], 1996, 2000). However, controversy does continue to surround what inquiry-based instruction involves operationally and what role text can play. This controversy centers on questions about the authenticity, efficacy, and efficiency of hands-on science experiences in helping students master the broad array of science content standards that are laid out by current state and national standards, and conversely, on the efficacy of text in

helping students to learn science with understanding and to develop the skills of inquiry (Bransford, Brown, & Cocking, 2000).

Over the past few decades, this controversy has played out between the extremes of text-only versus experience-only science instruction. Textbook science programs once included little or no firsthand experience for students, and a generation of hands-on science programs supported by the National Science Foundation (NSF) included no texts for students. Emblematic of the controversy is the tussle that occurred in 2003–2004 over California's criteria for K–8 science instructional materials. The proposed wording of the 2003 California Curriculum Commission's (CCC) *Criteria for Evaluating K–8 Science Instructional Materials in Preparation for the 2006 Adoption* specified that materials include *no more than* 20 to 25% hands-on instruction (Strauss, 2004). In the end, and after much struggle, the final wording now specifies that *at least* 20 to 25% of science instructional materials must be hands-on (California Department of Education, 2004).

Recently, science educators in the inquiry-based tradition have started to acknowledge that reading and writing are important tools in scientific inquiry and argumentation—that scientists are reliant on literacy skills particularly as they access ideas from text and communicate the results of their investigations. Yore et al. (2004) note that "scientists rely on printed text for ideas that inform their work before, during, and after the experimental inquiries" (p. 348). Nevertheless, the integration of text-into-inquiry science programs has been particularly tentative. Yore (2000), like many other inquiry-based science educators, suggest a limited role for text, where students "*do first and read and write later*" (p. 105). In addition, the past 5 to 10 years have witnessed a cautious approach to integrating text into inquiry-based science curricula and vice versa, where text-based programs have added materials kits to their programs, and inquiry-based programs have added student readers, each without changing the basic structure of the curriculum.

As we have created student texts and a related program of instruction, we have been confronted with the questions of how we can create a more meaningful form of integration and how text can support students' involvement in hands-on science, rather than supplanting their investigations. Our answer has been to offer students opportunities to use reading and writing in the service of conducting investigations, making sense of their investigations and sharing their learning—much as scientists do. In this chapter, we present (1) a model of text in inquiry science that prioritizes students' firsthand experiences, (2) guidelines for selecting texts that supports this kind of involvement in science, and (3) considerations that have guided our development of student text for inquiry science.

WHY FOCUS ON THE USE OF TEXT IN INQUIRY-BASED SCIENCE?

Much has been written lately about nonfiction and informational text genres and the use of these texts in subject-matter learning. While teachers are being encouraged to provide opportunities for students to read in content areas such as science, the question of what kinds of text students should be reading and when and how these texts should be used remains open. This question is particularly sensitive in science, where inquiry-based science educators have been tentative in their embrace of text, concerned that it might constitute a slide backward toward textbook science.

In designing an approach to using text in science, we have been aware of strong concerns from inquiry-oriented science educators about the ways that text has sometimes been used to misrepresent science and exclude students from involvement in inquiry. Inquiry-oriented science educators have expressed concerns about the use of text that represents science as a set of facts. Yager (2004) suggests that the typical content of science textbooks or supplemental materials is not *science*, but rather, statements of *fact* based on explanations of how the natural world has come to be accepted by most scientists. Trade books and textbooks about science often fail to represent "the heart and soul of the scientific enterprise"—the nature and processes of science—but instead emphasize the facts and generalizations that are the products of science (Yager, 2004, p. 95; Armbruster, 1992/1993).

Perhaps the most significant concern about text for educators in the inquiry tradition of science education is that texts often take the place of students' involvement in firsthand investigation and experimentation. Short and Armstrong (1993) emphasize that texts should support the doing of science, rather than replace it. Palincsar and Magnusson (1997) interviewed teachers about the role that secondhand (text-based) investigations can play in scientific investigations. They found that there was a shared view among teachers that emphasizing text too much in science can be risky. The risk lies in students' deference to the authority of the text even though they are capable of investigating and generating their own answers. In part as a result of these concerns, inquiry-oriented science educators have often shied away from the use of text, or they have positioned text experiences after firsthand experiences in inquiry-based science programs that include reading. Often, firsthand inquiry experiences set the context for the introduction of new science concepts or inspire further investigation in text. For example, in the in-depth expanded application of science (IDEAS) program (Romance & Vitale, 1992) and the concept-oriented reading instruction (CORI) program (e.g., Guthrie

& Cox, 1998), experience generally precedes reading. While the CORI creators do not make any explicit claims about order, hands-on exploration is the first phase of the program. The teachers that Palincsar and Magnusson (2001) interviewed supported this approach: "The teachers cautioned against introducing text early in the investigation and urged that text be used following a significant amount of firsthand inquiry" (p. 160). The teachers recommended that text be used to *extend* hands-on experiences. In the Explorers program aimed at upper-elementary students, Bruning and Schweiger (1997) used hands-on experiences to "energize" literacy learning. They suggest that "observation and active involvement provide immediate, compelling, memorable sensory experiences" for subsequent experiences with text (p. 149).

Despite widespread apprehension about the use of text in inquiry science, some inquiry-oriented science educators have become interested in the role of reading and writing in science education (Glynn & Muth, 1994; Lemke, 1990; Yore, 2000; Yore et al., 2004), recognizing that reading and writing are authentic ways that scientists and non-scientists learn about and do science outside of school. In addition, the goals that reading and science inquiry share are being recognized. That is, students read to find out about the natural world much like they inquire. 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).

Several programs of research have demonstrated how inquiry-based science experiences combined with science text can support students in building scientific understanding. Most notably, Guided Inquiry Supporting Multiple Literacies (GISML; Palincsar & Magnusson, 2001) and IDEAS (Romance & Vitale, 1992, 2001) use domain-appropriate experiences and text to build knowledge about the world that students then bring to bear on their understanding of related text. The GISML project demonstrates how hands-on experiences in combination with reading can be used to deepen students' conceptual understanding by helping them to extend, sharpen, and clarify their knowledge. By foregrounding conceptual understandings in science, and by using reading, writing, and concept mapping in combination with hands-on experiences in support of the understandings, the IDEAS program has produced positive learning outcomes and attitudes in reading and science compared with traditional instruction involving the use of a district-adopted basal reading series and science textbook with a few supplemental hands-on activities. Our own research has demonstrated that students in combined science-literacy curricula involving text and hands-on experiences exhibit greater growth in science knowledge and science vocabulary than students who participate in curriculum focused exclusively on hands-on inquiry experiences or reading science text (Cervetti et al., 2006).

It may be that students can't learn all they need to know about science from firsthand experiences alone. Palincsar and Magnusson (2001) problematize the notion that inquiry is exclusively activity based, noting "the impossibility that children will come to meaningful understandings of the nature of scientific thinking simply through the process of interacting with materials and phenomena" (p. 152).

In addition, researchers working at the interface of science and literacy have documented positive effects of a combined science-literacy approach involving the use of both text and hands-on experiences on student learning in both science and literacy (Guthrie & Ozgungor, 2002; Klentschy, Garrison, & Amaral, 2001; Romance & Vitale, 1992; Varelas & Pappas 2006). The CORI project provides especially powerful evidence that connecting reading and writing to expertise in content areas can engage students and support strategic reading, as well as improved science understanding. For example, Guthrie et al. (2006) have shown that stimulating firsthand experiences result in more motivated reading and improved reading comprehension when compared with instruction that includes a similar focus on reading comprehension and science understanding but uses fewer firsthand experiences related to the reading. Reading and hands-on investigations can be mutually reinforcing in the service of a knowledge goal such as understanding how animals survive in their habitats.

A FRAMEWORK FOR THE ROLES OF TEXT FOR HANDS-ON SCIENCE

In our work, we have focused on using text in the context of inquiry-based science instruction in support of students' hands-on experiences. We have been committed to creating texts that represent the processes and products of science and to using these texts in ways to support students' inquiry experiences. This approach involves students in using text before, during, and after their firsthand investigations.

We have developed a framework of the roles that texts can serve in supporting inquiry science. These roles appear in Table 5.1: providing context, modeling, supporting firsthand inquiry, supporting secondhand inquiry, and delivering content. To provide a context for the description of the text roles that follow, we describe a short sequence from a curriculum unit about the shoreline ecosystem as an example of the relationship between text and experience.

In this sequence, students learn about the physical characteristics,

TABLE 5.1. Functions and Illustrations of Five Roles of Text in Inquiry-Based Investigations

Function	Examples of texts
Role 1. Provide context for inquiry-based investigations	
• Inviting students to think about their everyday experiences in a new way (e.g., about all of the organisms that live in the soil beneath their feet) • Sharing an aspect of the natural world that is unfamiliar to students (e.g., how everyday objects are made or organisms that live in caves) • Introducing the natural contexts in which scientific phenomena operate (e.g., the habitats in which organisms under study live) • Connecting students' everyday experiences to classroom investigations (e.g., where chemical reactions happen in everyday life) • Connecting students' investigations to big ideas in science (e.g., the use of models or systems in science) • Connecting students' investigations to a specific domain (e.g., field of chemistry or forensic science) • Connecting students' investigations to the work of professional scientists (e.g., scientists who research new medicines)	• *Where Butterflies Grow* by Joanne Ryder • *Beach Postcards* by Catherine Halversen and Nicole Parizeau • *What the Moon Is Like* by Franklyn Branley and True Kelley
Role 2. Model scientific processes	
• Modeling inquiry processes, such as observing, recording, comparing, planning and conducting investigations, and making sense of data • Modeling scientific dispositions, such as posing questions, exploring, and testing • Depicting scientists and their work (e.g., biographies and portrayals of the dispositions of curiosity, passion, persistence, and open-mindedness that characterize good scientists)	• *Wild Mouse* by Irene Brady • *Protecting Primates* by Kate Boehm Nyquist • *Jess Makes Hair Gel* by Jacqueline Barber
Role 3. Support for firsthand investigations	
• Providing science information to supplement the evidence students are collecting in a firsthand way (e.g., a handbook with information to help students make sense of their observations) • Providing information to help students create a firsthand investigation (e.g., a book about how to build a habitat for an organism under study)	• *Tracks, Scats, & Signs* by Leslie Dendy • *Snails and Slugs* by Chris Henwood • *Gary's Sand Journal* by Gary Griggs, Catherine Halversen, and Craig Strang

(*continued*)

TABLE 5.1. *(continued)*

Function	Examples of texts
Role 4. Provide opportunities for secondhand investigations	
• Providing data for the reader to interpret. These data can be pictorial (e.g., a collection of pictures or graphics that represents a set of data), qualitative (in tables or organized in other ways), or quantitative (numbers in tables or on graphs). • Communicating visual information based on data (e.g., pie charts, bar graphs)	• *What Do You Do with a Tail like This?* by Steve Jenkins and Robin Page • *Introducing Frogs and Toads* by Graham Meadows and Claire Vial • *Snail Investigations* by Gina Cervetti
Role 5. Deliver content	
• Providing information about or illustrating phenomena that would otherwise be unobservable in a classroom context (e.g., internal structures of organisms or solar system objects) • Addressing misconceptions that might arise in the conduct of firsthand investigations • Supplementing, extending, and providing opportunities to apply what students are learning (e.g., detailed information about an organism or planet provided in a reference book)	• *Zipping, Zapping, Zooming Bats* by Anne Earle • *What Color Is Camouflage?* by Carolyn Otto • *Handbook of Interesting Ingredients* by Jacqueline Barber

composition, and formation of sand through firsthand investigations and reading specific texts that have been designed to accomplish particular goals.

1. *Read to set context.* Students read *Beach Postcards*, a text about beaches and shorelines (Halversen & Parizeau, 2006). By reading and comparing a set of postcards that feature different beaches around the world, students learn that a shoreline is a place where water meets land, that there are shorelines all around the world, and that a sandy beach is one kind of shoreline. For the many students who have never been to a shoreline, the text also communicates information about the experience of being at a shoreline and provides wide and close views of river, lake, and ocean shorelines.

2. *Investigate things that can be found on a sandy beach through hands-on activities.* Students explore a model beach (a bucket with sand and other materials found on sandy beaches). Students observe the materials they find and sort them into categories that suggest something about their origins (e.g., evidence of animals, plants, humans, or rocks).

In using the beach bucket, students examine real beach objects firsthand, experience the power of models to investigate questions about the world, and look for evidence to support explanations. Students' hands-on investigations suggest that many different kinds of objects from living and nonliving sources can be found on sandy beaches.

3. *Investigate the formation of sand.* Students investigate to learn more about how sand is made by using hard candy to model the process. Different colored candy represents different objects the students found in their model beaches, including rocks, shells, seaweed, and trash. Students shake the jar of candy to model wave action at the beach and watch how the candy breaks into smaller and smaller pieces and mixes together to form candy sand.

4. *Investigate the composition of sand.* Students investigate to learn more about what sand is made of. Students use magnifiers, magnets, and mineral kits to make inferences about the composition of sand: What are the observable properties of the sand grains? Are any of the sand grains metallic? Do some sand grains resemble particular minerals? Students record their observations in their own sand journals. Their investigations suggest that sand is composed of the different materials found at the beach.

5. *Read for modeling and for information to inform investigations.* Students read *Gary's Sand Journal*, a text about a real shoreline scientist that presents a model of the nature of science (how scientists view the world and how they investigate) and information about the composition of sand that can inform students' investigations (Griggs, Halversen, & Strang, 2006). The text shows how Gary uses the properties of sand as evidence to determine the sand's origin and composition and how he records his observational notes. The text also provides information that would be difficult to gather in a firsthand way in classrooms—for example, how different kinds of waves influence the size and shape of sand grains found on the beach.

6. *Continue to investigate.* Students continue their hands-on investigations, using the information from the text to inform their inferences about what the observable properties of individual sand grains tell them about the age, origin, and formation of the sand. They are given mystery sand and asked to identify its age.

Using Texts to Connect Students' Hands-On Experiences in Science with the World Outside of School: Providing Context

In the sequence just described, students begin their investigation of the shoreline ecosystem with a text that describes various shorelines around the world. The unit of study focuses on only one kind of shoreline, the sandy beach, but *Beach Postcards* situates students' investigations in the context of a world etched with thousands of miles of shoreline. Texts can be used to set a context for students' hands-on experiences in science. When students engage in classroom-based investigations, context-setting texts can situate their firsthand experiences in the contexts of the natural world, the scientific discipline, and society.

Contexts provide a natural link to the knowledge and experience that students bring to science investigations and can prepare students for inquiry-based investigations by provoking them to look at the natural world in new ways and by inspiring them to wonder about science. In a study by Anderson, West, Beck, Macdonell, and Frisbie (1997), students read texts to stimulate their wondering about a scientific topic. They asked questions about the topic and engaged in investigations to answer their questions. Students selected texts by asking, "Is this interesting? Does it make us wonder about science things? Do we want to talk about these wonderments with our friends?" (Anderson et al., 1997, p. 714). Collectively, the students found many texts that prompted wonderments that led them to conduct substantive explorations.

Text can also help students connect their firsthand investigations to the natural world and to the work of scientists. For example, many teachers offer students the opportunity to observe the development of a butterfly, from egg to butterfly. While students can observe this metamorphosis firsthand in the classroom, many students know very little about the natural habitat of butterflies. Ryder's (1996) *Where Butterflies Grow* shows how caterpillars are camouflaged in the surroundings they choose, how they move through the foliage of their habitat, and how and where caterpillars attach to vertical surfaces as they metamorphose into chrysalises. Reading this text can provide students with a rich understanding of the natural context in which butterflies live even as they observe an important event in the life cycle of butterflies.

In our own work, we have developed texts that connect students' hands-on investigations with desktop terrariums to the forest floor that the terrariums model. We connect model oil spills to a real oil-spill disaster in the ocean. We connect students' firsthand experiences designing new soda recipes with the work of professional food scientists.

Using Text to Demonstrate Science Skills and Dispositions: Modeling

Texts can model important science processes. In the sequence from the shoreline ecosystem unit described earlier, students' involvement in investigations of the composition and origins of sand is supported by

Gary's Sand Journal, a text that models how a scientist uses observations of sand to make inferences about its formation. Text is used not only to model the scientific process of observing and making explanations from evidence, but also to offer models of the written products of science (i.e., what observational notes look like).

Texts can model the entire inquiry process from question to conclusion, and they can provide rich models of specific inquiry skills, including what careful observation involves, how to compare and classify things, and how to make inferences and explanations based on collected evidence. Brady's (1976) *Wild Mouse* is a true account of a writer who discovers that a mouse has nested in the drawer of her desk. The writer goes on to make systematic observations and drawings every day for a month of what turns out to be a pregnant mouse. The text models careful observation and description and the use of drawings to amplify particular parts of the text. It also models fundamentals of observation over time, including dating each observation.

Text can provide insights into the scientific enterprise and scientific dispositions, as well as science processes. Text can model the wondering and exploration that are the heart of science (Yager, 2004). Texts can model missteps and dead ends, as well as successes of science. They can demonstrate how science is applied to everyday dilemmas. They can share the life and/or work of particular scientists in which they describe their interest in science, demonstrate scientific habits of mind, such as persistence and curiosity, and share aspects of their work.

Texts can provide models that support students in developing literacy skills associated with scientific inquiry. Just as stories can provide models for students' own narratives, science texts can provide models of how particular text genres are constructed, as well as scientific modes of communication, including argumentation and creating evidence-based explanations. Texts can even model the writing process, providing examples of the steps a writer might go through in recording observations or creating a journal or report.

In our work, we have developed texts that model the inquiry processes that students use in their own hands-on investigations. We provide biographical sketches of scientists (novice and professional) that provide a window into the processes and products of these scientists' work and share their excitement, commitment, and passion for science. For example, *Jess Makes Hair Gel* (Barber, 2006), a text for a unit about design and invention, describes one boy's attempt to design a mixture that will work as hair gel. The text models a design process, and students can use this process to develop other useful mixtures. The text also models the process of taking notes and analyzing data, as well as the need to sometimes rethink a design in the face of failure.

Using Texts to Provide In-the-Moment Support for Hands-On Investigations: Supporting Firsthand Inquiry

Texts can directly support students' involvement in firsthand investigations. Just as scientists rely on the work of other scientists to provide information they need in their investigations, texts provide this kind information for students. In the sequence from the unit on shoreline ecosystems, described earlier, *Gary's Sand Journal* is used to infuse new information that compels students to investigate their sand samples further and to make even more sophisticated explanations about their sand observations.

Informational texts, including field guides, handbooks, and other reference texts, can provide information that informs in-progress investigations. Just-in-time information can help students make sense of their observations (and other data they collect) and can inform their emerging conclusions. Dendy's (1998) *Tracks, Scats, and Signs* is an example of a field guide that can be used to identify evidence of animals the reader might see on a nature walk. Students might not encounter animals on a walk, but the opportunity that this text affords to identify evidence of animals' presence can inform and motivate careful observation.

In our own work, one of us (Barber) has written a reference text, *Handbook of Interesting Ingredients*, which provides information on the properties of a collection of substances that students can use to design their own products, such as glue and soda (Barber, 2006). Students use the text to look up properties of potential ingredients for their mixtures. The information they find in the text supplements the information they gather through hands-on experience and provides a richer collection of evidence than students can gather alone firsthand. For example, the text provides information about where the ingredients come from and other things that can be created with the ingredients.

Using Texts to Provide Opportunities to Interact with Data: Supporting Secondhand Inquiry

Students need opportunities to collect data, but they often have an even stronger need for repeated opportunities to practice the challenging skill of interpreting data. Secondhand investigations can also allow students to investigate phenomena in ways that are not easily accomplished in classrooms by providing students with information and data that would be difficult or impossible to gather through hands-on classroom inquiry. In secondhand investigations, readers interpret data presented in text and draw conclusions based on those data.

Secondhand data can also provide a common data set for a class of students, which might be presented in a variety of forms (numeric, tabular, and pictorial, for example), and which might be more easily interpreted than data students collect themselves.

The data students collect in classrooms can be imprecise, making interpretation challenging. Data provided in text can have greater accuracy and consistency, making it more likely that students will draw meaningful conclusions. Providing data in text increases the likelihood that students will be able to make sense of a set of data and draw reliable conclusions about the scientific phenomena under study.

Palinscar and Magnusson (2000) investigated the power of secondhand investigations—opportunities for students to make sense of someone else's data provided in text. Students were provided with science notebook entries of a fictional scientist, including data related to students' own firsthand investigations. The researchers observed that students were better able to coconstruct information about the topic under study (light) when they used science-notebook style texts that provided interpretable data in combination with their own inquiry experiences than when they used traditional, considerate expository text on the same topic.

Trade texts that provide interpretable data are harder to come by than texts that serve the other four roles in our framework. However, especially for younger students, there are a handful of trade selections that provide pictorial data that can support secondhand investigations. In Jenkins and Page's (2003) *What Do You Do with a Tail like This?* students draw conclusions about the function of specific animal structures based on illustrations of those animal structures. One spread of the text shows images of animal "feet" and asks, "What can you do with feet like these?"

In our own work, we have developed texts that provide students with opportunities to interpret data that augment their firsthand experiences and support their growing conceptual understandings. Our texts also provide students with practice interpreting data similar to the data they are collecting. In one unit, students read *Snail Investigations*, a text that models the inquiry process with an emphasis on the recording of data (Cervetti, 2006). Students are challenged to interpret some of the data tables in the text in preparation for their own firsthand investigations.

Using Text to Supplement Investigations with Information That Is Difficult to Access in Classrooms: Delivering Content

Text can present scientific concepts and facts. The presentation of information is the most traditional role for text in science, and it is the role that most concerns inquiry-oriented science educators. In the sequence from the shoreline ecosystem unit, described earlier, students are presented with scientific information in both texts. For example, they are told that water covers most of the earth, the difference between a beach and a shoreline, and that black sand is often composed of lava rock. All of these are facts that would be difficult to learn in a firsthand way in classrooms.

At its best, the delivery of information through text connects, supplements, and extends, rather than supplanting students' firsthand investigations. In combination with inquiry experiences, texts can lend cohesion to series of hands-on investigations. Texts can also expand and build upon the ideas that students explore in their firsthand investigations. And, texts can provide information about and even illustrate phenomena that would otherwise be unobservable in a classroom context. There are limits to the amount of the vast domain of science that can be experienced in the classroom. One cannot experience the astonishingly diverse array of life forms, the power of natural forces, the history of the earth, the behavior of matter in extreme conditions, or the depths of space in the classroom. Texts can deliver science content that is too dangerous or expensive, too big or small, too distant, or occurs over too long a period of time to observe firsthand in the classroom.

There are countless excellent trade texts that deliver information about the natural world. The text *Zipping, Zapping, Zooming Bats* by Earle (1995) provides information about bats and views of bats' internal and external structures—information not readily available for firsthand observation in most classrooms, even in a unit of study about bats.

In our curriculum development work, we encourage students to treat text like an additional source of evidence. Our content-delivery texts emphasize information about unobservable phenomena, like what happens to solids that dissolve in liquids and seem to disappear, and how, over time, the natural forces of wind, water, and ice shape Earth.

Text and the Inquiry Process

We believe that the apparent consensus among inquiry science educators—that text can interfere with experience, and that doing should therefore precede reading—is shaped by a limited view of the specific roles that text can play in supporting inquiry science. Many arguments about the potentials and pitfalls of text in science seem to rest on the assumption that the text is primarily or exclusively a means of delivering content. While it may be that text used in this role alone portrays science largely as a set of facts, text can play a set of dynamic roles in the inquiry process, including setting the context for firsthand investigations, supporting firsthand investigations, providing opportunities for secondhand investigations, and modeling scientific processes and dispositions, as well as the traditional role of content delivery. Each of these roles is authentically connected to the activities of practicing scientists and to ways of learning and communicating science. Figure 5.1 maps the text roles onto the work of scientists.

An expanded view of text in science has had many benefits for the integrated science-literacy program we are developing. Above all, it has helped us to create texts that support students' involvement in inquiry. Texts used in all of the roles described can support students at each stage of the inquiry process, from posing a question to investigating and making sense of their investigations. While inquiry-oriented science educators have typically situated text after firsthand investigations to avoid interference with students' processes of discovery, an expanded view of the roles of text in inquiry invites flexibility in the placement of text with respect to hands-on inquiry. While particular roles are more closely associated with reading before, during, or after firsthand investigations in our curricula, we prefer to be guided in our placement of texts by the unfolding inquiry and the role of the text in that inquiry. For example, we most often situate texts that primarily deliver content after students' firsthand investigations so students can focus first on their own discoveries, but texts that model scientific processes are used before, during, or after firsthand investigations to help students engage in their investigations as scientists do and to reflect on how their experiences are like those of scientists. Texts that set context might support students in the exploration phase of inquiry, or they might help students connect their classroom investigations already underway to natural phenomena and events.

Providing Context	→	Scientists read to situate their research.
Modeling	→	Scientists replicate others' procedures and experiments.
Supporting Firsthand Inquiry	→	Scientists use reference materials during their investigations.
Supporting Secondhand Inquiry	→	Scientists read and interpret others' data and findings.
Delivering Content	→	Scientists read about each other's work.

FIGURE 5.1. Examples of text roles mapped onto authentic uses of text in science.

CONSIDERATIONS FOR THE DEVELOPMENT AND SELECTION OF TEXTS FOR INQUIRY-BASED SCIENCE

The perspective that underlies our design of texts calls for texts to be accessible for students who are often unable to benefit from higher-level science learning. Our intent, in the design and implementation of this project, was to create texts that served critical purposes in the learning of science and in becoming literate and, at the same time, could be read by the students who most depend on schools for academic learning. Our focus in this chapter has been on the functions or roles that texts can have in a science curriculum. However, we want to emphasize that our intent in this project is to ensure that students who often have not been able to read science texts because of their inaccessibility, due to dense content can participate with the texts as readers—not only as listeners. Hiebert (Chapter 1, this volume) has described in detail the model of text accessibility that underlay the design of texts. By developing texts around the core concepts and processes related to a particular conceptual domain in science, we have been able to limit the use of unique, difficult words. The texts use a high percentage of high-frequency and easily decodable words, and the use of difficult words is reserved for a set of core science words that are encountered often. By limiting the introduction of new, difficult words and focusing on core concept and process words that students will encounter repeatedly in their investigations and discussions, we make it more likely that students will be able to independently read and understand the texts, and that they will gain active control over the most conceptually important science vocabulary. In addition, as students proceed through units, the careful unfolding of concepts and associated vocabulary can help them to gain powerful world knowledge and to access subsequent texts.

In closing, we want to offer some considerations for the selection of texts for use in science. These selection guidelines are culled from the design principles that we have used in our development of text. They focus on the selection of accessible texts that support students' involvement in inquiry.

- Does this text address a critical body of information related to the science theme under study?
- Is the information presented best introduced through text?
- Is the genre an authentic representation of the information? That is, are texts of this type used by practitioners and learners within this particular domain?

- Are difficult science words conceptually important, judiciously selected, and repeated sufficiently often?
- Is there in the style or content anything that will distract children from grasping the information that they need to learn?
- Do the visual elements (e.g., illustrations and visual representations of information) support readers in understanding the most important science ideas?
- Can this text be used to complement and support inquiry science (and avoid eclipsing the discovery process)?
- Does this text avoid the misinformation and misrepresentation so common in science trade texts?
- Does the set of texts being used, taken together, avoid mere declaration of fact and instead represent the complexity of the scientific enterprise?

The challenge of developing science texts for use as part of a hands-on science curriculum led us to think through the most appropriate use of text and experience, respectively, to promote students' inquiry into science topics. Considering the ways in which scientists rely on text and experience gave rise to a framework for the roles of text in inquiry science that describes how students can make active and authentic use of text as they inquire about the natural world. Our work in developing, implementing, and evaluating curriculum leads us to believe that a considered use of text in combination with experience can result in a curriculum that is richer, more coherent, and more authentic than hands-on-dominated or text-dominated approaches to teaching science. Further, when these texts are constructed to be accessible to students, students' inquiries can lead to the dual opportunities of learning to inquire through experience and through the use of content-rich nonfiction text.

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6

Informational Text Difficulty for Beginning Readers

NELL K. DUKE
ALISON K. BILLMAN

Baby Whale looked at her Mommy.
Whales have live babies, or *young*.

These sentences are similar in several respects: Both have six words; both involve whale mothers and babies; they even have nearly the same number of letters. They are also different in important ways. For example, the former requires children to understand that the text refers to individuals, the latter to whales in general; the former requires processing a third-person possessive pronoun (*her*), and the latter requires processing an appositive (or *young*). Most salient is that the books suggest different genres of text—the former a fictional narrative or storybook text, the latter an informational text.

For some time in U.S. history, fictional narrative has held a privileged place among texts for young readers. Informational text, in contrast, was assumed to be too difficult or inappropriate for use when children are learning to read. This assumption has been reflected in a scarcity of informational texts in young children's classroom environments and experiences (e.g., Duke, 2000), in core reading programs (Moss & Newton, 2002), and in beginning writing education (e.g., Pressley, Rankin, & Yokoi, 1995) (see Duke, Bennett-Armistead, &