Motivating Young Students to be Successful in Science:

Keeping It Real, Relevant and Rigorous

by Dr. Malcolm B. Butler

SUCCESSFUL ELEMENTARY SCIENCE TEACHING must include strategies that encourage students to learn the science that will help them in class and in life. The National Research Council and the American Association for the Advancement of Science address this issue in their *National Science Education Standards* (NRC, 1996) and *Benchmarks for Scientific Literacy* (AAAS, 1993), respectively. Knowing how to teach young children science is quite different from teaching science at the middle and high school levels. Elementary-aged children's attitude towards science is as important as the science content and scientific skills they must learn. Research findings show that teachers who are effective at supporting learners via the affective domain are also able to show improvements in student learning and academic achievement in science. Making the science real, relevant and rigorous for young children can help them be more successful. The strategies to motivate all students to learn science highlighted in this paper are consistent with current trends and research-based best practices in science education (Gallenstein, 2005; Mantzicopoulos, Patrick, & Samarapungavan, 2008).

> "Students' 'funds of knowledge' (i.e., the information and experiences they bring with them to school) can be tapped to encourage and engage them in the science they need to know and be able to do."

Motivating Young Children in Science

Research on motivation to learn shows that children are attracted to ideas that address both their cognitive and affective needs. Young children are typically already interested in nature, the environment and how things work. It serves elementary science teachers well to take advantage of the students' interests as a source for engaging and motivating students to high levels of achievement. Motivation can be an antecedent to and an outcome of learning. Thus, students must be interested and motivated to learn before learning will take place (Turner & Patrick, 2008), and this success can lead to motivation to learn more (Turner & Patrick, 2008). Sorting through those students' interests can make teachers' job a bit easier in connecting the needed science concepts and skills to the students. Addressing the affective domain can lead quite well into success in the cognitive and psychomotor domains. Current research is replete with findings that show when learners are engaged in classroom activities on a cognitive level, they acquire the conceptual understandings expected of them (Gallenstein, 2005; Turner & Patrick, 2008).

What are the Key Aspects of Motivation to Learn Science?

Making the Science Real

Young children's daily realities are fertile ground for helping them observe and understand the world around them. Students' "funds of knowledge" (i.e., the information and experiences they bring with them to school) can be tapped to encourage and engage them in the science they need to know and be able to do. Science assessments that tap into the reality of the students can increase the possibility that students will be successful. For example, having a second grader in an urban community consider the many and diverse transportation options in her city can serve as the starting point for looking at pollution, forces and motion, and physical and chemical changes. Each of these topics is grade-level appropriate and can open the door for students to explore science in new ways.

Making the Science Relevant

A young student's lived experience is an important consideration for teachers as she/he seeks to explain those scientific ideas that are age appropriate. What is relevant to a six year old about forces and motion can be different for a ten year old.

Relevance also extends into the arena of questioning, where students have to be taught how to pose scientific and investigable questions. However, teachers can take advantage of the inherent inquisitiveness of children to incorporate into the classroom those questions that students will see as natural extensions of the mental gymnastics in which they have already been engaging about their world.

Making the Science Rigorous

In addition to being real and relevant, the science young children must learn has to be rigorous enough to afford the students the opportunity to move forward in their understanding of key scientific concepts (Butler & Nesbit, 2008). These are the same concepts that are assessed on multiple levels, including classroom tests and quizzes, and district, state, national and international standardized assessments.

"Connecting the science to be learned to the reality of their lives, the relevance of their age-appropriate experiences, and the rigor of the science concepts can make science come alive in unique and meaningful ways for these children."

Consider the following fourth grade student's comment to his teacher at the end of the school year about science:

> *"Mrs. Johnson, I had a lot of fun in science. The activities we did were cool. I can't wait to get to fifth grade to do more of those cool things. I didn't learn a lot of science, but I sure had lots of fun. Thanks for a great year."*

Mrs. Johnson did an excellent job of engaging this student in science. However, the missing link to this young learner's success may have been the lack of attention to the importance of rigor in scientists' attempt to understand and explain our world.

Teachers can use writing in science as a source for increasing student learning. Thus, writing expectations must be clear. For example, students should be given detailed instructions about what their writing and/or sketches and drawings must include to demonstrate their understanding of concepts. In addition, students' writings must also communicate a depth of comprehension that is acceptable to the teacher. Students who are focused on the task at hand tend to lose themselves in the task and are not necessarily focused on the intensity of the activity. This highly focused, mentally intense kind of inquiry can greatly assist students with grasping scientific concepts.

Applying the Research

Inside National Geographic Science

Several components of *National Geographic Science* support motivating young children in science. The Science in a Snap gives the teacher the opportunity to make some quick and real connections to what is forthcoming in the Student Inquiry Book. Those simple activities serve as attention getters and thought stimulators to help students experience real science activities that tie to the content that will be explored.

The Student Inquiry Books build on making science relevant to students. They are tied to the unique experiences of children. When looking through the books, students connect to both the text and pictures. The book is seen as relevant to the students' lives and thus becomes a source of motivation for wanting to know more about particular science concepts.

The Open Inquiry activities in the Science Inquiry Books lend themselves to both the relevance and rigor students need to increase their scientific knowledge and skills. These activities give students the opportunity to develop their own questions to investigate. Also included are questions for students who might not be ready to come up with their own questions, but are ready to go deeper in their work.

The Become an Expert and Explore on Your Own books contain a plethora of the kinds of relevant science ideas for children to use to make sense of the science in their world. This source of relevance is focused on two levels of inquiry, where students are able to work as a group to engage in reading and experimenting, then work individually to further their understanding beyond the whole class discussions. The group work can give students the confidence they need to move on to exploring science on their own.

Finally, the rigor in science is also a critical aspect of the Science Notebooks, where students can document their scientific experiences in ways they think are important to them. In addition, the consistency in recording information in the science notebooks adds more rigor for students, as they consider how the recorded information accents their thoughts (Butler & Nesbit, 2008).

Conclusion

Young children typically have an affinity for nature and science. Connecting the science to be learned to the reality of their lives, the relevance of their age-appropriate experiences, and the rigor of the science concepts can make science come alive in unique and meaningful ways for these children. *National Geographic Science* contains the necessary components for motivating and engaging all elementary students so their proficiency in science improves and success becomes their norm.

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Teaching Science During the Early Childhood Years

by Dr. Kathy Cabe Trundle

IF YOU HAVE EVER WATCHED A YOUNG CHILD collect rocks or dig in the soil looking for worms you probably recognize that children have a natural tendency to enjoy experiences in nature. Young children actively engage with their environment to develop fundamental understandings of the phenomena they are observing and experiencing. They also build essential science process skills such as observing, classifying, and sorting (Eshach & Fried, 2005; Platz, 2004). These basic scientific concepts and science process skills begin to develop as early as infancy, with the sophistication of children's competency developing with age (Meyer, Wardrop & Hastings, 1992; Piaget & Inhelder, 2000).

The Importance of Science in Early Childhood Education

Research studies in developmental and cognitive psychology indicate that environmental effects are important during the early years of development, and the lack of needed stimuli may result in a child's development not reaching its full potential (Hadzigeorgiou, 2002). Thus, science education in early childhood is of great importance to many aspects of a child's development, and researchers suggest that science education should begin during the early years of schooling (Eshach & Fried, 2005; Watters, Diezmann, Grieshaber, & Davis, 2000).

There are several reasons to start teaching science during the early childhood period. First, children have a natural tendency to enjoy observing and thinking about nature (Eshach & Fried, 2005; Ramey-Gassert, 1997). Young children are motivated to explore the world around them, and early science experiences can capitalize on this inclination (French, 2004). Developmentally appropriate engagement with quality science learning experiences is vital to help children understand the world, collect and organize information, apply and test ideas, and develop positive attitudes toward science (Eshach & Fried, 2005). Quality science learning experiences provide a solid foundation for the subsequent development of scientific concepts that children will encounter throughout their academic lives (Eshach & Fried, 2005; Gilbert, Osborne, & Fenshama, 1982). This foundation helps students to construct understanding of key science concepts and allows for future learning of more abstract ideas (Reynolds & Walberg, 1991).

Engaging science experiences allow for the development of scientific thinking (Eshach & Fried, 2005; Ravanis & Bagakis, 1998). Supporting children as they develop scientific thinking during the early childhood years can lead children to easily transfer their thinking skills to other academic domains which may support their academic achievement and their sense of self-efficacy (Kuhn & Pearsall, 2000; Kuhn & Schauble, & Garcia-Milla, 1992).

Early childhood science learning also is important in addressing achievement gaps in science performance. Although achievement gaps in science have slowly narrowed, they still persist across grade levels and time with respect to race/ethnicity, socioeconomic status (SES), and gender (Campbell, Hombo, & Mazzeo, 2000; Lee, 2005; O'Sullivan, Lauko, Grigg, Qian, & Zhang, 2003; Rodriguez, 1998). Lee (2005) describes achievement gaps in science as "alarmingly congruent over time and across studies" (p 435), and these achievement gaps are evident at the very start of school. Gaps in enrollment for science courses, college majors, and career choices also persist across racial/ethnic groups, SES, and gender (National Science Foundation, 2001, 2002). Scholars have linked early difficulties in school science with students' decisions to not pursue advanced degrees and careers in science (Mbamalu, 2001).

Science education reform efforts call for “science for all students” to bridge the science achievement gaps. Yet attainment of this goal has been impeded by a lack of systematic instructional frameworks in early childhood science, insufficient curricula that are not linked to standards, and inadequate teacher resources (Oakes, 1990). Poor science instruction in early childhood contributes to negative student attitudes and performance, and these problems persist into the middle and high school years (Mullis & Jenkins, 1988). Eshach and Fried (2005) suggest that positive early science experiences help children develop scientific concepts and reasoning, positive attitudes toward science, and a better foundation for scientific concepts to be studied later in their education.

Young Children’s Early Ideas about Science

In order to help children learn and understand science concepts, we must first understand the nature of their ideas about the world around them. A number of factors influence children’s conceptions of natural phenomena. Duit and Treagust (1995) suggest that children’s conceptions stem from and are deeply rooted in daily experiences, which are helpful and valuable in the child’s daily life context. However, children’s conceptions often are not scientific and these nonscientific ideas are called “alternative conceptions.” Duit and Treagust proposed six possible sources for alternative conceptions: sensory experience, language experience, cultural background, peer groups, mass media, and even science instruction.

The nature of children’s ideas, the way they think about the natural world, also influences their understanding of scientific concepts. Children tend to view things from a self-centered or human-centered point of view. Thus, they often attribute human characteristics, such as feelings, will or purpose, to objects and phenomena (Piaget, 1972; Bell, 1993). For example, some children believe that the moon phases change because the moon gets tired. When the moon is not tired, we see a full moon. Then, as the moon tires, we see less of the moon.

Children’s thinking seems to be perceptually dominated and limited in focus. For example, children usually focus on change rather than steady-state situations, which make it difficult for them to recognize patterns on their own without the help of an adult or more knowledgeable peer (Driver, Guesne, & Tiberghien, 1985; Inagaki, 1992). For example, when children observe mealworms over time they easily recognize how the mealworms’ bodies change from worm-like, to alien-like, to bug-like (larva to pupa to adult beetle). However, they have difficulty noticing that the population count remains constant throughout the weeks of observation.

Children’s concepts are mostly undifferentiated. That is, children sometimes use labels for concepts in broader or narrower ways that have different meanings than those used by scientists (Driver et al, 1985; Inagaki, 1992).

Children may slip from one meaning to another without being aware of the differences in meaning, i.e., children use the concept labels of living and non-living differently than do adults or scientists. For example, plants are not living things to some young children because they do not move. However, the same children consider some non-living things, such as clouds, to be living things because they appear to move in the sky. Finally, children’s ideas and the applications of their ideas may depend on the context in which they are used (Bar & Galili, 1994; Driver et al., 1985).

Children’s ideas are mostly stable. Even after being formally taught in classrooms, children often do not change their ideas despite a teacher’s attempts to challenge the ideas by offering counter-evidence. Children may ignore counter-evidence or interpret the evidence in terms of their prior ideas (Russell & Watt, 1990; Schneps & Sadler, 2003).

Effectively Teaching Children Science

Contemporary instructional approaches described in science education literature draw heavily on the constructivist philosophy. Although there are many forms of constructivism, all of the instructional applications of constructivism view children as active agents in their personal construction of new knowledge (Fosnot, 1996; Gunstone, 2000). Further, these instructional approaches aim to promote active learning through the use hands-on activities with small groups and with sense-making discussions. A common expectation is that learners are more likely to construct an understanding of science content in this type of inquiry-based learning environment (Trundle, Atwood, Christopher, & Sackes, in press).

However, minimally guided instructional approaches, which place a heavy burden on learners’ cognitive processing, tend to not be effective with young children. A heavy cognitive burden leaves little capacity for the child to process novel information, thus hindering learning (Kirschner, Sweller & Clark, 2006; Mayer, 2004). As educators consider young children's limited cognitive processing capacities, inquiry-based instructional approaches, which are guided by the teacher, seem to offer the most effective way for young children to engage with and learn science concepts.

A guided inquiry-based approach allows for scaffolding of new scientific concepts with the learner's existing mental models (Trundle et al., in press). In a guided inquiry approach, children are expected to be active agents in the learning activities, which strengthens children's sense of ownership in their work and enhances their motivation. With this approach, children usually work in small groups, which promotes their collaboration skills and provides opportunities to scaffold their peers' understandings. Meaningful science activities, which are relevant to children's daily lives, allow children to make connections between what they already know and what they are learning. Sense-making discussions promote children's awareness of the learning and concept development and facilitate the restructuring of alternative ideas into scientific mental models.

As teachers work with children to develop their inquiry skills, the instructional strategies should move toward more open inquiry where children are posing their own questions and designing their own investigations (Banchi & Bell, 2008).

Integrating Text with Inquiry Learning

- Traditional science instruction has unsuccessfully relied heavily on didactic textbook-based approaches. A growing body of literature suggests that traditional, text-based instruction is not effective for teaching science because children are usually involved in limited ways as passive recipients of knowledge. However, nonfiction, expository text can be integrated effectively into inquiry-based instruction. Researchers suggest that the use of expository text should be accompanied with appropriate instructional strategies (Norris et al., 2008). Teachers should ask questions that activate students' prior knowledge, focus their attention, and invite them to make predictions, before, during, and after reading the expository text. These types of questions promote children's comprehension of the text and improve science learning (Kinniburgh, & Shaw, 2009).

- The structure of the text can affect science learning. The main ideas in the text should be supported with several examples, and these examples serve as cognitive support for the children. Examples should be highly relevant to the main idea so that children can establish connections between the text content and their own personal experiences (Beishuizen et al., 2003).

- Diagrams also support science learning. Effective, clear diagrams that represent causal relationships in the text support children's comprehension of causal mechanisms (McCrudden, Schraw, & Lehman, 2009).

- Illustrations and images in textbooks can be effectively integrated into inquiry-based instruction. Learning by inquiry involves, among other skills, observation in nature over time. However, teachers are presented with several challenges when they try to teach science concepts through actual observations in nature. For example, some phenomena are not observable during school hours. Weather conditions and tall buildings or trees can make the observations of the sky difficult and frustrating, especially for young children. Also, observations in nature can be time consuming for classroom teachers who want to teach science more effectively through an inquiry approach. Images can be used to allow children to make observations and inferences. Teachers also can have children compare observations in nature to illustrations and images in books. While many science educators might argue that observing phenomena in nature is important, the use of illustrations and images in the classroom offers a practical and effective way to introduce and teach science concepts with young children (Trundle & Sackes, 2008).

Conclusion

Young children need quality science experiences during their early childhood years. *Science and Literacy* provides a systematic instructional framework, a standards-based curriculum, and high quality teacher resources. This program also effectively integrates text, illustrations, and diagrams into inquiry-based instruction.

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Teaching Scientific Inquiry:

Exploration, Directed, Guided, and Opened-Ended Levels

by Dr. Judith Sweeney Lederman

THE TEACHING AND LEARNING OF SCIENTIFIC INQUIRY is viewed as an essential component of all current K-12 science curricula. Science educators have historically been concerned with students' ability to apply their science knowledge to make informed decisions regarding personal and societal problems. The ability to use scientific knowledge to make informed personal and societal decisions is the essence of what contemporary science educators and reform documents define as scientific literacy. However, many scientists and science educators have difficulty agreeing on what scientific literacy is, let alone knowing how to teach and assess it. This paper presents the various perspectives of scientific inquiry as well as the continuum of levels of instruction of inquiry that are necessary to engage students in authentic scientific experiences.

> "Scientific inquiry, in short, refers to the systematic approaches used by scientists in an effort to answer their questions of interest."

Teaching Scientific Inquiry

Students' understandings of science and its processes beyond knowledge of scientific concepts are strongly emphasized in the current reform efforts in science education (AAAS, 1993; NRC, 1996; NSTA, 1989). In particular, the National Science Education Standards (NSES)(1996) state that students should understand and be able to conduct a scientific investigation. The Benchmarks for Science Literacy (AAAS, 1993) advocates an in-depth understanding of scientific inquiry (SI) and the assumptions inherent to the process. Both documents clearly support the importance of students possessing understandings about scientific inquiry, not just the ability to do inquiry. Research, however, has shown that teachers and students do not possess views of Scientific Inquiry that are consistent with those advocated in reform documents. Moreover, research illustrates teachers' difficulties in creating classroom environments that help students develop adequate understandings of Scientific Inquiry (Lederman, 1992). Many classroom environments do not include explicit attention to the teaching and learning of scientific inquiry or systematic assessment of students' learning with respect to aspects of scientific inquiry.

What is Scientific Inquiry?

Although closely related to science processes, scientific inquiry extends beyond the mere development of process skills such as observing, inferring, classifying, predicting, measuring, questioning, interpreting and analyzing data. Scientific inquiry includes the traditional science processes, but also refers to the combining of these processes with scientific knowledge, scientific reasoning and critical thinking to develop scientific knowledge. From the perspective of the *National Science Education Standards* (NRC, 1996), students are expected to be able to develop scientific questions and then design and conduct investigations that will yield the data necessary for arriving at conclusions for the stated questions. The *Benchmarks for Science Literacy* (AAAS, 1993) expects that all students at least be able to understand the rationale of an investigation and be able to critically analyze the claims made from the data collected. Scientific inquiry, in short, refers to the systematic approaches used by scientists in an effort to answer their questions of interest. The visions of reform, however, are quick to point out that there is no single fixed set or sequence of steps that all scientific investigations follow. The contemporary view of scientific inquiry advocated is that the questions guide the approach and the approaches vary widely within and across scientific disciplines and fields.

At a general level, scientific inquiry can be seen to take several forms: Experimental, Correlational and Descriptive. Experimental designs very often conform to what is presented as the Scientific Method and the examples of scientific investigations presented in science textbooks many times are experimental investigations. Classic experiments are those investigations that include controlling variables. But we want our students to understand that there are other valid inquiry methods used by scientists to answer their questions. Most of what we know about the disciplines of Astronomy and Anatomy comes from Descriptive scientific methods. Descriptive research describes the nature of physical phenomena. The purpose of research in these areas is very often simply to describe. But very often, descriptive investigations lead to new questions that can be answered with experimental and correlational methods. The initial research concerning the cardiovascular system by William Harvey was descriptive in nature. However, once the anatomy of the circulatory system had been described, questions arose concerning the circulation of blood through the vessels. Such questions lead to research that correlated anatomical structures with blood flow and experiments based on models of the cardiovascular system. Correlational inquiry involve investigations focusing on relationships among observed variables. The evidence that cigarette smoking is linked to lung cancer is derived from Correlational research. It would be unethical to actually do an experiment on humans!

> “Scientific inquiry is a complex concept possessing many nuances and facets.”

Applying the Research

Scientific inquiry is a complex concept possessing many nuances and facets. Because of this, teachers often become confused about exactly what it means to teach and do scientific inquiry. But no matter what method of inquiry is being employed there are always three basic parts to any scientific investigation: a question, a procedure and a conclusion.

The NSES Content Standards for Science as Inquiry suggests the following fundamental abilities necessary for elementary students to do Scientific Inquiry:

- Ask a question about objects, organisms, and events in the environment.
- Plan and conduct a simple investigation.
- Employ simple equipment and tools to gather data and extend the senses.
- Use data to construct a reasonable explanation.
- Communicate investigations and explanations.

The basic components of these recommendations imply that all scientific investigations begin with a question, followed by an investigation designed to answer the question, that ultimately develops data that can be analyzed to develop an evidence based conclusion.

In the late 1960s and early 1970s, researchers developed a tool for determining the level of inquiry promoted by a particular activity. Known as Herron’s Scale, the assessment tool is based on a very simple principle: How much is “given” to the student by the teacher or activity? Using this question as a framework, Herron’s Scale describes four levels of inquiry:

Level 1. Exploration

The *problem, procedure,* and correct *interpretation* are given directly or are immediately obvious. During these activities, students are give the question and instructions about how to go about answering the question. They are already familiar with the concepts being presented and they already know the answer to the question being asked. This type of activity involves confirmation of a principle through an activity in which the results are known in advance. For young children, this level of Inquiry is necessary for them to become familiar with what a good testable question looks like, how to safely design a procedure to answer the question, and how to collect and analyze data to form an evidence based conclusion. This level of Inquiry if often employed at the beginning of a new unit. They can serve as an advanced organizer for the learning to come and allow teachers to taps students’ prior knowledge and understanding of the concepts. Exploration levels often create experiences that cause students to become more curious and ask more questions!

Level 2. Direct Inquiry

The *problem* and *procedure* are given directly, but the students are left to reach their own conclusions. Students are often asked to make predictions about what they believe will be the outcome of the investigation. In this type of activity, students investigate a problem presented by the teacher using a prescribed procedure that is provided by the teacher. Here they now have the opportunity to develop their own conclusions by analyzing the data and coming up with their own evidence-based conclusions.

Level 3. Guided Inquiry

The *research problem* or *question*, is provided, but students are left to devise their own methods and solutions. During this level of inquiry, students have the opportunity to apply their analytical skills to support their own evidence-based conclusions to the question being investigated. Guided inquiry provides opportunities for students to take more responsibility during the investigation. Students may have choices of methods, materials, data organization and analysis, and conclusions.

Level 4. Open-ended Inquiry

Problems as well as methods and solutions are left open at this level of Inquiry. The goal is for students to take full responsibility for all aspects of the investigation. These activities involves students in formulating their own research questions, developing procedures to answer their research questions, collecting and analyzing data, and using evidence to reach their own conclusions.

Conclusion

Obviously, the four levels Inquiry are hierarchical. In other words, students cannot be expected to successfully complete a Guided activity without plenty of experience with Exploration and Directed Inquiry activities. Furthermore, although it may be desirable for elementary students to participate in some Guided, and Open-ended investigations , it is not meant to imply that the ultimate goal is to make all inquiry activities Open-ended investigations. Rather, teachers should strive for a mix of inquiry levels appropriate to the abilities of their students. However, providing students only with activities at Exploration levels denies them the opportunity to develop and practice important inquiry skills and gives them an incomplete view of how science is done. It is only with experience with all of these levels and methods of Scientific Inquiry that our students will achieve the ultimate goal of becoming “Scientifically Literate”!

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Teaching the Nature of Science:

Three Critical Questions

By Randy L. Bell, Ph.D.

CURRENT REFORMS IN SCIENCE EDUCATION emphasize teaching science for all, with the ultimate goal of developing scientific literacy. In this view, science instruction must go beyond simply teaching science as a body of knowledge. Today's teachers are challenged to engage students in a broader view of science—one that addresses the development of scientific knowledge and the very nature of the knowledge itself (National Research Council, 1996). In other words, Science teachers are increasingly being encouraged (and, according to many state standards, required) to teach about the nature of science.

Unfortunately, decades of research has demonstrated that teachers and students alike do not possess appropriate understandings of the nature of science (Lederman, 2007). This lack of understanding negatively impacts what teachers teach about science, and in turn, what students learn. Too often, science is taught as a subject with little connection to the real world. Students view scientists as strictly adhering to "The Scientific Method," and in so doing, producing "true" knowledge that is untarnished by human limitations. In this caricature of science, hypotheses are educated guesses, theories have yet to be proven, and laws are absolute and infallible. It is no wonder that so many students fail to see any connection between what they learn in science class and what they know about the "real world," where science controversies abound and scientists often disagree about the results of their investigations.

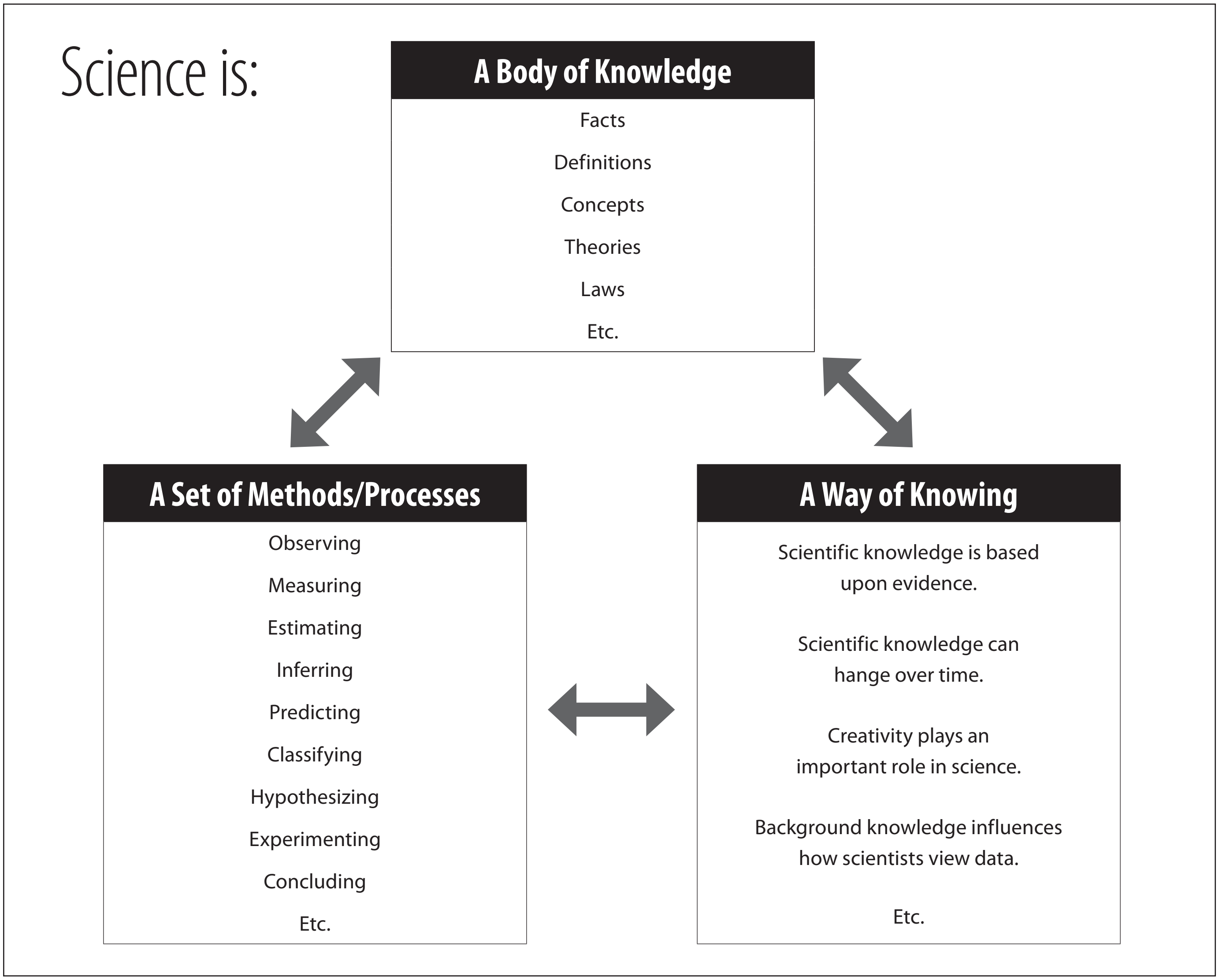
Why Teach about the Nature of Science?

Science educators have promoted a variety of justifications for teaching about the nature of science. For example, Matthews (1997) has argued that the nature of science is inherent to many critical issues in science education. These include the evolution/creationism debate, the relationship between science and religion, and delineation of the boundaries between science and non-science. Others have related teaching about the nature of science to increased student interest (Lederman, 1999; Meyling, 1997), as well as developing awareness of the impacts of science in society (Driver, Leach, Millar, & Scott, 1996). Perhaps the most basic justification for teaching the nature of science is simply to help students develop accurate views of what science is, including the types of questions science can answer, how science differs from other disciplines, and the strengths and limitations of scientific knowledge (Bell, 2008).

What is the Nature of Science?

The nature of science is a multifaceted concept that defies simple definition. It includes aspects of history, sociology, and philosophy of science, and has variously been defined as science epistemology, the characteristics of scientific knowledge, and science as a way of knowing. Perhaps the best way to understand the nature of science is to first think about scientific literacy. Current science education reform efforts emphasize scientific literacy as the principal goal of science education (American Association for the Advancement of Science, 1989; 1993). Reform documents describe scientific literacy as the ability to understand media accounts of science, to recognize and appreciate the contributions of science, and to be able to use science in decision-making on both everyday and socio-scientific issues.

Science educators have identified three domains of science that are critical to developing scientific literacy (Figure 1). The first of these is the body of scientific knowledge. Of the three, this is the most familiar and concrete domain, and includes the scientific facts, concepts, theories, and laws typically presented in science textbooks.



Scientific knowledge is based upon evidence.

Scientific knowledge can hange over time.

Creativity plays an important role in science.

Background knowledge influences how scientists view data.

Etc.

Figure 1. Three Domains of Science

Scientific methods and processes comprise the second domain, which describes the wide variety of methods that scientists use to generate the knowledge contained in the first domain. Science curricula delve into this domain when they address process skills and scientific methodology.

The nature of science constitutes the third domain and is by far the most abstract and least familiar of the three. This domain seeks to describe the nature of the scientific enterprise, and the characteristics of the knowledge it generates. This domain of science is poorly addressed in the majority of curricular materials, and when it is addressed, it is often misrepresented. The myth of a single "Scientific Method" and the idea that scientific theories may be promoted into laws when proven are two examples of misconceptions that are directly taught in science textbooks (Abd-El-Khalick, Waters, & An-Phong, 2008; Bell, 2004).

Key Concepts

When describing the nature of science, science educators have converged on a key set of ideas that are viewed as most practical in the school setting and potentially most useful in developing scientific literacy (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003). These include the following concepts:

1. Tentativeness. All scientific knowledge is subject to change in light of new evidence and new ways of thinking—even scientific laws change. New ideas in science are often received with a degree of skepticism, especially if they are contrary to well-established scientific concepts. On the other hand, scientific knowledge, once generally accepted, can be robust and durable. Many ideas in science have survived repeated challenges, and have remained largely unchanged for hundreds of years. Thus, it is reasonable to have confidence in scientific knowledge, even while realizing that such knowledge may change in the future.

2. Empirical evidence. Scientific knowledge relies heavily upon empirical evidence. Empirical refers to both quantitative and qualitative data. While some scientific concepts are highly theoretical in that they are derived primarily from logic and reasoning, ultimately, all scientific ideas must conform to observational or experimental data to be considered valid.

3. Observation and inference. Science involves more than the accumulation of countless observations—rather, it is derived from a combination of observation and inference. Observation refers to using the five senses to gather information, often augmented with technology. Inference involves developing explanations from observations and often involves entities that are not directly observable.

4. Scientific laws and theories. In science, a law is a succinct description of relationships or patterns in nature consistently observed in nature. Laws are often expressed in mathematical terms. A scientific theory is a well-supported explanation of natural phenomena. Thus, theories and laws constitute two distinct types of knowledge. One can never change into the other. On the other hand, they are similar in that they both have substantial supporting evidence and are widely accepted by scientists. Either can change in light of new evidence.

5. Scientific methods. There is no single universal scientific method. Scientists employ a wide variety of approaches to generate scientific knowledge, including observation, inference, experimentation, and even chance discovery.

6. Creativity. Creativity is a source of innovation and inspiration in science. Scientists use creativity and imagination throughout their investigations.

7. Objectivity and subjectivity. Scientists tend to be skeptical and apply self-checking mechanisms such as peer review in order to improve objectivity. On the other hand, intuition, personal beliefs, and societal values all play significant roles in the development of scientific knowledge. Thus, subjectivity can never be (nor should it be) completely eliminated from the scientific enterprise.

The concepts listed above may seem disconnected at first. However, closer consideration reveals that they all fall under the umbrella of tentativeness: There are no ideas in science so cherished or privileged as to be outside the possibility of revision, or even rejection, in light of new evidence and new ways of thinking about existing evidence. In fact, one way to look at concepts #2 through #7 is that together they provide the rationale for why scientific knowledge is tentative.

The absence of absolutes in science should not be seen as a weakness. Rather, the tentative nature of science is actually one of its greatest strengths—for progress toward legitimate claims and away from erroneous ones would never be possible without skepticism and scrutiny of new and existing claims, along with the possibility of revising or rejecting those that fall short (Sagan, 1996). One need only look at the advances in such diverse fields as medicine, agriculture, engineering, and transportation (all fields that make extensive use of the body of knowledge produced by science) for verification that science works. History has shown no other means of inquiry to be more successful or trustworthy. Change, then, is at the heart of science as a way of knowing and one of the key characteristics that distinguishes it from other ways of experiencing and understanding the universe.

What Constitutes Effective Nature of Science Instruction?

At first glance, teaching about the nature of science can appear esoteric and far removed from students' daily experiences. Decades of research on teaching and learning about the nature of science points to some specific approaches that can make instruction about the nature of science both more effective and engaging.

Be Explicit

First, it is important to realize that doing hands-on activities is not the same as teaching about the nature of science. Having students "do science" does not equate to teaching about the nature of science, even if these activities involve students in high levels of inquiry and experimentation. Several researchers have addressed this very issue (e.g., Bell, Blair, Crawford, & Lederman, 2003; Khishfe, & Abd-El-Khalick, 2002) and all have found explicit instruction to be central to effective nature of science instruction. Learning about the nature of science requires discussion and reflection on the characteristics of scientific knowledge and the scientific enterprise—activities

Process Skill	Relevant Nature of Science Concepts
Observing	Scientific knowledge is based upon evidence. Scientific knowledge changes as new evidence becomes available. Scientific laws are generalizations based that summarize vast amounts of observational data.
Inferring	Scientific knowledge involves observation and inference (not just observation alone). Scientific theories are based partly on entities and effects that cannot be observed directly, and hence are inferential.
Classifying	There is often no single "right" answer in science.
Predicting/Hypothesizing	Scientific theories provide the foundation on which predictions and hypotheses are built.
Investigating	There are many ways to do science. There is no single scientific method that all scientists follow.
Concluding	Scientific conclusions can be influenced by scientists' background knowledge. Theories provide frameworks for data interpretation.

Figure 2. The relationship between sample process skills and the nature of scientific knowledge.

students are not apt to engage in on their own, even when conducting experiments (Bell et al., 2003). In short, research demonstrates that students will learn what we want them to learn about the nature of science only when they are taught about it in a purposive manner.

Connect to Context

Keep in mind that purposive instruction is not synonymous with direct instruction. Students are not likely to develop meaningful understandings of the nature of science simply by reading a list of nature of science concepts. Instead, students need to experience specific activities designed to highlight particular aspects of the nature of science. Inquiry activities, socio-scientific issues, and episodes from the history of science can all be used effectively as contexts in which to introduce and reinforce nature of science concepts.

Link to Process Skills

While there is no single "right" approach, researchers has begun to show that linking the nature of science to process skills instruction can be effective (Bell, Toti, McNall, & Tai, 2004). Science process skills are a familiar topic for most elementary teachers. At an early age, students are taught to observe, measure, infer, classify, and predict as part of normal science instruction. By linking instruction about the nature of science into lessons involving process skills, students can learn about science as they learn the skills necessary to do science (Figure 2). Thus, any science process skills lesson is a potential lesson about the nature of science, provided teachers highlight the connection between the two.

Conclusion

Current science education reform efforts focus on scientific literacy as a principal goal and framework for instruction. *National Geographic Science* integrates science content, science process skills, and the nature of science in ways that promote accurate understandings of science. The program uses engaging text, pictures, and activities to encourage students to "think like scientists" as they learn standards-based science content.

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Best Practices in Science Education

Science through Literacy

by Dr. David W Moore

RESEARCH REVIEWS AND COMMENTARIES AGREE that students can develop their science content and literacy learning during inquiry-based instruction (Douglas, Klentschy, Worth, & Binder, 2006; Saul, 2004; Yore, Bisanz, & Hand, 2003). This professional literature supports three fundamentals – three bedrock principles – that underlie the literacy practices embedded in *National Geographic Science*. The principles are (a) Engage learners in rich and varied science texts, (b) Emphasize literacy as a tool for learning, and (c) Teach multiple reading strategies.

Engage Learners in Rich and Varied Science Texts

Texts play an important role in science learning by helping open students' eyes to the natural world and by encouraging and informing their inquiries (Palincsar & Magnusson, 2001). Texts can take students vicariously to places where direct firsthand experiences are not feasible. For instance, a few pages of text can survey Earth's habitats from space, reveal habitats deep below ocean surfaces, and juxtapose prairies, forests, and deserts. Books can bring new light to the shapes and textures of everyday objects as well as to the forces that move such objects. And they can provide insights into scientific callings, highlighting diverse scientists' commitments to systematic observation and interpretation.

> "Texts can take students vicariously to places where direct firsthand experiences are not feasible."

National Geographic Science engages learners in rich and varied texts. Big books present science content and different genres of science writing for whole class utilization. Become an Expert texts are sets of leveled books are perfect for guided reading, and *Explore on Your Own* texts are leveled for independent reading. Notebooks and online resources support scientific inquiries. Students access these informative materials regularly throughout each unit.

Emphasize Literacy As a Tool for Learning

Students develop their science content and literacy learning well when their overall purpose is to learn science (Guthrie & Wigfield, 2000). This means using literacy to develop conceptual knowledge, to seek out relationships among scientific phenomena. It means viewing facts and ideas found in print as facts-in-action and ideas-in-action. It means using print as a tool for investigating and learning about the natural world.

To emphasize literacy as a tool for learning, *National Geographic Science* regularly poses questions like "How do plants and animals depend on each other?" "What can you see in the sky?" and "How do liquids and solids change?" These questions promote conceptual knowledge because they have no single simple answers and they sanction inventive responses. These questions encourage students to share and compare their emerging understandings, to work out with others the meanings they are making of their texts and inquiries.

Realizing the crucial role word knowledge plays in science knowledge (Marzano, 2004), *National Geographic Science* focuses on scientific vocabulary. Analyzing an animal in science differs from analyzing a story in literature, so terms like analyze with particular shades of scientific meaning are highlighted throughout this program. Technical terms like germinate, offspring, and trait are contextualized by presenting them authentically in a relevant unit on life cycles.

National Geographic Science brings science terminology to life through visuals and learner-friendly explanations. It leads students to actively employ and elaborate such words during scientific investigations and discussions. It presents science vocabulary as a vital and integrated part of scientific knowledge.

Teach Multiple Reading Strategies

Elementary-school students who learn science through literacy are active learners (Baker, 2003). They take charge of texts, use authors' arrangements of ideas as devices for anticipating, comprehending, and retaining the ideas. When texts become confusing, active learners realize this immediately, shift mental gears, and apply appropriate strategies to restore understanding.

Active learners connect textual presentations with personal observations and investigations to generate new understandings. After completing texts, active learners think through the new ideas, frequently talking about them with others and consolidating what they have learned. Active learners are strategic.

> "Active learners connect textual presentations with personal observations and investigations to generate new understandings."

National Geographic Science presents four reading strategies known to benefit learning with text. This set is based on reviews of studies into reading comprehension (National Reading Panel, 2000) and content area learning (Vaughn, Klingner, & Bryant, 2001). By emphasizing the before, during, and after phases of reading, the following strategies comprise a coherent set:

Preview and Predict

- look over the text
- form ideas about how the text is organized and what it says
- confirm ideas about how the text is organized and what it says

Monitor and Fix Up

- think about whether the text is making sense and how it relates to what you know
- identify comprehension problems and clear up the problems

Make Inferences

- use what you know to figure out what is not said or shown directly

Sum Up

- pull together the text's big ideas

Teaching students to use a set of comprehension strategies like these has been shown to improve science content and literacy learning (Reutzel, Smith, & Fawson, 2005). Such instruction focuses on learners orchestrating a repertoire of reading strategies; it involves students in using multiple strategies for understanding science texts.

National Geographic Science provides a highly regarded model of instruction for explicitly teaching students how to apply reading strategies. The model is based on a gradual release of responsibility (Duke & Pearson, 2002), a practice where teachers initially assume all the responsibility for using a particular strategy, then they fade out as students fade in and assume responsibility for using the strategies. This model of instruction contains the following steps:

Describe the Strategy
Explain what the strategy is and when and how to use it.

Model the Strategy
Show students how to use the strategy by talking aloud as you read.

Collaboratively Use the Strategy
Work with students to jointly apply the strategy.

Guide Application of Multiple Strategies
Gradually release responsibility to small groups of students to use the strategy, along with other strategies they have learned.

Support Independent Application of Multiple Strategies
Continue releasing responsibility to students to use strategies they have learned when they are reading on their own.

Finally, literacy in science involves more than reading words on a page; it also involves reading the images used to express scientific ideas and information (Kress, Charalampos, & Ogborn, 2001). Science texts contain numerous photographs, illustrations, diagrams, tables, and charts. And these categories of images have sub-categories, such as diagrams that can be a cross-section or a flowchart, as well as components, such as photographs that have labels as well as captions. *National Geographic Science* provides instruction in visual literacy throughout each unit, explicitly drawing attention to the purpose, structure, and special features of its textual images.

Closing Word

The rich and varied texts, focus on literacy as a learning tool, and strategy instruction found in *National Geographic Science* provide students meaningful opportunities to develop their science content and literacy learning. It shows students how to learn science through literacy, and how to learn literacy through science.

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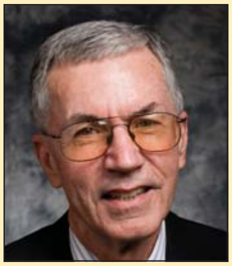

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Informational Text and Young Children:

When, Why, What, Where, and How

by Dr. Nell K. Duke

OPPORTUNITIES to read and write informational text are a key part of *National Geographic Science*. In this paper, I discuss when, why, what, where, and how to use informational text with young children.

When?

There is broad consensus that informational text is appropriate even for young children. One study found that kindergarten children can learn the language of information books through having these books read to them in school (Duke & Kays, 1998). Another study found that children whose first grade teachers included more informational text in classroom activities and environments became better writers of informational text and had more positive attitudes toward reading by the end of first grade (Duke, Martineau, Frank, & Bennett-Armistead, 2008). In *National Geographic Science* children are reading, writing and listening to developmentally appropriate informational text in kindergarten, and throughout the elementary grades.

Why?

Given opportunities, young children can successfully listen to, read, and write informational text, but why should they? One reason is that informational text can be an important tool for learning. In *National Geographic Science*, informational text works in tandem with rich inquiry experiences to build children's understanding of big ideas in science. Experience with informational text is also important to literacy development. Most literacy standards documents and assessments expect that children can read and write informational text successfully by fourth grade or earlier. For example, the 2009 National Assessment of Educational Progress (NAEP) fourth grade assessment has fifty percent informational text (National Assessment Governing Board, 2007).

Another important reason to include informational text in curriculum and instruction for young children is that some young children really *prefer* this kind of text. Educators Ron Jobe and Mary Dayton-Sakari (2002) call these children "Info-kids," and I have encountered many of them in my work. When we offer these children only storybooks and story-writing activities, we deny them the opportunity to read and write the kind of text they find most engaging.

What?

The National Assessment of Educational Progress 2009 Framework (National Assessment Governing Board, 2007) uses a broad view of informational text as including expository text, persuasive text, and procedural text. *National Geographic Science* features these along with nonfiction narrative, or true stories. Although all four of these types of text are often given the general label "informational text," they differ in both purpose and features (e.g., Duke & Tower, 2004; Purcell-Gates, Duke, & Martineau, 2007). Following are the purposes and a few common features for each kind of text.

Expository Text

Purpose: Convey Information about the Natural or Social World

Some Common Features:

- Uses specific organizational patterns such as compare/contrast
- Includes definitions or explanations of words that may be unfamiliar
- Employs graphics such as diagrams to convey information

Persuasive Text

Purpose: Persuade People to Think or Do Something

Some Common Features:

- Presents a position supported by evidence or reasons
- Employs devices such as strong language to incite to action
- Uses graphics to persuade

Procedural Text

Purpose: Give Directions for Doing Something

Some Common Features:

- Includes a materials list and steps to follow
- Employs units of measurement and other devices for specificity
- Uses graphics to show steps and the expected result

Nonfiction Narrative

Purpose: Tell a True Story

Some Common Features:

- Relays events in chronological order
- Presents a problem and resolution
- Uses devices such as photographs or artifacts from an event(s)

National Geographic Science provides books and writing opportunities for children that reflect these purposes and include these features. More important, *National Geographic Science* features topics, language, and graphics likely to be engaging to children.

Where?

You can work informational text into many places in your classrooms and curricula. I recommend including informational text in classroom libraries. Here, children can choose informational text for independent reading and as resources for writing. Displaying information books and giving book talks about some of your favorite informational texts is likely to stimulate interest in selecting these books for independent reading.

National Geographic Science includes a number of books that are likely to be popular choices for independent reading and re-reading. For example, the book *Watch Out!* by Christopher Siegel features deep sea creatures as they lure and then eat their prey. The fascinating photographs feature creatures most people have never seen. The book *A Coyote in the City* by Barbara Wood tells the true story of a coyote that walked into a sandwich shop in downtown Chicago! Children experience an engaging story, with photographs from the event, while at the same time having an opportunity to deepen their understanding of animal habitats.

I also recommend including informational text on classroom walls. The walls of your classroom are like valuable billboard space – you can use them to “advertise” informational text and content. In *National Geographic Science*, Big Idea Cards and a number of student writing activities can provide worthwhile material for your classroom walls.

Finally I recommend including informational text in your classroom activities. If you read aloud, some of your read-alouds should be informational text. If you have children write every day, the writing on some days should be informational text. *National Geographic Science* is designed to provide considerable informational reading and writing opportunities that can support your literacy as well as your science curriculum.

How?

Teaching young children to read and write informational text is as challenging as it is important. Following are five essential elements of informational reading and writing instruction.

Rich Content Informational reading and writing skills are best developed by using texts that contain rich content that is new to children. Sometimes I see information books for children that feature content children are likely to already know. These books do not work well for informational reading and writing instruction. In order for children to develop their ability to learn from text, there has to be something in the text for children to learn. One of the reasons I am enthusiastic about teaching reading and writing through *National Geographic Science* texts is that there is a great deal of rich content that is not likely to be already known to children.

Texts with rich content also serve to build children’s background knowledge, which can help them when reading later texts (Wilson & Anderson, 1986). So often the children I see struggling with informational reading in later schooling simply don’t have the broad and deep store of knowledge about the natural and social world required to understand what they are reading. *National Geographic Science* is designed to build that knowledge base to support later reading.

Important Vocabulary By the later elementary grades, vocabulary knowledge is an excellent predictor of reading comprehension (e.g., Anderson & Freebody, 1981; Wagner, Muse, & Tannenbaum, 2007). Unfortunately, many books designed for school reading instruction contain limited vocabulary, and some science texts for young children even promote misconceptions by using less accurate words (e.g., *sleep* for *dormant*). *National Geographic Science* uses key vocabulary for each topic and provides children with plenty of support for learning new words —definitions, repeated uses in multiple contexts, illustrative graphics, and opportunities to use the words in discussion and inquiry activities.

One of the things I am most proud of in *National Geographic Science* is that the program is designed to teach all children the key vocabulary of each unit, regardless of their reading level. This is critical because otherwise we are placing children with lower reading levels at a further disadvantage by denying them opportunities to learn important vocabulary needed for understanding content in present and future reading.

Strategy Instruction Teaching comprehension strategies improves reading comprehension even in primary grade children (e.g., Pearson & Duke, 2002; Roberts & Duke, in press; Stahl, 2004). The kindergarten units of *National Geographic Science* teach children to *preview* and *predict* and to *monitor* and *fix up*. In later grades, students are also taught to *make inferences* and *sum up*. The teacher's edition is designed so that teachers who are already teaching these strategies can use the materials to reinforce the strategies, and teachers who are new to teaching these strategies have important information they need to get started *National Geographic Science* follows a five-step model for teaching comprehension strategies (Duke & Pearson, 2002). The program includes books specifically designed for reading aloud, for guided reading, and for independent reading, providing material appropriate for each of these five steps.

Discussion Opportunities Occasions to talk about text can also improve children's reading comprehension (Murphy, Wilkinson, Soter, Hennessey, & Alexander, in press) as well as their science learning. Indeed, teachers who ask more higher order questions beginning early in schooling have students who show stronger growth in reading comprehension (Taylor, Pearson, Clark, & Walpole, 2000).

National Geographic Science includes higher order, open-ended questions during reading as well as in inquiry. In addition, each unit includes a sharing experience called "Turn and Talk." During this time, children who read different books for guided and independent reading (for example, students who read about ocean habitats who may talk with students who read about desert habitats) get together to talk about what they learned. In the Habitats unit, students are instructed as follows: "Compare the habitats in your books. How are they different? How are they alike?" Because children in different groups have not read one another's books, these are authentic opportunities for discussion, and allow all children, even those in the lowest group, to share their expertise on a particular topic.

Authentic Writing Young children need opportunities to write as well as to read and discuss informational text. In *National Geographic Science*, children have opportunities to write in their science notebooks and through writing projects suggested for each unit. Writing projects are launched by reading the unit's Write About book These books connect to the unit's science content and are specifically designed to exemplify a target genre (expository, persuasive, procedural, or nonfiction narrative) and to demonstrate many elements of authors'/writers' craft in that genre, such as use of an opening to engage the reader in expository text or use of compelling photographs to incite action in persuasive text.

After reading these mentor texts, children have the opportunity to write their own texts in these genres. For example, after reading the book *How To Make a Wind Vane* by Kathryn Kuhn in the weather unit, one writing project option is to have students write their own procedural texts about how to make other weather tools (ideas are provided). After reading the book *Wild Animals in the City* by Gerard Mahoney, one option provided is to have students create a book about wild animals that live in their area and to give a copy to a local nature center.

One of the important things to notice about these writing projects is that they are authentic. That is, students are writing text that is similar to text that people read and write outside of school. Students are writing for the same purposes as people who write these kinds of texts outside of school (Duke, Purcell-

Gates, Hall, & Tower, 2006/2007). As such, many of these projects have outside audiences, such as other classes within the school, organizations relevant to the writing content, and students' friends and family members. For example, in the *Life Cycles* unit, one writing project option is to have students decorate paper grocery bags for a local grocery store with persuasive messages encouraging people to plant trees (after reading the book *We Need More Trees* by Natalie Rompella). A recent study found that second– and third–graders whose teachers provided more authentic reading and writing opportunities in science showed stronger growth in reading comprehension and writing (Purcell-Gates, Duke, & Martineau, 2007).

Summary

In summary, informational text is appropriate even for young children, and there are many reasons to include it in elementary school curricula. There are several important kinds of informational text with specific purposes and features. You can incorporate these texts into classroom libraries, display them on classroom walls, and include them in classroom activities. In so doing, it is important to emphasize rich content, vocabulary, strategy instruction, discussion opportunities, and authentic writing. *National Geographic Science* provides many opportunities for enriching children's understanding and appreciation of informational text.

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