Where Literacy and

Learning about the world and sharing one's own discoveries can be powerful motivators for learning to read, write, and speak effectively.

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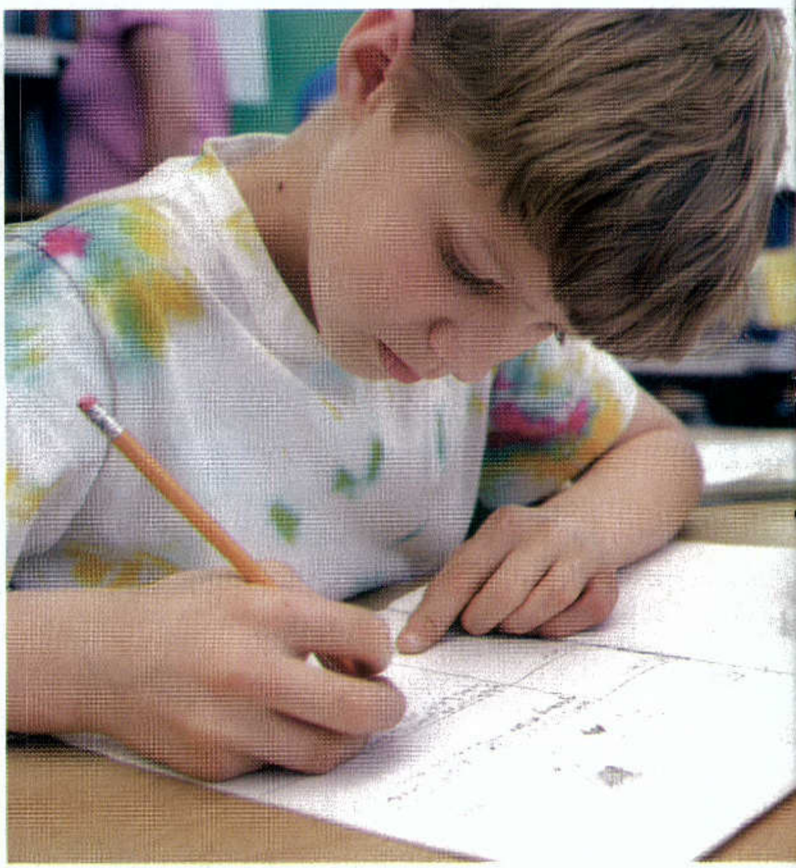

To build literacy, young children need more than instruction in such fundamental skills as recognizing letters, decoding words, learning vocabulary words, and reading and discussing stories. They also need opportunities to *use* oral and written language to learn about the world and to communicate their ideas and observations.

Although educators traditionally have not thought of science instruction as a setting for literacy learning, inquiry-based science instruction can provide a rich context in which to build language skills. Students are typically curious about the world around them and eager to talk, read, and write about what they are learning.

Inquiry-based science, as we define it, involves students in using the tools of science to answer questions about real-world phenomena. This type of inquiry is a collective effort in which students compare their thinking with others' thinking, actively communicate with one another, and express their ideas through words and graphics. Inquiry science and literacy intersect when students use reading, writing, and oral language to address questions about science content (for example, why humans are able to see different colors, or how an object's rate of motion is related to its mass), and to build their capacity to engage in scientific reasoning (for example, how to collect data in a controlled way, or how to generate claims about a phenomenon on the basis of patterns in data).

Reading, Writing, and Oral Language

What kinds of literacy learning can educators promote in the context of inquiry-based science? The following list is illustrative but not exhaustive.

Reading and Scientific Inquiry

People sometimes contrast reading with inquiry as though they are the antithesis of each other. Teachers may believe that students should engage in inquiry by exploring questions through their own activity and thinking rather than by turning to books for answers. But when combined with hands-on activities as a way to explore scientific phenomena, rather than merely as a way to find the correct answers, reading can be an important part of the inquiry process.

To promote this kind of science reading, we need to understand the importance of introducing children, even very young children, to informational text. Recently, researchers have paid considerable attention to the dearth of informational texts in the reading diets of young children, who are primarily exposed to narrative texts (Duke, 2000). With such

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impoverished reading diets, children miss many opportunities that informational texts provide.

For example, informational texts use a wide range of text structures, such as cause/effect, compare/contrast, problem/solution, listing, and a chronology of events. It is important that students become familiar with these assorted text structures. As they do so, they increase their own repertoire of writing strategies (Purcell-Gates & Duke, 2004).

In addition, informational texts typically communicate information about the world beyond the child's home environment. Hence, these texts—particularly if we make them available at a range of levels—can play an important role in leveling the playing field for students who have not had access to enriching real-world experiences (Neuman & Celano, 2006). In particular, science texts offer many opportunities to expand students' vocabulary, an important benefit because one of the most robust findings regarding literacy is the relationship between vocabulary knowledge and reading achievement (National Reading Panel, 2000).

Finally, reading informational texts can increase student engagement. Research has shown that students' motivation and reading comprehension increase when the students are directed toward content goals (such as learning science) rather than performance goals (such as getting a good grade) (Grolnick & Ryan, 1987; Guthrie et al., 2006). Guthrie and colleagues' research on Concept-Orientated Reading Instruction (2004) suggests that students who have both strategy instruction and sustained opportunities to read interesting texts to learn about a particular theme (for example, animal habitats) are more motivated to read and more strategic in their reading than are students who receive strategy instruction alone. Vitale and Romance (in press) also report that content-oriented instruction yields higher gains in reading comprehension than does strategy-oriented instruction.

Students have many compelling occasions to use writing in the context of scientific inquiry.

If students are to learn to approach informational text with an inquiry stance, teachers need to consistently model how to read critically and question the ideas presented in the text. They need to ask, "How did the author know that?" and comment, "I find this confusing. How can I find more information to help me understand?"

Writing and Scientific Literacy

Students have many compelling occasions to use writing in the context of scientific inquiry. They can record questions of interest, document how they have set up investigations, represent data they have collected, and develop explanations for the phenomena they are investigating. Students can also incorporate such graphic elements as drawings, tables, and graphs into their writing.

Perhaps the most frequent way that students experience writing in science classrooms is by keeping notebooks. Notebook-writing activities, however, are often reduced to reports of teacher-expected results (Shepardson & Britsch, 2001). To promote literacy, teachers need to encourage more thoughtful uses of writing in science.

For example, the Science Writing Heuristic (SWH) is a tool to help teachers and students use writing to promote collaborative thinking and reasoning. This heuristic calls for students to (1) identify the ideas and questions they bring to the study of a phenomenon, (2) record what they do in the course of their inquiry, (3) record their observations, (4) identify their claims, (5) provide supporting evidence for their claims,

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(6) read others' entries to compare their thinking, and (7) reflect on how their ideas have changed.

Wallace, Hand, and Yang (2004) determined that 7th grade students who were instructed in the use of the heuristic learned more about the content they were studying than did students who did not learn this heuristic. Further, students who used textbooks in addition to the Science Writing Heuristic learned the most content. Finally, students who experienced opportunities to write, guided by the heuristic, developed an understanding of the role of claims/evidence relationships in scientific reasoning. Klentschy and Molina-De La Torre (2004) reported similar findings from their work with K–8 students, many of whom were English language learners.

Oral Language and Scientific Literacy

Discussions about ideas found in informational trade books offer students opportunities to restate ideas in their own words, expand on their initial understandings as they learn more about a topic, notice how their thinking has changed over time, and make connections between the ideas found in books and their own lives.

Varelas and Pappas (2006) have studied urban primary-grade classrooms serving high numbers of Hispanic English language learners to explore how engaging young students in discussions about science books can help the students develop scientific understandings and acquire the language of science. In one of their studies, the teachers read aloud and discussed seven trade books about the water cycle and states of matter. In these discussions, they provided opportunities for the students to make connections between their home and school experiences as well as among the various texts. The researchers observed that students began to note such connections. For example, during snack time a student wondered aloud whether the juice would evaporate if it were left on the table. On another occasion, a student noted that "when you leave your milk for a long time in the refrigerator, it will become thick" (p. 219).

The read-aloud sessions were accompanied by opportunities for the students to engage in their own hands-on investigations. This program of studies eventually resulted in positive changes. Teachers became increasingly experienced in engaging students in the discussions and increasingly comfortable making the students' ideas the anchor for the discussions. Over time, students learned to use discussions to explore theories about how the world works, and they began to appropriate the specific vocabulary they had come across in the readings to describe scientific concepts. Other researchers (for example, Conant, Rosebery, Warren, & Hudicourt-Barnes, 2001) have reported similar patterns in language use and language learning.

Models for Combining Literacy with Inquiry-Based Science

Here we describe the research on two instructional models that have been developed to integrate science and literacy in the classroom.

Science IDEAS

Romance and Vitale have developed an integrated model called Science IDEAS, which replaces traditional language arts instruction in upper elementary grades with a daily two-hour block that combines instruction in science, reading, and writing. Using challenging content-area texts, teachers integrate reading comprehension instruction and writing tasks that encourage students to think deeply about the topics being studied. For example, in a unit called "Processes of Life," students conduct experiments to determine what factors increase the growth of bread mold or to determine whether the color of light reaching plant seedlings affects their growth, and then write about these experiments to describe what they have observed and learned. Students also read trade books and basal textbook passages about such topics as classification or metamorphosis; their teachers guide them in noticing text structure, learning new vocabulary, identifying main ideas, asking questions, and making inferences.

Research on the model has found that Science IDEAS instruction resulted in significantly higher levels of student achievement on nationally normed science tests, as well as in reading comprehension. In addition, students in Science IDEAS classrooms displayed significantly more positive attitudes toward both science and reading, as well as more confidence in their capacity to learn science (Romance & Vitale, 2005). The Science IDEAS Web site (http://scienceideas.org) contains such resources as concept maps, writing prompts, discussion boards, lists of trade books appropriate for specific topics, and planning checklists to help teachers tailor the model to their districts' curriculum and their students' needs.

Guided Inquiry supporting Multiple Literacies (GIsML)

We have researched another integrated instructional approach to science and literacy that we call Guided Inquiry supporting Multiple Literacies (GIsML). In this approach, K–6 elementary teachers guide their students in sustained inquiry about specific topics, usually centering on physical phenomena, using both firsthand investigations (during which students collect and analyze data themselves) and secondhand investigations (during which the teacher and students read and ask questions about specially written texts). This approach has significantly increased students' science content knowledge and scientific reasoning at both the lower and upper elementary levels.

For example, during a program of study about the motion of balls down inclined planes, which took place for 1–2 hours daily over 10 consecutive days, 2nd grade students read and discussed two simulated scientist notebooks. The notebooks were designed to be read in a highly interactive manner. They were written in the voice of fictional scientist Leslie Park, and they included her research questions, diagrams of her investigative setups, data tables with the results of investigations, and her reflections on patterns in the data she had collected and the claims she felt she could make on the basis of those data. The students and their teacher approached reading these texts as a type of investigation. They puzzled over how Leslie developed the questions she asked, whether the methods she described were adequate, what patterns appeared in her data, and how to interpret those data. The class also engaged in complementary firsthand investigations about the motion of balls down inclined planes, collecting data themselves. Like Leslie, they tried to find patterns and make claims about relationships—for example, how the mass of a rolling object affects its momentum and how the starting height of an object is related to the amount of time it takes that object to roll to the bottom of an incline.

Science texts offer many opportunities to expand students' vocabulary.

Results of paper-and-pencil pretests and posttests indicated that the unit produced a significant increase in the students' conceptual understandings about motion. In the students' writing, we also found evidence of learning; by the end of the program of study, almost all of the students were able to justify their claims with evidence and use data tables to organize their findings (Hapgood, Magnusson, & Palincsar, 2004; Magnusson & Palincsar, 2005).

A Powerful Combination

The results of these programs of research suggest the following conclusions:

- Because students generally find science engaging, inquiry-based science instruction is rife with learning opportunities.
- Inquiry-based science instruction encourages students to stretch their capacities to express, digest, and critique ideas in written and oral forms.
- Reading texts to explore science topics, combined with firsthand investigations and discussions, can help students acquire reading strategies even better than direct instruction in those strategies can.
- Discussing ideas, along with reading and writing about them, is especially beneficial for building students' vocabularies and their ability to use complex sentence structures.
- Inquiry-based science instruction can give students a reason for communicating in different genres and forms (for example, graphs, diagrams, tables, and prose). Knowing how and when to use various ways of representing ideas is a fundamental literacy skill.
- Taking an inquiry approach to informational texts helps students learn to question and be critical of texts rather than to always defer to the text or use texts simply for finding answers.

Science instruction in the early grades provides an opportunity not only to build knowledge about the physical world but also to learn about the basic literacy tools of science. Learning what others have discovered about the world and sharing one's own discoveries can be powerful motivators for learning to read, write, and speak effectively. In today's classroom environment of ever-increasing demands, every instructional minute must count. Finding time for science instruction and literacy instruction does not have to be an either/or proposition—in fact, the two subjects can be more powerful when combined. EL

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