



Literacy in science: a natural fit; Promoting student literacy through inquiry.

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Reading is an essential part of science literacy, but what, when, and how can we incorporate reading in the science classroom? Like many of my colleagues, I avoided relying on the textbook by engaging students in lectures, hands-on activities, demonstrations, and videos. Unfortunately, as each year passed, my students read less while I worked harder.

I wanted students to become the scientifically literate citizens envisioned in the National Science Education Standards: students who read science, enjoy reading science, and even experience the passion I feel for the natural world. However, with 65% of incoming freshmen at my school reading below the sixth-grade level, it was clear that our science curriculum, especially the textbook, did not include motivating or accessible reading for most students. To bring reading back into our science classrooms, my colleague, Ann Akey, and I designed four quarterly reading projects with yearlong literacy routines that we use successfully with our ninth-grade students, including English language learners.

An inquiry approach to literacy and science

We created these projects as part of a three-year professional inquiry into literacy in science with our colleagues at the Strategic Literacy Initiative at WestEd. The two yearlong literacy routines we developed are based on Reading Apprenticeship, an instructional framework offered by the Strategic Literacy Initiative (Schoenbach et al. 1999) to support middle and high school student literacy in content areas. Reading Apprenticeship encourages reading in classrooms as an active problem-solving process. Students and teachers engage in a shared inquiry into literacy by taking mental risks as they read together and discuss their reading processes, confusions, and methods of resolution. Creating a classroom climate that supports inquiry is essential to both science and literacy learning. This connection to inquiry made the Reading Apprenticeship approach a natural fit in our science classrooms (Schoenbach et al. 2003).

[ILLUSTRATION OMITTED]

Yearlong metacognitive conversation

To begin our classroom inquiries into science literacy, we talk about our thinking processes every day as we delve into lab procedures, graphs, data tables, and all the different "texts" of science. I model talking aloud about my own thinking processes and encourage students to "think aloud" about how they make sense of what they are doing. Through this metacognitive conversation, students learn that text includes labs, data, and their own work, and that reading is an active problem-solving process.

As this way of working becomes comfortable and routine, I teach students to record their thinking by writing down their confusions, questions, connections, clarifications, and summaries in "Metacognitive Reading Logs." [Editor's note: The tools and projects described in this article, including Metacognitive Logs, were created by the author and can be downloaded from the Reading Apprenticeship website at <http://wested.org/stratlit>.]

As a yearlong literacy routine, these logs take on different forms depending on their purpose. Some are as simple as a vertical line drawn down the center of a piece of binder paper with an "I read" heading on the left and an "I thought" heading on the right. At other times logs may contain a series of sentence stems to choose among and complete such as "I was confused by" or "This reminded me of."

Often students are asked to write questions, short summaries, or personal connections to what they are reading. Some logs have a printed format, some are kept in spiral notebooks, and others are simply written on the edges of the reading handout itself. This routine metacognitive writing and conversation supports students throughout the year as they encounter more difficult texts and complex reading tasks. Once we establish this foundation, we are ready to expand our reading experiences.

Four nontextbook reading projects

We begin our reading projects in the first quarter with "Science in the News" (SIN), which we also continue throughout the year--along with the Metacognitive Logs--as a yearlong literacy routine. In the second quarter we introduce a nonfiction reading project and accompanying children's science book writing project. In the third quarter students read a biography of a scientist and present Interactive Historical Vignettes (Roack and Wandersee 1993). In the fourth quarter, students read fiction books and participate in book clubs (Steineke 2002). Although we sequenced these projects to take advantage of students' growing skills, motivation, and stamina, any of these projects can be used independently of the others (Figure 1).

Science in the News

To help students read, evaluate, and discuss scientific issues and findings that appear in popular media, we developed SIN, a format to help students have an informed scientific perspective. Figure 2 summarizes the student objectives of SIN.

We assigned the first SIN as homework, providing a structured report format and instructions to find a science article in a newspaper or magazine (Figure 3). We thought our highly structured report format would help students read deeply. Looking at student work samples, however, we realized that even with relatively accessible text, such as the daily newspaper, students were not able to read and respond to the science without more help. The report format was not enough support; we had to teach our students how to read science in the news.

I started by finding an article to read and discuss in class. In small groups, students read the article and completed a SIN reading together, discussing how they approached highlighting the methods and results and how they constructed summaries. Teams shared their results with the whole class while I recorded their reading strategies on an overhead. Later we read anonymous student work samples, evaluating them using our new understandings of how to read SIN.

Our efforts paid off. With practice, students are able to do the SIN reading activities independently. Teams discuss the science in the reading, instead of how to read the science. Working together, students become expert readers of science in the news. More importantly, we are learning that science literacy is not a fixed object; people are not good readers or nonreaders, but evolving readers. Figure 4 (p. 26) shows the grading rubric for this project.

Read a nonfiction book and write a children's science book

In the fall our classes make a trek to the school library's nonfiction science section. We give students a chart that describes where science topics can be found and let students look for a book that interests them. Once they find one, we negotiate. Because our goals for this project are to build fluency, stamina, and motivation as well as general science knowledge, our focus is helping students find books that genuinely interest them and that are not too difficult. As a result, I start to see science-based library books appearing at Sustained Silent Reading--20 minutes of reading a day, a schoolwide policy--instead of magazines and newspapers.

[FIGURE 3 OMITTED]

During the next four to five weeks students complete most of their reading outside of class with the support of teacher-generated Metacognitive Logs designed specifically for nonfiction text. I collect and check these logs weekly to give students written encouragement on their progress. When they finish reading, students demonstrate their understanding of the topic by writing and illustrating a children's science book on the same subject.

Tapping into students' interests produces some amazing results and encourages student engagement. One English language learner filled her book with photos and descriptions of her own beloved parrots. Another student, who produced little other work during the year, wrote a book about lizards, which he proudly shared. Many students chose their children's book projects (from their science class!) to include in their schoolwide assessment portfolios as evidence for meeting reading and writing expectations.

Read a scientist's biography and present an interactive historical vignette

Empowering students with personal knowledge about real scientists and the work they do is our primary goal for the biography project. For instance, during a class discussion of the Tacoma Narrows Bridge failure, a student who had just finished Joseph Strauss'

biography for his reading project eagerly explained that Strauss, who designed the Golden Gate Bridge, planned for the bridge to flex up and down several feet to prevent a failure like the Tacoma Narrows disaster.

When we initially introduced the biography project, we encountered a familiar problem. We lacked motivating and accessible text to read. Our library had a scant collection of dusty, unused volumes of "classics." Over the next three years, we added biographies of women scientists, such as *A Feeling for the Organism: The Life and Work of Barbara McClintock* (Keller 1983); scientists of color, such as *Charles Drew: Life-Saving Scientist* (Shapiro 1997); contemporary researchers, such as *The Beak of the Finch* (Weiner 1994) about the work of Peter and Rosemary Grant; and the accessible biography series *Great Minds of Science and Scientists Who Changed the World*. For a full list of the books we have added, visit <http://wested.org/stratlit> and click on "Resources," then "Resources for Teachers," and finally "Extensive Reading in Science."

Once we had enough texts involving scientist biographies that students could and would read independently, students could do most of the reading outside of class. We developed new Metacognitive Log prompts to help students make connections to the influence of culture and society on scientific thought. Once students finish their reading, they write 250-word vignettes about a major event in the scientist's life. They dress like their scientists, bring props representing the scientists' work, and read their vignettes in small groups. The "scientists" ask their peers in these small groups to discuss opinions about their work and discoveries.

As students present I walk around and listen. Within groups, students keep track of each other's presentations by using a checklist to assure that all required aspects of the scientist's life are covered. Students are asked to use this checklist to prompt the speaker if omissions occur, thus creating a collaborative approach to discovering the scientist's achievements with the reporting student serving as resident expert.

This is my favorite literacy activity of the year. I give extra credit if students make and wear a life-size mask of the scientist's face for their presentation. Later, I hang the masks around the room to create a gallery of scientific greats "participating" in class for the remainder of the school year. Allowing students to assume identities of scientists is a powerful tool to help them connect to the process of scientific discovery and the impact of political and religious beliefs on the history of scientific thought, as related to Content Standard G, *The History and Nature of Science* (NRC 1996, p. 200).

Read a fiction book with good science content and participate in a book club

Do you remember reading something that hooked you on science--a novel, or even a comic book? This last project elicits raised eyebrows--popular fiction in a science class? When considering what students should read, we uncovered a closely guarded secret: Science people love to read good fiction about science. When reading fiction, we engage with the ideas of science in imaginative and enjoyable ways that we might not when reading for information. [Editor's note: For more on science fiction in science class, see "Science Fiction and Scientific Literacy," p. 38, in this issue of *The Science Teacher*.] We wanted students to have access to this experience while providing opportunities for them to evaluate and discuss the scientific ideas they encountered. Our critical reading and discussion goals make the book clubs our most demanding project, which is why we save it for last.

Book clubs are discussion groups of four to five students who have chosen to read the same book. To facilitate book choice, I bring copies of the books to class for students to look through and talk about. They rank first, second, and third choices on an individual, reading-level appropriate list. I use their choices to arrange book club groups. The book clubs meet twice a week during 100-minute blocks, plan their own reading schedules, and discuss their books. Each student assembles and decorates a reading journal specifically designed for fiction narrative. New Metacognitive Log prompts help students make connections to situations or characters in the novel and analyze the science presented in the story.

Students bring these journals with them to their book club and use them as the basis for group discussions that often lead to new insights about the far-reaching impact of science in their lives. As they contribute to scientific and literary conversations with their peers, students see themselves as successful readers of science. (For examples of books, see Figure 5.)

Making progress

Three years into our inquiry, one thing is clear: Our students have become more capable and more willing science readers. Although many students read well below grade level,

they could still become science readers. Similarly, while we are not reading teachers, we can teach students to read science. Our goals in beginning this inquiry were to improve student's attitudes toward science reading and give students the tools to become lifelong science readers.

We made significant progress toward establishing the kind of scientific literacy that "expands and deepens over a lifetime, not just during the years in school" (NRC 1996, p. 22). By the end of the school year, reading becomes an established routine in my classroom, and students' attitudes about reading change dramatically. When I announce the first book project in the fall, the general response is "What, we have to read the whole book?" By the time the last project rolls around in late spring, students say, "Read another book? Okay, I can do that."

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FIGURE 1 Extensive reading in freshman integrated science class at Woodside High School.

First quarter Second quarter Third quarter Fourth quarter

Metacognitive Logs (Yearlong literacy routine)
Science in the News (Yearlong literacy routine)

Introduction to Read a Read the Read a fiction book with
metacognitivenonfiction biography of good science Book club
conversation, science booka scientistdiscussions
MetacognitiveWrite a Present a
Logs, Sciencechildren's historical
in the News science bookvignette

FIGURE 2 Monthly Science in the News objectives.

- * Highlight the research methods or procedures.
- * Highlight in a different color the results or conclusions.
- * Use highlighting to summarize procedures and results.
- * Report the name and expertise of a researcher or scientist involved.
- * Draw a picture or diagram of an important aspect of the research.
- * Compose a brief summary of the big idea.

* Ask a question of the researchers or the author.

FIGURE 4 Science in the News rubric.

Beginning Developing Proficient

Selection of article Not about science. Includes science article No authority quoted. content. scientific

Source of article Authority research.

not stated. Fewer quoted. Source Authority quoted.

than 200 words. stated. 200 Reliable source

words or more. stated. 200 words

or more.

Understanding of article Highlighting misses Most Highlighting

of article important points highlighting shows

and/or includes correctly understanding of

extraneous material. identifies scientific

Summary misses key important methodologies and

points and/or points. Summary results. Summary

includes shows shows

nonessentials. understanding of understanding of

most key points. all key points.

Completion One or more section All sections All sections

not attempted and/or attempted. completed.

partial responses to Responses do not Responses address

prompt. always address all aspects of

prompt. the prompt.

Quality Responses show Responses show Responses show

limited partial evidence of

understanding of the understanding of complete

article. Responses the article. understanding of

are not written in Most responses the article. All

complete sentences. are written in responses are

Responses are complete written in

unorganized, sentences. complete

hurried, scattered, Responses are sentences.

or messy, with poorly organized Responses are

little evidence for and show some organized, show

active engagement in engagement, with attention to

the project. attempts at detail,

Question is responding thoughtfulness,

unrelated to or thoughtfully. and active

answered in the Question is engagement in the

article. related to project. Question

article but is related to

tangential or article and

vague. thoughtful.

FIGURE 5 Examples of book club options.

Low reading level book choices

A Bone From A Dry Sea Peter Dickinson

Julie of the Wolves Jean George

The Missing Gator of Gumbo Limbo Jean George

There's An Owl in the Shower Jean George

Shark Beneath the Reef Jean George

Clan Apis Jay Hosler

Medium reading level book choices

The Core Dean Wesley Smith

The Dechronization of Sam Magruder George Simpson

The Perfect Storm Sebastian Junger

Singularity William Sleator

The House of the Scorpion Nancy Farmer

High reading level book choices

The Andromeda Strain Michael Crichton

Jurassic Park Michael Crichton

Toxin Robin Cook

Rendezvous with Rama Arthur C. Clarke

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Reinforcement of Scientific Literacy through Effective Argumentation on an Energy-related Environmental Issue. A Critical Review of Scientific Argumentation in Science Education. Learning to Teach Argumentation: Case Studies of Pre-service Secondary Science Teachers. Indexes. scientific literacy through the implementation of learning principles (i.e., assessing prior understandings, linking fact to conceptual frameworks, metacognitive monitoring, setting performance expectations, providing feedback). The Communication in English and Science Inquiry Project (CESIP) professional development project investigated whether or not high school teachers have the science content knowledge necessary to broach the interdisciplinary theme of Energy in Systems. We developed a two-tier Energy Test, linked to both national and state science standards, which was administered both before and after science teacher participation in 23 hours of professional development on energy sources, flows, sinks, and conservation in natural and human-made systems.