



Making Thinking Visible: A method to encourage science writing in the upper elementary grades

By Roxanne Greitz Miller and Robert C. Calfee

What does it mean to “write to learn science,” and why should we use writing as a vehicle for science learning when other alternatives exist? Many studies have examined the role of writing in the learning process, demonstrating that writing, in conjunction with other activities such as reading and hands-on experiences, contributes to greater critical thinking, thoughtful consideration of ideas, and better concept learning.

We would like to add a basic and universal observation to these findings supporting the use of writing, particularly in science: writing makes thinking visible. Few activities can achieve what writing can in science—enabling students to self-assess complex content knowledge and allowing the teacher to assess the student in two dimensions: overall writing ability and specific content area achievement.

However, for writing to fulfill these standards, carefully planned and scaffolded writing activities—beyond what we normally see in science classrooms, especially at the elementary level—must be implemented. To illustrate this point, we will describe the Reading and Writing About Science (RWS) Project conducted between 2000 and 2003 with support from the National Science Foundation. Twenty-one teachers, with levels of experience ranging from beginner up to 30 years, participated in the project, teaching 587 students in grades four through six.

The goal of the project was to provide upper elementary teachers with the skills to create classroom situations that integrated literacy with science, equipping students to communicate their thinking and understanding through exemplary science reading and writing activities. This approach aimed to produce deeper science concept learning, while also serving as an authentic indicator of student achievements in science and literacy.

A CORE Framework

What does it mean to “write to learn science,” and why should we use writing as a vehicle for science learning when other alternatives exist? Many studies have examined the role of writing in the learning process, demonstrating that writing, in conjunction with other activities such as reading and hands-on experiences, contributes to greater critical thinking, thoughtful consideration of ideas, and better concept learning.

We would like to add a basic and universal observation to these findings supporting the use of writing, particularly in science: *writing makes thinking visible*. Few activities can achieve what writing can in science—enabling students to self-assess complex content knowledge and allowing the teacher to assess the student in two dimensions: overall writing ability and specific content area achievement.

In order to make a dramatic change in the way teachers approach science writing, we found it necessary to address both science instruction as a whole and the use of writing during various stages. To guide us in this endeavor and communicate a concrete idea of an ideal foundation for highly effective science writing to teachers, we turned to the CORE Model of Instruction (Chambliss and Calfee 1998).

The CORE Model was originally developed as a representation of the manner in which reading and writing can be linked and reinforcing to each other; we saw possibilities to extend this model to experiential learning (such as science inquiry).

The CORE Model incorporates four elements: Connect, Organize, Reflect, and Extend. The elements can be used for designing a sequence of instructional activities. Students first connect what they already know about a topic to new science content or experience. Then they organize information from multiple sources into coherent packages. They then reflect on the collection of “stuff” by discussing it with others in preparation for the writing task. Finally, completion of the project serves to “stretch” or extend the learning.

Cite this article as: Miller, R.G. & Calfee, R.C. (2004). Making Thinking Visible: A method to encourage science writing in the upper elementary grades. *Science and Children*, (42) 3, 20-25.

The following paragraphs expand on each of these elements. The interactive elements serve both teacher and students as lenses (and common language) for thinking about their progress through a unit. In our project, teachers appreciated the logical and easy sequencing of activities; students quickly internalized the complementary nature of the stages and their usefulness as aids in learning and writing.

Connecting Knowledge

During the *Connect* phase, teachers used classroom discussions to determine students' prior topical knowledge. Virtually all teachers are familiar with collaborative activities such as think-pair-share, brainstorming, and hands-on science. A critical strategy in the RWS Project was "wall-papering" the room with written documentation of these activities.

For example, during an initial brainstorming session on earthquakes, the teacher wrote students' comments and shared experiences on flip-chart paper to facilitate the discussion and activate background knowledge. Rather than removing this artifact after the discussion was over, it remained posted in the room for the remainder of the unit, during which it was revisited and revised as necessary by both teacher and students.

This technique was especially important in our local area, where large numbers of students who are at-risk or English language learners benefited from the instant availability of ideas and vocabulary to scaffold subsequent academic tasks. Students quickly "caught on" to the fact that they could revisit their initial sharings, correct misconceptions, and add new knowledge throughout the unit.

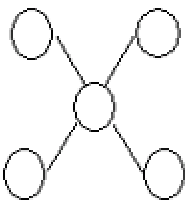
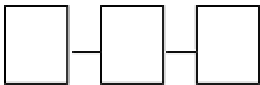

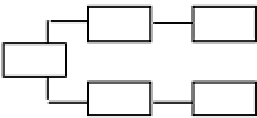
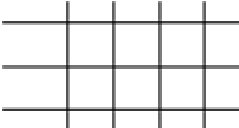
Organizing Information

Information is essential in science but it can quickly become overwhelming; students need to learn strategies to *Organize* and manage their collections. To facilitate organization, the RWS Project relied on teaching students to create graphic organizers before, during, and after science reading. (These same organizer structures can also be used for organizing information from hands-on activities.)

We identified five basic graphic organizers as particularly effective for organizing science content. We have found that closely matching the organizer's structure to the nature of the science concept is particularly effective when tasking students with subsequent writing. For example, when studying tsunami, students were shown how to construct a "falling domino" organizer, a sequential graphic that indicates cause and effect (akin to what happens in a line of falling dominoes), with each occurrence causing something else to happen. The graphics we used with great success include the web, linear string, falling dominoes, branching tree, and matrix.

In response to post-project surveys conducted one to three years after participation, many RWS teachers commented that one of the most beneficial things they learned from our professional development sessions was how graphic organizers, and specifically choosing a "matched" organizer rather than a more general one, dramatically improved student writing.

Once students completed their organizers (constructed collaboratively in small groups, in large groups with the teacher, or independently) and thereby had a foundation for writing, they moved onto the prewriting phase. The organizers served a dual purpose here; not only were they used to organize science concepts before and during content acquisition activities, but they were used again after—in preparation for writing.

Graphic organizers used in the RWS Project.			
Name	Use	Science Example(s)	Picture
Web (also referred to as the topical net or cluster)	To group similar concepts/ideas related to a unifying theme; may also be used to indicate sequence if arrows are used to connect subgroups	The rock cycle (with subgroups indicating the different types of rock and processes); states of matter	
Linear String	To represent a sequence but with no indication of cause/effect	Food chain; scientific timeline; steps of an experiment	
Falling Dominoes	To represent a causal sequence	Tsunami; origin of the solar system	
Branching Tree	To represent sequences from multiple perspectives	Parasite/host interaction, each line representing what is happening to one of the organisms	
Matrix	For categorization and classification	Compare and contrast different animals and their characteristics	

Reflecting on Learning

Metacognition and self-evaluation are large components of all of the phases of the CORE Model; however, they are most prominent in the *Reflect* phase. During this phase, students reflect on their learning in large and small groups facilitated by the teacher. At this time (prior to writing), students have a final opportunity to correct any science misconceptions and solidify their content knowledge. Cross talk between students and groups extends the experience of the individual student and further lessens academic disparity between diverse students and English language learners.

At the end of the reflection phase, students in the RWS Project received their writing prompt. We placed the prompt in this phase, rather than the extend phase during which the composition is actually written, because a significant factor in writing success is the ability to effectively “dissect” a writing prompt by reflecting on the task to be performed, its components, and the knowledge needed to perform the task.

Immediately upon beginning to work with schools, we found drastic inconsistencies between how teachers structure (or do not structure) their writing prompts. RWS teachers were trained to construct their prompts to use five common elements: focus, audience, type, purpose, and supporting details. Guidelines for these elements appear in Figure 1.

Teachers guided students through the prompt dissection process, facilitating identification of individual prompt elements, until students were able to do so for themselves. By using a consistent format, students were able, over time, to recognize more easily what they were being asked to do and how to set about doing it.

Cite this article as: Miller, R.G. & Calfee, R.C. (2004). Making Thinking Visible: A method to encourage science writing in the upper elementary grades. *Science and Children*, (42) 3, 20-25.

When first exposed to this method, teachers often said that using a prompt like this was “too long and too complicated” for their students. We persuaded them to try anyway. The overwhelming response was longer and richer student responses, even with students as young as third grade. We believe part of the success of this system is how it not only makes the writing task easier for the student to approach but also scaffolds teachers in creating better-designed writing assignments that assess student thinking and learning.

Extending the Experience

The writing composition is the focus of the Extend phase, with students working individually to respond to the writing prompt. Figure 2, features an example of a writing prompt along with an example of a student’s composition and graphic organizer.

The traditional “process writing” approach (develop, draft, revise, polish, and publish) was used to guide the steps of the composition process.

Toward our goal of real communication through writing, we attempted whenever possible to target the writing task for an authentic audience, including readers of a school science magazine, pediatric patients, and a younger elementary student. After composing, students were given the opportunity to share their writing with other students and the teacher. In addition to facilitating writing as communication, sharing allowed students to become familiar with how and what other students write, giving them concrete examples of others’ work. Without this type of sharing, students have no idea where their work stands in comparison with others; it is essential—particularly for students from diverse achievement levels—to have this type of feedback and examples of outstanding student writing to which they can aspire.

Evaluating the Results

A final challenge for our project was to develop a rubric for scoring science content in student writing. Often we were confronted with a fine piece of student writing, coherent and well written but missing the “meat”; the challenge was to design a rubric that would enable teachers (and students) to identify key features distinguishing poor, fair, good, and excellent science content writing from one another.

We aimed to design a generic rubric that could be used with virtually any science writing assignment, while allowing teachers to target specific key ideas and benchmarks within the scoring levels. Upon examining many writing rubrics in use in science and other subjects, we drew upon a rubric previously published in *Science Scope* (Harding 2002) and adapted it considerably.

In addition to this rubric, we also used more traditional rubrics for other traits (such as grammar/mechanics, spelling, and vocabulary) to give us an indication of overall student writing ability as well as content knowledge.

Measures of Success

We addressed success of the project from two perspectives: student and teacher. For students, writing scores on RWS science writing assessments demonstrated growth in all rubric components, with the most substantial gains emerging in length and coherence.

Fourth-grade students appeared to benefit most from the program. This may be due to previous inexperience with exposition and science content; thus, training in expository reading/writing techniques and science content early in grade four may provide students with what they need to succeed. However, additional analyses showed that students who participated in two years of the program (either in fourth and then fifth grade or fifth through sixth grade) continued to increase their writing scores throughout the extended exposure to the program.

Additionally, and of great interest to our region, was that students who performed poorly at the outset of the program showed the most benefit from participation. Within each classroom, students were divided into tertiles (low, medium, and high) based on the prewriting score. The writing performance gap between high and low tertile students was reduced by approximately 40 to 50 percent as a result of RWS participation.

Cite this article as: Miller, R.G. & Calfee, R.C. (2004). Making Thinking Visible: A method to encourage science writing in the upper elementary grades. *Science and Children*, (42) 3, 20-25.

Figure 1. Guidelines for constructing effective writing prompts.

Prompt Element	Criteria	Example
Focus Statement	The focus statement has a twofold purpose: It activates students' prior knowledge, and it models implicitly to students that thinking before writing is critical to writing a coherent and interesting essay. Focus statements may be separated from the actual writing directive by placing them in separate paragraphs, folding over the sheet of paper, or using two separate sheets.	You are learning about different kinds of rocks and how they are formed through the rock cycle process. Although rocks can have many differences, they all are related to each other through the rock cycle.
Audience	Tell the students who the audience is for this composition. Giving the students an idea of whom they are writing to/for gives them critical/essential information about tone, vocabulary, and structure. It also makes the writing more real to the students and encourages them to consider audience in their writing, and, by extension, authorship in their reading.	Suppose you want to explain to your parents about the rock cycle.
Form (Type)	Tell the students what form the writing is to take, whether it is a letter, paragraph, essay, or another form.	Write as many paragraphs as you need to explain (1) what the rock cycle is, (2) what the different kinds of rocks formed by it are, and (3) how the rocks can be changed from one kind into another. Be sure that your composition has a clear beginning, middle, and end.
Purpose	Be specific and simple with instructions on the purpose of the students' writing. Use specific phrases and keep them consistent between assignments throughout the year.	General examples: "Write a story that tells...." "Write an essay to explain...." "Write a letter to convince...." "Write a letter to persuade...."
Supporting Details	Always remind students to give supporting details. Include a concluding sentence in your prompt directing them to do so.	Use examples from the reading passage [or an alternate/additional source, such as an experiment, if it is appropriate to the prompt] to support your writing.
Planning Space and Directive	Students should be provided with space to create webs, weaves, and/or graphic organizers of their own design to help organize their thoughts prior to writing. This space may be provided between the focus and directive statements or on a facing page. A statement directing students to use the space should be included in the prompt (or after it) so that students (1) are encouraged to develop a written organizer, and (2) know they are allowed to write in the blank space (obvious to us—but not to students accustomed to being told "don't write in the book"). Younger students may be provided with an advanced organizer that accompanies the writing prompt.	After prompt: You may use this space to plan your writing.

Figure 2. A sample prompt and its corresponding student writing and graphic organizer.

Writing Prompt:

Today you learned about bacteria. You learned some are helpful while some are harmful. Pretend you are a reporter writing an article for a fourth-grade science magazine. The title of this article should be "The Good, The Bad, and The Ugly." In your writing, explain how bacteria are helpful and harmful. Also, explain how they are different and the same. Be sure your article isn't just a list of illnesses or symptoms that are caused by bacteria. Instead, use details and examples from your reading to compare and contrast these bacteria. Use paragraphs to show main ideas.

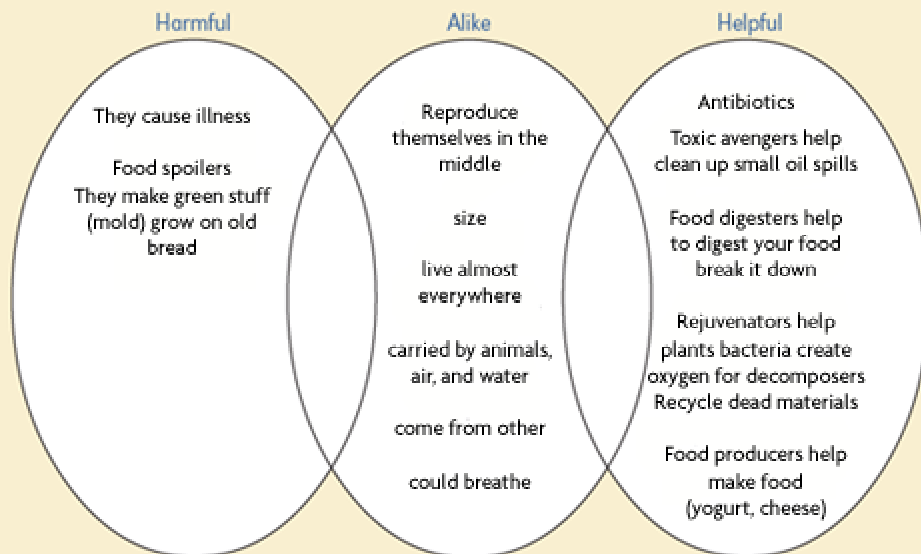
Student Work:

The Good, The Bad, and The Ugly

Bacteria can be harmful because it causes illness. It could spoil your food. For example, they make green stuff mold on old bread and it's bad if you eat a lot of mold.

Bacteria can help you by digesting the food you eat. It could be a toxic avenger that means it cleans up oil spills. Bacteria rejuvenates plants to create oxygen. They are decomposers they recycle dead things back into the air, water, soil. And they produce food and they help you make food. For example yogurt and cheese. And antibiotics is a medicine made by bacteria.

Harmful and helpful bacteria are alike because they both reproduce themselves. They are both a small size. They live almost everywhere. They are carried by animals, air, and the water. And bacteria come from other bacteria.



Cite this article as: Miller, R.G. & Calfee, R.C. (2004). Making Thinking Visible: A method to encourage science writing in the upper elementary grades. *Science and Children*, (42) 3, 20-25.

Science writing rubric		
Score	Description	Criteria
4	Exceeds expectations	<ul style="list-style-type: none"> • Commanding use of key terms with very few or no errors • Connections between concepts are well developed • Concepts presented demonstrate understanding at the analysis, synthesis, or evaluation levels; reflect transformation of content beyond that provided in the text/activity by the student • Further examples and extensions are provided and illustrate excellent comprehension
3	Meets expectations	<ul style="list-style-type: none"> • Sufficient use of key terms to illustrate comprehension; majority of key terms used accurately • Connections between concepts are beginning, although they may be limited to the applications provided in the text/activities
2	Not yet within expectations	<ul style="list-style-type: none"> • Relatively few key terms present; or a majority of the key terms present are used inaccurately • Connections between concepts not present; or generally incorrect
1	Below expectations	<ul style="list-style-type: none"> • No examples from text or activities present (text/activities not referenced) • However, paper is scorable
NC	Not scorable	<ul style="list-style-type: none"> • Unrelated, unintelligible, or length not sufficient to score • Copied from board or another student

Teachers' Insights

A major concern of our team was to design a science-writing program that “worked” in real schools with real teachers. Results from teacher artifacts and discussion sessions showed the design was perceived as effective, efficient, and adaptable. Long-term surveys showed teachers continue to implement the writing strategies outside their participation in the research project; rather than reverting to prior practices, teachers’ change in instructional practice is sustained, and their self-perception of knowledge regarding effective writing techniques continues at high levels.

Teacher insights shared with us were especially thought provoking. In a discussion of “What do you believe about the most effective ways to teach reading and writing, from your experience in the project?”, the following comments emerged during a videotaped discussion near the end of the project:

- “We [teachers] realize that narrative and exposition share features. But we now prefer exposition over narrative for teaching reading and writing—it’s more concrete, and instead of teaching narrative first to students, we think that exposition should be taught first and that read/write instruction should be content-based.”

Cite this article as: Miller, R.G. & Calfee, R.C. (2004). Making Thinking Visible: A method to encourage science writing in the upper elementary grades. *Science and Children*, (42) 3, 20-25.

- “The instructional methods we are using in RWS clue the kids in on what the instructional format is going to be. After doing one unit, the kids know what’s coming and prepare themselves along the way. It’s creating a reflective student, not just the teacher. Students are “owning” the instruction and are motivated.”
- “Instead of just creating scaffolds for content, we’re creating scaffolds for process. We’re creating successful practice, and think that it will lead to successful large-scale assessment.”

These excerpts must be viewed as testimonials, to be sure, but the substance of the comments also merit attention. These are teachers serving students with significant needs, working with limited resources under extraordinary pressures to increase test scores in all subject areas, discussing curriculum and instruction in language more typical of gifted classrooms. To use a metaphor to Neil Armstrong’s famous words—while what we have learned in the RWS Project may be viewed by some as a small step toward effective science writing, we believe it was a giant leap for RWS Project students toward their success in science and in future schooling.

Roxanne Greitz Miller (Roxanne@roxannegmiller.com) is a postdoctoral scholar at the University of California, Riverside, and a veteran science teacher in the Florida public schools.

Robert C. Calfee (Robert.Calfee@ucr.edu) is a distinguished professor in the Graduate School of Education at the University of California, Riverside.

Acknowledgment

The work described in this article was made possible by a grant from the National Science Foundation’s Interagency Education Research Initiative (No. 9979834).

Resources

Chambliss, M.J., and R.C. Calfee. 1998. *Textbooks for Learning: Nurturing Children’s Minds*. Malden: Blackwell.

Harding, T. 2002. Svithjod, stories, and songs: Rewriting earth science in creative ways. *Science Scope*, 26(1):19–21.

National Research Council (NRC). 1996. *National Science Education Standards*. Washington, D.C.: National Academy Press.

Copyright © 2004 NSTA
www.nsta.org