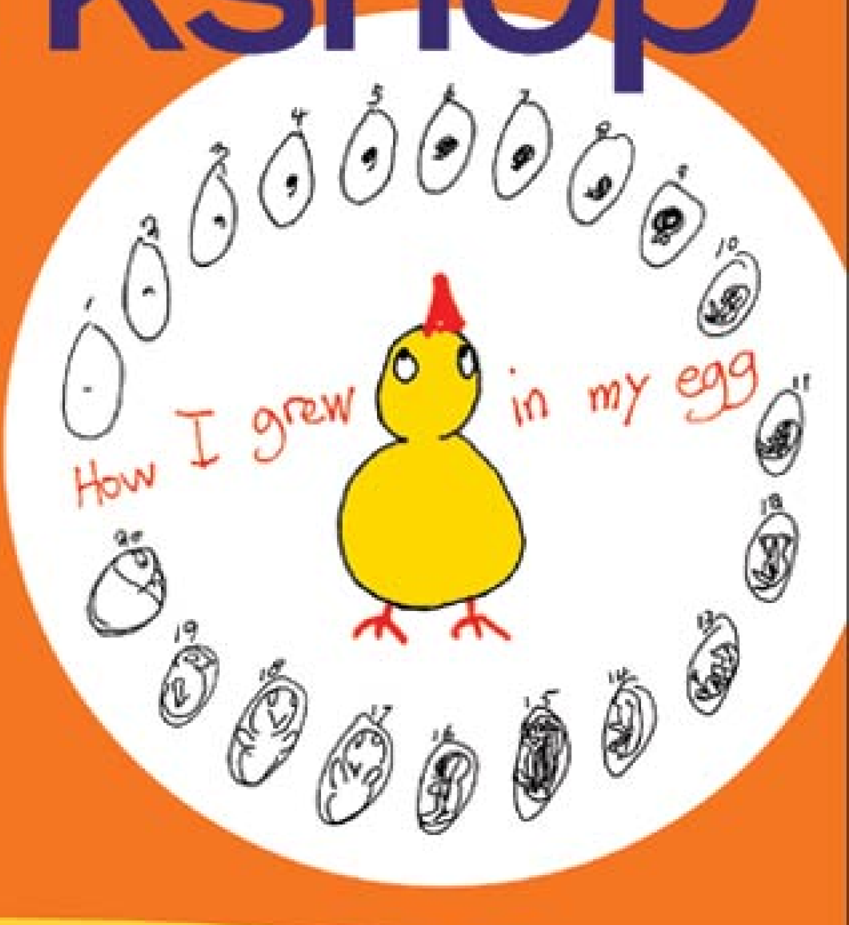
Second Edition

Science Workshop

Reading, Writing, and Thinking Like a Scientist



Wendy Saul

Donna Dieckman • Donna Neutze • Jeanne Reardon • Charles Pearce

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Second Edition
Wendy Saul, Jeanne Reardon, Donna Dieckman,
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5 *Writing: A Way into Thinking Science*

Jeanne Reardon

Writing in science does more than provide a record of investigations and a way of collecting data for analysis and interpretation. Writing is a way into thinking science. While writing, child-scientists not only recount what they observed and did, but they also question, make connections, interpret, confirm or revise explanations, and plan next steps. As teachers, we can provide children with a framework for science writing, prompt them to push their thinking, and model how teacher-scientists write and use writing to think about and understand science.

This chapter is built on my experiences with student writers and my experiences while watching students learn science. Sometimes I will speak of reading, speaking, and listening as well as writing. It is the writing that ties the pieces together. In our classroom the act of writing is as common as greeting and talking with friends. We write lightly and playfully; we write seriously and thoughtfully; we write every day, and in every discipline. Often the very act of writing clarifies our understanding, but there is more. Writing is the way we think, organize, reflect, plan, and solve problems. Writing holds our thinking still so that we can revisit; rethink; and revise our plans, our conceptual understandings, our explanations, our theories.

What we write, when we write, and how we write are important, but the use we make of what we have written is equally important. I believe that students write so willingly during Science Workshop because they use what they write. During Science Workshop, I have never heard a student, even a fifth-grade student, ask, "How much do I have to write?" Writing is not viewed as an assignment; it is seen as valuable to students and to their classmates. It is essential to their inquiry. It is not possible to question, investigate, analyze data, and revise plans without written records.

Teachers' Writing in the Classroom

Before I describe students' science writing, I would like us to consider our writing—the teachers' writing. From reading Chapter 2, you know that I keep a journal. This is reflective writing that I do for my teaching-self, as contrasted to the observational writing and recordkeeping, example/model writing, and writing to prompts that I do as part of my day-by-day teaching, and different still from the personal writing I do at home. My journal reflections are very important to me, but I know that not everyone is a journal writer or diary keeper. If you have never kept a teaching journal, you may want to try it. My advice is not to be slavishly rigid about making entries, but to be spontaneous and see how it goes. Journal writing is optional. Writing in the classroom is not optional, however. If we believe writing is essential to thinking, then we must write with and for the children in our classrooms.

Observational Notes

I make observational notes during the exploration/investigation part of Science Workshop and during Scientists' Meetings. These observations help me to maintain the course and energy of our Science Workshop, to plan minilessons, to identify needed resources, to consider writing prompts, and to assess and evaluate student learning. I have experimented with several different arrangements for recording my observations and am still looking for the perfect one. My challenge is not in the making of observations, but in noting what I see in such a way that I can use my observations for multiple purposes.

The observational form that I find most useful for planning is quite simple. I use a large spiral notebook and fold each page in half vertically. As I walk around and interact with the students during exploration/investigation time, or listen during Scientists' Meetings, I make observational notes on the left side. I include the names or initials of the students beside my observation. The right side is where I list needs, problematic areas, and possible solutions. As I read and reread my observations, I think about next steps: "Do students need some more examples of scientists' recordkeeping? Are there other materials that will assist them in finding solutions to their problems? Will using new materials challenge their existing explanations and push them to consider alternative explanations? Are there books, Internet sources, or people who can provide needed background information? Who can help Leigh and Roberto to more accurately read a thermometer? How can I best demonstrate cause-and-effect relationships? Whose data can I use to demonstrate looking for patterns? What questions can I ask to help students evaluate their explanations?"

While this observation notebook is useful for planning and for assessing the class's progress toward inquiry and science knowledge goals, it is inadequate for assessing the progress of individual students. I find that I can reread my notes for evidence of some skills, abilities, and attitudes observed in students, but further observations of individual students are needed. So, in addition to my spiral notebook, I also maintain a looseleaf one with pages for each student. This is where I keep track of individual student progress. At the front of this notebook I keep my status-of-the-class records. This alphabetical list of student names and their plans for the next workshop was discussed in Chapter 2. I use this record sheet, together with students' Scientist's Notebooks and notes in my spiral notebook, to plan conferences and consultation meetings with students.

Teacher Modeling of Science Writing

Those of you who regularly write in front of the students as part of writing workshop understand the importance of demonstrating how you think as you write. When I model science writing, I write for a specific purpose and I draw on the explorations and investigations of students in the class. I write on chart paper and think aloud as I write.

Many students in our combined first/second-grade classroom were exploring questions related to a broad topic—"What is it about mittens that keeps your hands warm?" The students were at different places along the path of inquiry. Their questions reflected their growing ability to use observation to find questions that can lead to productive investigations—investigations that produce data to use in building explanations: "What's in mittens that keeps my hands warm? Are mittens always warm inside? Do mittens stay warm inside if they are empty—like when nobody's wearing them? How come wet mittens don't keep my hands warm? Do mittens keep the cold out or do they keep the hot in?" Many students were engaged in productive investigations and had recorded data in their Scientist's Notebooks. Several students had reported their explanations during a Scientists' Meeting. Now I wanted to demonstrate science thinking and writing that would show the relationship between evidence and explanations.

> "Today we are going to work on writing that explains what is happening. We have to do two things: explain *what's going on* and tell *how we know*. Sometimes scientists call the "what's going on" sentence a claim. The how we know is called evidence. I want to write to explain how mittens keep my hands warm. My first sentence will be the claim that tells what's going on that causes mittens to keep hands warm. I'll write some of our ideas on the chalkboard. Next we'll look in our Scientist's Notebooks for evidence that supports the claim. If we find evidence I'll underline the claim sentence on the chalkboard."
>
> To explain what was going on, students suggested that "Mittens are thick." "The stuff mittens are made out of keeps the cold from getting in.""Mittens make what's inside get hot.""Mittens keep your hands warm cause the warm can't get out."
>
> I asked, "Did anyone do an investigation to show that mittens keep the cold from getting in?" Three children said they had and so they

searched in their Scientist's Notebooks for what they did and the records of their findings. Then they underlined those parts of their notebooks. We did the same thing for each of the claims on the chalkboard, searching through notebooks and underlining anything we did that supported a claim. For some claims there were no investigations, for others there were investigations, but few records. Some children had done investigations and kept records. (We had to stop to discuss what we could do to show that mittens make what's inside them hot.)

Kevin had carried out several experiments where he put a thermometer in a mitten and closed the opening of the mitten with rubber bands. He had recorded the temperature on the thermometer before and after he put the mitten outside "for a while" and when he left the mitten in our room. He had also put a thermometer in his mitten and had worn his mitten with the thermometer in it when we went out for recess. Kevin's explanation for "how mittens keep your hands warm" was: "There is something in mittens that keeps the cold air from getting inside. Your hand is like a cork and keeps the air from getting in the open end."

I told the class, "We will be writing lots and lots of explanations about what we discover in Science Workshop. Today I am going to use Kevin's investigation to show how scientists write explanations. Kevin wants to explain how mittens keep your hands warm. Remember, I said that first scientists make a claim—what is happening, then they write the evidence—how they know that it is happening. The evidence is what they did and what they found that supports their claim. If there are findings that don't support their claim, scientists write that too. I'll write Kevin's claim on the chart. . . . Now I need to write the evidence. "What did Kevin do that shows something in mittens keeps the cold air from getting in?" I continued thinking aloud, asking the children questions and writing on the chart paper.

Writing in Response to Prompts

Another type of teacher writing is writing in response to the questions or prompts we give to students. We provide our students with questions to uncover their assumptions, to help them think about and understand how science works; to anticipate, introduce, focus on a new topic; to summarize; to identify and solve problems; and to assess and evaluate skills and conceptual understanding and knowledge. When we write with our students in response to prompts, we are pushed to thoughtfully consider the questions we ask. After writing our response, we are more curious about, and open to, the responses of others. I will elaborate on writing to prompts in the next section about students' writing.

Students' Writing During Science Workshop

Let's look first at student writing done within the Science Workshop, and then at science writing done outside of the structure of Science Workshop. As I discuss a variety of student science writing, I would like you to think about how often, and in how many ways, a single piece of writing is used by the author of a piece and her classmates.

In the Chapter 2 example of Science Workshop, I passed out Scientist's Notebooks the first day. That day the students wrote about what they had done and what they had observed during their exploration of building materials. They brought their pencils and Scientist's Notebooks with them to the first Scientists' Meeting. During the meeting, the students read and coded their entries with a *D* for something they did, an *O* for something they observed or noticed, and a *W* for something they wondered about. This helped them focus on one aspect of their exploration to share with others. After listening to other students' comments, they drew a line across the page to mark the end of their original entry, and then added anything that they wanted to try out for themselves, about which they wanted to find out more, or talk over with someone else. In this way, they were able to take advantage of their classmates' work and to plan for the next workshop.

The Scientist's Notebook provides each student with a record of his inquiries. It includes questions raised, questions answered, procedures followed, materials used, data collected and organized, references consulted, explanations generated, plans made, and personal reflections. The notebook is more than a collection of scientific drawings, tables, and charts, although those are included. It is a working document to be read and reread as the inquiry progresses. As such, it is part narrative; part lists and jottings of ideas; part numbers, symbols, drawings. The primary audience for this writing is the student scientist who is engaged in the inquiry. The Scientist's Notebook is a source of information to be used in discussions, and in writing expanded explanations, informative articles, and reports for the larger community of classroom scientists.

Setting Up and Using the Scientist's Notebook

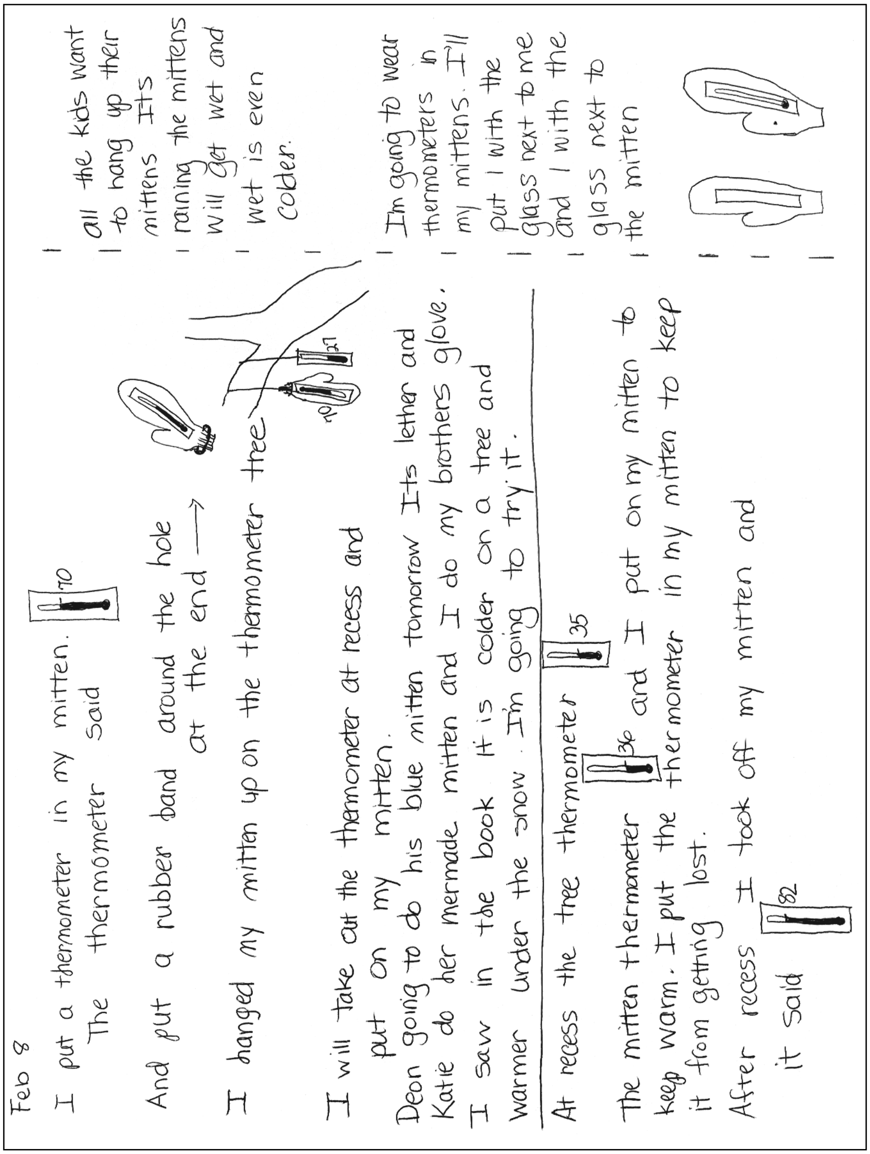
I use legal size, unlined, white copy paper (8-1/2″-by-14″). A notebook is made of twenty to twenty-five sheets stapled together horizontally. The title, Scientist's Notebook, is written on the front cover, then the booklet is flipped over from bottom to top and ???? Plans is written on the back cover. Students work from both ends to the middle of their Scientist's Notebooks. Questions are central to inquiry and although questions appear within the routine entries, as students work from the front of the notebooks, it is important to have a place to record questions whenever they come to mind. I have noticed that students often write questions in the back of their notebooks during Scientists' Meetings while listening to other students report on work. Students often fill several notebooks during a school year.

Before students make entries in their journal, they fold under 1-1/2 to 2 inches from the right edge of the page. When unfolded, this provides space for children to react and respond to their work; to write comments, ideas, explanations, plans for future explorations. . . . Some students make drawings for next steps, some make comments inside conversation bubbles: "Starts here—the real explanation." I once had a student who left a margin on the left side as well as the right. She would ask questions about the investigation on the left—"Where did you hold the flashlight? How come the shadow's so long?" She would answer herself in the right margin—"I better measure and draw the flashlight. Good question—don't know." Scientist's Notebook writing is single-draft writing and we need to have space available to react to our work at the place of response rather than beginning a new page at the end. It is essential to have this wide empty margin.

If children are exploring, I ask them to stop every ten or fifteen minutes to "Write what you did . . . what you noticed . . . what you wonder about . . . anything that surprises you." Children use drawings, lists, phrases, sentences, charts, conversation bubbles, . . . to record what they are exploring and thinking. If students are investigating a question, then they record as they work. While students are investigating, I stop by to watch and ask, "How will you record what is happening, what you see? What are you writing to show how much . . ., how long . . ., the procedure you used . . .?" When students are first introduced to Science Workshop, they often become so involved in their investigation that they forget to make records. When I see a student recording his measurements, procedures, findings . . ., as he works I will call, "Stop and come over for a minute" (see Chapter 2). Everyone comes over to look at and to talk over the entry with the student.

Since my retirement a year and half ago I no longer have student notebooks to show you. The example in Figure 5–1 is based on my notes from a writing across the curriculum presentation I made to the staff in my school. It is typical of a first-grade student's notebook including the sentence fragments and misspelled words. The student is the audience for his Scientist's Notebook writing. It is not written for the teacher or for a distant audience needing detailed background information. This is not a time for complete sentences and corrected spelling, but for keeping track of ideas, observations, actions taken, and reactions.

My notes indicate that the student had been talking with his classmates about his idea that the stuff mittens are made of keeps the cold from getting in. (We would probably think of this as the insulation



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I put a thermometer in my mitten. The thermometer said 70

And put a rubber band around the hole at the end ⟶

I hanged my mitten up on the thermometer tree

70 27

I will take out the thermometer at recess and put on my mitten.

Deon going to do his blue mitten tomorrow Its lether and Katie do her mermade mitten and I do my brothers glove.

I saw in the book it is colder on a tree and warmer under the snow. I'm going to try it.

At recess the tree thermometer 35

The mitten thermometer 36 and I put on my mitten to keep warm. I put the thermometer in my mitten to keep it from getting lost.

After recess I took off my mitten and it said 82

all the kids want to hang up their mittens Its raining the mittens will get wet and wet is even colder.

I'm going to wear thermometers in my mittens. I'll put 1 with the glass next to me and 1 with the glass next to the mitten

Figure 5–1.

theory.) He did not record the material of his mitten, but later notes the blue leather of Deon's mitten and Katie's mermaid mitten. He records the details he thinks will be important: the temperature of the room (and his mitten), closing the opening with a rubber band, the temperature of the air outside. He notes that the mitten with the thermometer will hang outside until recess. After hanging up his mitten, the author joins his classmates' conversation. Katie has noticed that when she first gets in bed it is really cold, no matter how many blankets. Later on she gets hot. Deon thinks maybe the temperature in the mitten hanging outside will go down first, then go up just like in bed. The entry states that Deon is going to do his blue mitten tomorrow. It's leather. . . . Next comes another planning entry. The student will try for himself to see if the temperature of the soil under the snow is warmer than the air. I clearly remember when he talked about this in Scientists' Meeting, and I was amazed when he made a connection between the snow keeping the cold out and his mitten keeping the cold out.

The line drawn across the page shows the end of the morning investigation. After lunch recess the student records his findings: the temperature of the air outside and the temperature inside his mitten. He also writes that he put on his mitten with the thermometer in it, and records the temperature shown on the thermometer when he gets back in after recess—after he had been wearing the thermometer.

Earlier I noted that the space made available by folding over the edge of the page could be used for different purposes. I may direct the students to read entries and to code for observations, or procedures followed, or for evidence. Other times I may direct the students to read and reread their entries thinking as scientists and then write what they are thinking. On the day of this entry, my directions were probably to read what you wrote, then think about what it means and what you will do next.

In the fold-over space, this student notes that others want to do what he has done. (Students often include social comments in their notebooks.) He also starts a whole new idea about wet being even colder and wrote this comment in the back of his notebook as something he wanted to investigate later. The class became very curious about the temperature of wet and dry mittens. Perhaps the student is beginning to think about the effect of the warmth of his hand on the temperature in the mitten and so he plans his next step. The thermometers we use in our room have the glass column stapled to a cardboard or plastic backing. He is going to put one thermometer in his mitten with the glass column next to his skin and in his other mitten he will have the plastic or paper next to his skin.

It is important to have space for thoughts while rereading notes. I find that when students have space available for writing reactions and responses they think and rethink their investigations.

Drawings, Charts, Diagrams, Graphs, and More

It is important for the student to decide when, for what purpose, and in what form she will record information. Too often students are provided with an empty form to use for recording information without a discussion of the purpose of that particular representation. Some forms are better for recording observations, some are better for collecting or analyzing data, others are better for communicating findings. When the teacher provides the table or chart to be filled in, students' thinking is restricted and alternatives are lost. I remember a first-grade child placing a variety of objects in a clear plastic aquarium and watching the materials sink or float. During Scientists' Meeting she shared the chart she had constructed to record her observations. Her chart listed the objects she used along the left side, but rather than the usual headings of sink or float, she had three categories: *sink, float,* and *strange*. She told the class that *strange* was for objects that didn't sink and rest on the bottom, but floated part way down, or objects that floated for a while and then sank, or sank after she dropped water on them. She added that she planned to investigate the strange ones. We need to read, discuss, and analyze the drawings, tables, charts, graphs, and diagrams found in books and news and scientific articles. A student who has experience reading, analyzing, and using a variety of representational forms is better able to select or create a form that serves her purpose.

Coding Entries

Before coming to Scientists' Meetings the students date and reread their entries. I may direct them to code their entries to facilitate thinking and discussion. Recall that in Chapter 2 I asked the students to use letter codes to mark their notebooks after rereading, "*D* for something you did, *O* if it is something you observed, and *W* if it's something you wonder about." Sometimes I have the students code with letters and other times I ask them to underline. If children are having a difficult time distinguishing between observations and comments, I say, "Reread what you wrote today and underline what you noticed—observed with your senses—with a red pencil. Underline any comments you wrote with a blue pencil." When we meet, we discuss both comments and observations. Comments help children make connections and build explanations, but they are not the same as observations. Other times I may have students underline procedures they used, explanations, evidence, or something they found surprising. Then we focus our discussion on the aspect of their work that they have been asked to underline.

Additional Thoughts

During Scientists' Meetings, three or four children report on their work and lead the follow-up discussion. Other children offer questions, suggestions, challenges. After each discussion there is time for students to enter additional thoughts, questions, plans, ideas in their notebooks. In science we want students to adopt a speculative stance. Providing time to make additional entries after discussion helps students realize the tentative and unfinished nature of scientific knowledge and understandings.

Scientist's Notebooks are used at other times during the day outside the Science Workshop structure. The notebook often becomes the text for reading groups or a resource for expanded writing. We read notebooks in small groups or during whole-class lessons to look for implied questions, to plan for or refine our testing of hunches, to share ways to find answers to questions, to discuss the significance of surprises, to settle on a common vocabulary, and/or to make connections to other work.

Prompts for Writing

Frequently I provide the class with a question or prompt to write to. You may recall from Chapter 2 that I gave the children a prompt to write to before our first Science Workshop when I asked: "What do you think will happen when we have science workshop this afternoon? Take a few minutes to think and write down your ideas." Sometimes we write at the beginning of Science Workshop, to bring prior experiences and understandings to the surface or to identify and consider a problem. We may write at the end of an exploration/investigation time to summarize or reflect on some aspect of our work. Sometimes we write after Scientists' Meetings to uncover assumptions about how science works or to assess knowledge and understanding.

Over the years I have compiled a collection of prompts that I find effective in assisting students in their inquiries and in developing their understanding of the ways of science. These are some of the questions that help us think about our own inquiry processes:

- What surprised you?
- What are you wondering?
- Where do your questions come from?
- What makes a good question?
- How do you decide what to record?
- How do you use your Scientist's Notebook?
- What are you doing when you are doing science?
- How do you know when to stop investigating, that is, know that you are finished?
- Do you ever give up on, abandon, your idea/question/explanation? Why? When?
- How do you decide if an explanation is a good explanation? What makes one explanation better than another?
- If someone asked you to help write an explanation, what would you do, that is, how would you help?

- What makes you revise your explanation?
- What kind of evidence do you find convincing?
- What do you do when you get stuck?
- How do you decide what to do next?

When students write and share responses to these kinds of prompts, it makes the thinking of all the scientists in the room available to everyone. It gives students new ways of thinking about and doing science, and provides an opportunity for them to assess their own understanding of the inquiry process.

After we have written in response to a question, we discuss not only the content of our response, but how the particular question pushed our thinking. Later, I shorten the prompt to a stem and then add it to a chart I call "Writing to Think and Learn in Science." Students often refer to this chart when they are writing their unprompted reflections at the end of an exploration/investigation time. In the following lists, I have grouped some of the stems I use by the purpose they fulfill.

Focusing, Anticipating, Introducing

- What is ____________? (Fill in with a topic you will begin studying—What is electricity? . . . a material? . . . a tool? . . . a concept? . . .)
- Write three (five) things you know (believe) about ____________. (electricity, friction, . . .)
- What are you doing when you are ____________? (lifting a heavy object, . . .)

When we share responses to these stems, I find out where the students are, what they already know and understand, their misconceptions or confusions. Using this information, we are able to identify experts in the class who can assist us in our study.

Learning Something New, Making Connections, and Summarizing

- What I discovered/learned about________________.
- How ________________ fits in with what I already know about ____________.
- What I think about ________________.
- I think ________________ means.
- This is my definition of ________________.
- I could teach someone about / how to / how to use a ______________.

Coupling the introducing stems with these stems provides a basis for comparison and a way to document change in students' knowledge and understanding.

Problem or Question Identification

- I was surprised when_________________.
- This is the problem I had when I _________________.
- think my problem is _________________.
- Some questions I have (still have) about _________________ are _________________.
- The problem I had doing _________________ is _________________.

Problem Solving and Assessment

- This is how I solved the problem _______________________________.
- The procedure I used to _________________ is _________________.
- My rule for _________________ is _________________.
- My idea about why _________________ happens is _________________.
- This is how I know that _______________________________.

Writing Outside of Science Workshop

The science writing I have discussed so far has been single-draft writing done by students during Science Workshop. This writing helps students pursue their inquiry questions and construct explanations based on their investigations. Students also need opportunities to write longer pieces such as expanded explanations, reports, informative articles, and writing to encourage action. I find that writing workshop is the place to write longer pieces because its structure provides the necessary time, support, and responses for such writing.

The example I gave of modeling explanation writing took place during science workshop; it was single-draft writing aimed at understanding the relationship of explanation and evidence, not writing for publication. We work on expanded explanations, the kind that can be published, during writing workshop. These explanations are discussed in response groups, revised, edited, and prooofread before they are published and shared with a wider audience.

Reports are one way to communicate information to a wide audience. Students engaged in inquiry generate findings and make claims based on their investigations. Older students need to compare their work with published material, consider claims and/or arguments that support or disagree with theirs and think about the basis for the agreement or disagreement. Reports for Scientists' Meetings require students to organize their work for an audience of their classmates. Students need to read reports of practicing scientists to see how they are written and to think about what to include and how to present data and findings.

I have found that often the short scientific research articles, which appear in a weekly science news magazine—for example, *Science News*—provide a good basis for discussion and analysis of a report. This particular magazine is written for adults, but I have used articles with fourth- and fifth-grade students. I just read a report about the cognitive capacity of jays entitled "Birds with a Criminal Past Hide Food Well" (Milius 2001). In addition to findings, this brief article includes other information such as: "The experiment grew out of some big questions about the capacities of animal cognition, as well as Clayton's lunching habits during a year in California, where scrub jays forage for crumbs. Several times Clayton noticed what she later observed in the lab" (p.325). Tests are described and connections are made to other research: "Emery draws evidence to challenge longtime assumptions about animal cognition. For years people have assumed . . ." (p. 325). It is a good idea to collect articles written by professional science writers for use with students who are writing science reports.

I have also worked with fourth- and fifth-grade students on other kinds of science writing, including writing about controversies and to encourage action. Controversial science issues are national and international in scope; several come to mind immediately: global warming, genetically altered food, and stem cell research. I recently discovered the K through 12 SCOPE (Science Controversies: On-Line Partnerships in Education) website *http://scope.educ.washington.edu/*. The site focuses on scientific controversies with descriptions for in-school projects. Students are encouraged to take a position on a given issue, and then to investigate the pros and cons of their position through guided activities and web research. Students who participate in these projects write as they research to support an opinion.

Writing to encourage action is persuasive writing about an issue of importance to the class and relevant to an authentic community problem. When the declining frog population in our creeks was publicized, we began investigating local pollution and ways to lessen the effects of water pollution in our community. Writing to encourage action about issues requires scientific knowledge as well as an understanding of persuasive writing.

I have not discussed all of the science-related writing that is done by students. Students' writing is strongly influenced by their reading, so it is important to have a wide variety of written texts, photographs, and other media available for them. Science articles from the popular press, journal articles, information books or trade books written about a single topic, papers and notebooks of practicing scientists, identification guides, photo essays, reference books, articles found on the Internet all provide useful text to familiarize students with the discourse of science. Students must read widely and discuss what they read in order to distinguish scientific and nonscientific ideas, to recognize facts and opinions, to have examples of ways to represent data and findings, to evaluate practices—to become science writers.

The science of our Science Workshops—the students' scientific awareness and their wide reading—is apparent in their writing. There is always a large collection of poetry books in our classroom and children frequently write poems that reflect their close observation of the world and their engagement with science. After a book of superstitions made its way around the classroom, I noticed students writing science superstitions. Students often use science-based similes and metaphors in their writing. Reviews of science trade books and science television shows regularly appear on our classroom message board. Some may not consider this to be science writing but much of the writing I see is clearly informed by close observation of natural phenomena and a burgeoning knowledge of science.

I began this chapter saying, "Writing is a way into thinking science." Writing is the way we think, organize, reflect, plan, and solve problems. Writing holds our thinking still so that we can revisit, rethink, and revise our plans, our conceptual understandings, our explanations, our theories. In conclusion I would add, writing does all of that and more—it puts us in touch with the beauty of science.

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