Writing in Science
In memory of my father
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In the mid-1990s there were a very few people trying to figure out how connecting science and literacy might benefit students. Betsy Rupp Fulwiler was one of these. Working closely with a team of science educators in the Seattle Public Schools, she and her colleagues began using science notebooks to support inquiry learning. At first the assessments they collected were “formative”—they looked closely at both the hands-on activities and the literacy learning of students, asking always how each might support the other. And regularly, they would go back and tinker with the directions, the scaffolds, the teacher development piece—nothing was left unscrutinized. They listened and looked carefully at student work. They visited classes. They taught model lessons. At every turn they sought to improve their “product.” For those of us who have watched from the sidelines it is a gift to finally have in our hands the result of their work.

Although the book begins with a report of their school improvement data, my teacher bones sent me straight to the sections that describe practices. At present, there is significant agreement among those of us concerned with linking science and literacy about what practices to support—we know that notebooks and journals, vocabulary instructions and graphic organizers all support improved student achievement. But as in all matters education-related, the success of any practice is realized in the concrete details of the plan.

Here is where Writing in Science shines! The descriptions of the proposed activities are done with amazing clarity and care. In the section on word walls, for instance, we learn about the importance of keeping words mobile and accessible, so that they can be used in a variety of ways and not just displayed like artwork or the school calendar. Definitions are tied to hands-on demonstration (Yes, put the filter that you used up there next to
the word filter to remind us not only of the word’s meaning, but also of the experience we had filtering that liquid!)

Most proponents of science notebooks are pleased to have students write a kind of “dawn to dusk” chronological accounting of what they did and what they noticed. Fulwiler takes us much further, pointing out that most science writing is not, in fact, chronological, and that students need to become familiar with the structures used most frequently in expository writing, for instance compare and contrast or cause and effect.

She also shows us how writing can be helpful in moving students to think more deeply about their observations or analyses. In an era of assessment and evaluation, the section on evaluating notebooks may prove especially helpful.

What I like best about Fulwiler’s book is that it is real. I KNOW that each and every suggestion proposed here has been tried not once, but hundreds of times with thousands of children. And what I like second best is that even though the author has given me a very clear map of where to go and what to do, complete with compass and any other tool I might need to follow her well-worn and highly successful path, there is also room for a teacher anxious to blaze new trails to learn from the experiences of Fulwiler and the Seattle team.

So as gifts go, I am very happy with this one. I will open it regularly. I have already learned much that can be shared the next day with students. Through this volume, Fulwiler makes all of us seeking salient connections between science and literacy better teachers.

—Wendy Saul
The work that I share with you in this book began in my fifth-grade classroom a decade ago. Since then, the financial support and vision of some, the expert advice of many, and the inspiring work of over a hundred teachers—and hundreds more whom they have influenced—have helped thousands of elementary children learn to think and write like scientists and to love science.

I want to begin by thanking the organizations that have provided the additional resources necessary to develop such a unique and specialized project as the Expository Writing and Science Notebooks Program in Seattle Public Schools. The National Science Foundation supported the initial phase of the project, and subsequently awarded a five-year grant in 2006 to the district to develop materials that will enable us to share the program with teachers and districts across the country.

The Stuart Foundation in San Francisco funded the seminal work from 2000 through 2005. I am deeply grateful to the foundation for their substantial support. In particular, I want to thank Ellen Hershey, the senior program officer, who oversaw our project. Her expansive but pragmatic vision, wise counsel, and tireless championing of the work have been crucial in developing the program.

The Science Notebooks Program and Seattle’s K–5 Inquiry-Based Science Program would not have been possible without Lee Hood and Valerie Logan and the Institute for Systems Biology in Seattle. They know better than anyone the need to provide high-quality science education for all students, and they have been an inimitable force in helping Seattle Public Schools and other districts move toward realizing this goal.

The Nesholm Family Foundation in Seattle also has provided generous grant support through the years. We have been proud to help them with
part of their mission: to provide quality educational experiences to develop the potential of underachieving students.

In 1998, Social Venture Partners in Seattle awarded a grant to two Seattle elementary schools to support teachers in learning how to teach inquiry-based mathematics. I developed the writing component for the grant, and what I learned during that project informed later work in the Science Notebooks Program.

In addition to this external support, the program has benefited immeasurably because of contributions and encouragement from the board of directors, Superintendent Raj Manhas, and staff and teachers in Seattle Public Schools. In particular, I want to thank Elaine Woo, who currently is manager of the PreK–12 Inquiry-Based Science Program. Long before literacy in science became a dominant trend, Elaine envisioned a program that could help elementary students learn to write about science. Then, as she always does, she recruited people who could carry out the vision, found resources to fund the project, and supported everyone in ways that made us achieve more than we ever thought was possible. Her mantra is always that we must “do what’s best for children.” Seattle students are lucky to have her working for them.

Another of the principal reasons this science-writing program has been successful is that we have worked as a team of specialists. Although I have a strong background in writing (I was an editor before becoming a teacher), I initially had as minimal a background in science, especially physics, as most elementary teachers do. I can never express the degree to which the Science Resource Teachers, the district’s science-education specialists, have influenced the development of the Science Notebooks Program. I especially want to thank Kathryn Show, who from the beginning has modeled for me and so many other teachers the standards of excellence in inquiry-based science education and professional development. I also want to thank Awnie Thompson, Joseph Thompson, Laura Tyler, Wanda Lofton, Cathy Stokes, and Lezlie de Water for their support in ensuring that the writing program fosters students’ science learning in the best possible ways.

All of us also turned to scientists for guidance. In the writing program, I relied most often on Stamatis Vokos, now at Seattle Pacific University, who is a physicist, a gifted educator, and a champion of science-education reform.

The writing and science programs are highly respected in Seattle Public Schools because they serve the teachers, and thus the students, so effectively. This would not be possible without Penny Knutzen, who expertly and graciously manages the myriad of administrative details involved in these complex programs.

For the student notebook entries in this book, I am indebted to the following Seattle Public Schools teachers, who not only are stellar educators but also have contributed extensively to the development of the science and science-writing programs: Ana Crossman, Paula Schachtel, Dan Jordan,
Kirsten Nesholm, Katie Renschler, Janine Tillotson, Joni Pecor, Tim Salcedo, Stephanie McPhail, Deb Schochet, Erika Shearer, Janine Knappe, Vivian Fuller Dusenbery, and Doris Toy Patin. I also owe a special thank-you to Laurie Spickard, our honorary Lead Science Writing Teacher from Bainbridge Island School District.

These teachers are part of the Lead Science Writing Teachers (LSWT) team, which since its inception in 2000, has included over one hundred teachers who work together to improve their own instruction and develop support for other teachers. In addition to those I have already mentioned, I would like to acknowledge the exceptional work of the teachers who have served as LSWTs for three years or more: Christine Patrick, Kristina Wendorf, Jim Buckwalter, Diane Eileen, Ann Kumata, Stephanie Penrod, Katherine Berg, Theresa Healey, Billie Halliday, Heather Araki, Marcie von Beck, Sarah Kuney, Althea Chow, Mindy Woodbury, Shauna Oswald, Kay Ellis, Jean Ihler, Jeannie Shu, Patsy Swartz, and Patsy Yamada.

All of us in the Science Notebooks Program and the K–5 Inquiry-Based Science Program have benefited enormously from our relationship with Mark St. John, Laura Stokes, and their colleagues at Inverness Research Associates in Inverness, California. As our evaluators and our advisors, they create an intelligent, highly professional framework in which we can analyze our work. I am especially grateful for Laura’s insight, empathy, and guidance by metaphor during the development of the science-writing program and this book.

I could never have produced the final manuscript of this book without the insightful and knowledgeable counsel of Ana Crossman, Paula Schachtel, and Dan Jordan—all gifted teachers and science-education leaders in Seattle Public Schools who read and commented about each chapter. I also feel extraordinarily fortunate that Linda Clifton, former director of the Puget Sound Writing Project at the University of Washington, took a major role in this process as well, providing perspective that no one else could provide so astutely and graciously.

As part of our new grant from the National Science Foundation, the Science Notebooks Program is benefiting from the vast experience of Susan Mundry of West Ed. I am grateful for her initial insights and kind support in producing this book.

I also am indebted to Robin Najar, acquisitions editor at Heinemann, who asked me to write this book and then guided me patiently through its development; and to Sonja Chapman, Doria Turner, and their colleagues on the Heinemann production, design, and marketing team for their support and multiple talents.

I never would have made it through the years of developing this program were it not for the incredible support and expertise provided by my mentors and friends on the faculty of Seattle University’s Master in Teaching Program. Whenever I was floundering in new territory, Margit McGuire, David Marshak, and Katherine Schlick Noe provided
professional advice and moral support. They are my exemplars for great teaching.

As my friends and family know, I am an editor by nature. So for months, I have done battle with every word I have written on these pages. I especially am indebted to Deb Easter, editor-at-large, for her clarity, intelligence, humor, and moral support during countless phone calls. Kate, Derek, and Jonathan deserve special accolades for bringing me back, on a daily basis, to what I value above all else in my life—my children. I am incredibly proud of them and thankful that each one provides, in a unique and invaluable way, the humor and perspective that keep me on course.

Finally, I want to honor the memory of my parents. I was blessed to have a mother who embodied unconditional support and love. If she ever had concerns about my choices, she always phrased them as questions, never as criticism. My father, who died just as I was beginning this work a decade ago, is still a guiding presence. Everything I understand about the nature of clear thinking and the beauty and power of language I owe to his example. In one of a series of yearly resolutions about writing that he sent to the attorneys in his firm, he wrote: “Let us here now highly resolve that we will stop and think about what we want to say or write before we say or write it. Doing so is not difficult, and when you get used to it, it may even become a source of pleasure.” I offer his words now as an introduction to the work I share with you—and your students—in this book.
When I began the school year in 1996, I had just completed a week of intensive training in inquiry-based science. As part of a five-year grant from the National Science Foundation (NSF), elementary teachers in Seattle Public Schools were participating in one hundred hours of professional development to learn how to teach science by guided inquiry and develop an understanding of science content. As excited as I was about helping my fifth graders learn science in such a meaningful and effective way, I also felt overwhelmed and uncertain. For one thing, I fit the typical elementary teacher profile—my science background in school was minimal and had not involved, quite purposefully on my part, any classes in physics. Yet both of the units I was to use were physical science units. Furthermore, I was to teach this unfamiliar content through inquiry, a way of teaching and learning that I was just encountering.

Another daunting challenge was planning how I was going to teach my students how to write about science. Writing in general is not an issue for me. Before becoming a teacher, I was an editor and I have a master’s degree in English. Teaching children how to write—especially within content areas so that students have something meaningful to think and write about—has always been a fundamental goal in my teaching. But scientific writing is a distinctive genre. I was going to need some help.

Whenever I had time, I tried to find information to help me. But this search was disappointing. From the perspective of literacy specialists at the time, integrating writing and science often meant having students write stories or poetry about what they were learning in science. I felt then, as I still do, that students typically have many opportunities to write creatively; my students did not need to write poetry about physics. What they desperately needed was to learn how to write analytically, and that required learning different expository text structures.
When I read articles about scientific writing in the elementary grades, I found that science specialists typically focused on procedural writing. Students were to write about how they set up and conducted an experiment so that someone else could replicate the experiment and get the same result. As I was beginning to learn about inquiry-based science, I thought this made sense. So I taught my students how to write procedures. I soon realized, however, that by spending so much time doing the one kind of writing, we did not have time to work on other forms of scientific thinking and writing such as observations, cause and effect, data analysis, and conclusions. And these were the forms that required increasingly higher levels of thinking and writing skills. So I clearly needed to learn more about the teaching and learning of science in order to develop the writing instruction I thought my students needed.

Fortunately, the NSF grant gave me—and about twelve hundred other teachers in Seattle Public Schools—ongoing professional development opportunities that included training in inquiry-based instruction and in science content at the adult level. In these workshops, we not only were able to learn from the district’s elementary science-education specialists, who helped us understand the units we were teaching and how to teach them, but we also were able to interact with and learn from scientists.

Over the next three years, my fifth-grade teaching partner, Katie Renschler, and I worked together to apply what we were learning through the grant opportunities. We became lead teachers in the program, which meant we participated in ongoing professional development with the science-education specialists, scientists, and nationally known experts in the field. We also worked closely with our mentor, Kathryn Show, the science-education specialist who had helped plan the NSF grant for Seattle Public Schools.

During this same period, I was developing some strategies that I initially had used when I had taught remedial reading and writing classes for elementary students. Struggling students in particular need structured support in order to be successful. They especially benefit from visual reminders or cues such as graphic organizers (for example, flow maps and Venn diagrams) to help them make sense of and remember what they are learning. They also need writing frames to support them as they learn how to write different forms of text. About 25 percent of my fifth-grade students were served in remedial or special education classes, but I was realizing that all my students were benefiting from the strategies.

In 1998, the third year of the inquiry-based science training, our principal, Elaine Woo, wrote a grant so that teachers at our school and a neighboring school could work together to learn how to teach inquiry-based mathematics. (Social Venture Partners, a philanthropic organization in Seattle, funded this project.) Elaine believed it was critical for students to learn how to write about their mathematical thinking. Because of my background, she asked me to develop a writing component for the grant.
In the course of this work, I began developing strategies—based on using graphic organizers and writing frames—for teaching elementary students how to write about geometry and problem solving. A tremendous benefit of the math grant was that it allowed me to work with other teachers at my own and other grade levels so that we could determine what was working and what challenges we and the students were facing. I had taught kindergarten and worked on literacy skills with students in grades one through five. But I had not taught inquiry-based mathematics or science at any grade levels besides fifth grade.

So while Katie and I continued to work at determining what strategies and support worked well with fifth graders and the intermediate students, I turned to two excellent primary teachers to field-test the strategies at the primary level. Theresa Healey was invested in instruction that developed her kindergartners’ critical thinking skills, so she taught many of the reading and writing skills through science and mathematics. Billie Halliday had the same mind-set with her second graders, and later with first graders. Together, the four of us were able to refine the strategies so that students from kindergarten through fifth grade were able to write at very sophisticated levels about their mathematical, and later their scientific, thinking. As the math writing, and then science writing, began appearing in hallway displays, parents and other visitors were amazed at how well the students, even the five-year-olds, were communicating their thinking.

In 1999, I left the classroom and began working full time with the science-education specialists in the central office of Seattle Public Schools. Elaine Woo had become the project director of the district’s elementary NSF grant. Having decided that we needed to develop a formalized writing component to help teachers teach students how to write analytically about their scientific thinking, she asked me to develop the program.

The other members of the elementary science team were specializing in the different inquiry-based science units the teachers were teaching. These consisted of units developed, with the support of NSF, by Science and Technology for Children (STC), Full Option Science System (FOSS), and Insights (see Appendix C for information about these units). The specialists also had received extensive professional development in science content from scientists at the University of Washington, especially from the Physics Education Group in the Department of Physics, and in science-education reform from experts from around the country. I benefited from much of this training as well, but the specialists were the experts with whom I consulted as I began planning what the students needed in order to think and write scientifically.

With the support of Seattle Public Schools, a year of funding from NSF, then five years of funding from the Stuart Foundation in San Francisco, as well as support from the Nesholm Family Foundation and the Institute for Systems Biology (both in Seattle), I have spent the last seven years working with teachers and students to see where they are struggling and trying out solutions for those challenges.
The challenges are daunting in a district like Seattle, which has about seventy elementary schools and about 22,000 elementary students, almost 40 percent of whom receive free or reduced-price lunch. These students are not evenly distributed among the schools. For example, half the students whose notebook entries are featured in this book come from poor neighborhoods, with 70 to 78 percent of their school populations living below the poverty line. Strikingly, students in the district speak 129 languages, and 21 percent of the children come from families who do not speak English. About 13 percent of all students receive special education services.

Overall, 41 percent of the students in the district are white, 22 percent are African American, 22 percent are Asian, 12 percent are Latino, and 2 percent are American Indian. Again, however, these statistics represent the demographics of the district as a whole, not of individual classrooms. For example, two of the fifteen teachers whose students’ work appears in this book have classrooms in which about 50 percent of the students are learning English. In one of these classrooms, 55 percent of the students are Asian, 26 percent are Latino, and 10 percent are African American. The classroom roster of another one of the teachers is 62 percent African American, 22 percent Asian, and 12 percent Latino. One student whose writing is included in this book attends a school in which 73 percent of the students are white, only 6 percent are learning English, and only 13 percent receive free or reduced-price lunch.

In a district with such diversity, the overwhelming challenge in developing the Science Notebooks Program was to create and field-test science and science-writing instructional practices and materials that would enable teachers to help students of all backgrounds and abilities reach their potential. In early 2000, I began conducting science-writing workshops to share the materials and strategies I already had developed. Then, in the fall of that year, I invited teachers who had been attending the workshops and had shown a particular interest in science writing and inquiry-based science to join what later became known as the Lead Science Writing Teachers (LSWT) team.

We needed to form this team for several purposes. First, the science and science-writing programs needed feedback and help from classroom teachers from a variety of schools in order to further develop and refine the programs. The teachers needed support as well. With all the competing instructional requirements, especially the emphasis on reading and mathematics, many teachers did not feel they had much time to teach science. Those who did want to devote quality instruction time to inquiry-based science usually had little collegial support in their schools. The LSWTs began meeting monthly to plan their instruction together, critique student notebook entries using new approaches to assessment, and build bonds with colleagues who shared a common interest and vision.

The LSWTs had another vital role. At this time, I began writing a supplementary writing curriculum for each of the district’s eighteen elemen-
tary science units. Each curriculum gives teachers suggestions for how to integrate science writing in every lesson, blackline masters of appropriate graphic organizers and writing frames for the unit, and samples of student notebook entries with annotations about instruction and assessment. The LSWT team field-tested these curricula, then gave me feedback, including how well the strategies and materials met the needs of different types of students. The LSWTs also provided the samples of student notebook entries for the science-writing curricula. Their feedback and students’ work were invaluable in the development of the Science Notebooks Program. Their work also influenced the ongoing science-writing workshops I provide three times a year for each grade level so that LSWTs and other teachers can learn about specific issues for each of their science units.

The LSWT team had twenty teachers when it began six years ago; it now includes over sixty members. They come from schools with exceptionally high rates of poverty as well as a few with very low rates. Many of them teach students who perform well below the state standards; two teach classrooms of students who test in the top 1 percent of their age group and present other types of instructional challenges. One of the things these teachers have in common is an excitement about teaching science and science writing and seeing the growth in their students’ learning and love of science and science writing.

The best way to communicate this excitement is to share with you some of what they have written over the years in their annual testimonials about how participating in the Science Notebooks Program and the district’s K–5 Inquiry-Based Science Program has affected their teaching and their students’ learning. Sarah Kuney, for example, was teaching first grade in a school in which almost 80 percent of the students received free or reduced-price lunch. In her testimonial, she wrote:

I wouldn’t have a clue of how to teach expository writing without these classes [science-writing workshops]. It has improved my students’ writing tremendously. They are able to explain their higher-level thinking in writing. It has also improved their quantitative and qualitative writing in math, as well as their journal and creative writing.

Paula Schachtel, who at the time was teaching kindergarten in the same school and now is a science-education specialist in the district, wrote the following:

The writing program has raised my standards for what my students are capable of doing. The kids are doing more of their work on their own now, and I’m focusing my instruction on developing their scientific thinking.

Paula helped raise the bar for what kindergartners, including those who enter school not knowing their letters, can accomplish when they have the
right type of support and are focused on developing the content of their writing rather than a product that simply looks good.

Ana Crossman teaches fourth and fifth grade in a school in which almost 50 percent of the students are learning English. In one of her reflections, she remarked:

I think this writing program has greatly improved my students’ writing. It has given me the support to provide my students with consistent, structured lessons in expository writing that both strengthen their scientific understandings and strengthen their expository writing skills. I have many ELL [English Language Learners] students and low-income students, many of whom perform below standards in basic skills, and the science-writing program has helped them come close to or even surpass writing standards.

Diane Eileen and Tim Salcedo loop with their students from third to fourth grade. About 14 percent of their students receive services in special education, and part of their joint testimonial focused on those students:

Students with highly impacted learning disabilities almost always have breakthroughs in science writing first before we see it in other content areas. We believe this is due to the inherent structure of the writing frames that allow students to grow and write on their own later.

Katherine Berg, who teaches fourth grade in a school in which about 91 percent of the students receive free and reduced-price lunch and a significant number of children are homeless, noted the following:

Student ideas and subsequent writing are much more organized as a result of using these thinking and writing frames. They allow all students to participate at some level whether they have two ideas or ten.

One elementary school in Seattle Public Schools supports the teaching and learning of students who score in approximately the top 1 percent on standardized tests. Althea Chow teaches second graders there and offered these thoughts about students who exceed most, if not all, academic standards but still present instructional challenges:

I think that my participation in this writing program has given me important skills and tools for teaching expository writing. As a result, my students’ writing is more organized, thorough, and reflective. I see real growth in their abilities to put their thoughts down on paper with organization and detail in other content areas also.

Kirsten Nesholm, who has been an LSWT since the beginning of the Science Notebooks Program, has taught first and second grades in a school in which about 54 percent of the students receive free or reduced-price lunch...
and 24 percent are learning English. She offers a reflection that is typical of teachers who have been participating in the program for several years or more:

    I never would have thought that I would feel comfortable teaching science. But now I love teaching it, and my kids love science, too.

The excitement and sense of accomplishment reflected in all these testimonials are common among teachers who have participated in the science-writing and inquiry-based science programs. The collective voice of these lead teachers and the specialists who have influenced the development of the programs are the “we” you will encounter throughout this book. The chapters are designed to lead you through what we all have learned in developing the different components of this integrated science-writing approach of the Science Notebooks Program:

Chapter 1
■ overview of the approach
■ research that documents its success

Chapter 2
■ the teaching-learning sequence: when and how to teach science and expository writing in the context of inquiry-based science lessons
■ science notebooks: their content, audience, and physical characteristics

Chapter 3
■ science word banks and graphic organizers that develop and organize student thinking and understanding

Chapter 4
■ simple forms of scientific thinking and writing: observations, cause and effect, and comparisons (includes student notebook entries)
■ development of sentence fluency and independent writing skills

Chapter 5
■ complex forms of scientific thinking and writing: reasoning, data analysis, and conclusions (includes student notebook entries)

Chapter 6
■ assessment of student notebook entries using protocols
■ an approach to providing constructive feedback about notebook entries

Chapter 7
■ a strategy for developing the science writing and questions for a science unit
Chapter 8

- a realistic continuum of implementation: where to start and what to add over time

Appendix A

- blackline masters for graphic organizers and writing frames

Appendix B

- a first grader’s complete science notebook

Appendix C

- resources for inquiry-based science units

Appendix D

- focus and investigative questions for inquiry-based science units
CHAPTER TWO

Using Science Notebooks in Integrating Science and Expository Writing Instruction

To integrate science and expository writing instruction in meaningful and effective ways, you need to balance your students’ science experiences with writing instruction. We have found in years of working with hundreds of elementary teachers in the Science Notebooks Program that one of the greatest challenges to achieving effective integration of the two domains is knowing when and how to focus on science and when and how to focus on expository writing so that the two domains enhance, rather than detract from, each other. We have always used science notebooks as a tool for integrating science and writing. Students use them for recording observation notes and data, providing evidence during discussions, and writing about their higher-level thinking and understanding. But too often, teachers and students became more focused on producing something in the notebooks than in engaging students’ minds in the scientific investigations.

This chapter will help you avoid these problems. It explains solutions we have found for this challenge as well as specific information about the audience, content, and physical characteristics of science notebooks in this integrated science-writing approach.

Scheduling Science and Science-Writing Sessions

When we first started this science-writing program, we expected students to be able to write about their thinking during the science session. But students were not processing their thinking as they wrote. When we included writing instruction so that students could learn to write in more complex ways, students did not have enough time to work with the materials and conduct their investigations. Consequently, the learning of both science and expository writing suffered, and many students resented the writing because it interfered with their experiences in the investigations.
Since then, our teachers routinely schedule two separate sessions, one for science and one for writing. In the primary grades, the teaching-learning sequence of a science session takes from forty-five to fifty minutes; in the intermediate grades, the science session requires from fifty to seventy-five minutes depending on the lesson and time available.

In a separate writing session of about twenty to thirty minutes—in what is actually an integrated literacy block—students revisit their thinking about what they have discovered, then learn how to write in whatever form is appropriate. This writing session occurs later in the day of the science session or sometime the next day. Initially, new teachers in our program are concerned about spending this much time “on science” when their scheduling must accommodate so many competing needs. But those who have allocated their science and science-writing instruction in this way are thrilled with the unanticipated benefits. Students develop strong conceptual understanding of science, scientific thinking, scientific skills, and expository writing skills. Furthermore, they apply these skills in mathematics and other content areas as well as in written responses in reading.

**Science Session: The Teaching-Learning Sequence**

The typical teaching-learning sequence of science instruction shown in Figure 2–1 provides a sequential framework for you to use in understanding and planning when your students should write in their notebooks, what type of written communication they can use at different times during the science session, and what you need to do to support them. (This book is not intended to explain inquiry-based science, but good science instruction—including having students actively engage in learning and using the scientific skills listed in Chapter 1—is critical to effective integration of the teaching and learning of science and writing.) This sequence, which in inquiry-based science often is called a learning cycle, is a way of teaching science that is based on research about how children learn. Teacher’s guides and other publications refer to the phases of this sequence with similar names. In this brief description, the sequence includes four stages of science instruction and learning: engagement, active investigation, shared reflection, and application.

**Stage One: Engagement**

When it is time for science, your students should automatically take out their science notebook and write the day’s date in numerals at the top of the next blank page. (We have found that kindergartners can write the numerals, too, if you model how to do it. Do not worry about how the date looks.) In this first stage of the teaching-learning sequence, you need to engage your students in what they are going to be thinking about and investigating.
using questioning and brainstorming to help them make connections with their prior knowledge or previous investigations.

At an appropriate time during this initial stage, begin to focus the discussion on what your students will be investigating when they work with concrete materials in the second stage, active investigation. As the discussion becomes more focused, either provide a question that directs the students toward what they should be thinking about as they explore with the materials or guide students in writing a question to investigate. These focus or investigative questions are a vital component of both effective science and science-writing experiences because the questions give teachers and students a focal point for their investigation, their thinking, and their talking. (Chapter 7 explains how to develop these questions for a science unit.)

The following are some examples:

- What do you notice about the body of a land snail? (*Animals Two by Two*, a kindergarten unit published by Full Option Science System or FOSS)
- What do platys do when you put a tunnel in the aquarium? (*Animals Two by Two*)
- What are the properties of a good bouncer? (*Balls and Ramps*, a first-grade unit published by Insights)
- What happens to the brightness of a bulb when you change the length of wire in a closed circuit? (*Circuits and Pathways*, a fourth-grade unit published by Insights)
- How does greater water flow affect erosion and deposition in the stream table? (*Land and Water*, a fourth-grade unit published by Science and Technology for Children or STC)

When you introduce or, as a class, create the focus or investigative question, students write it in their notebook. For young students, you can type and copy the question before the science session. Then give students a copy of the question, either on a strip of paper or on an address label, so they easily can glue or attach it below the day’s date in their science notebook. After students have entered the question in their notebook, ask them to circle the key words in the question. Next, lead a class discussion about which words the students think are important and why. For example, in the question above—What are the properties of a good bouncer?—students would discuss the meaning of the words *properties*, *bouncer*, and *good*, as well as the question mark. This process helps students focus on the question, teaches them to read a question carefully, and improves their reading skills. The question then serves as a title for their notebook entry.

In a more complex investigative question for intermediate lessons, students would identify variables. Using the investigative question, How does greater water flow affect erosion and deposition in the stream table? you would want students to identify *water flow*, which is the variable they are going to change or manipulate by making it greater. To determine if changing or manipulating the variable is going to have an effect on *erosion* and *deposition*, students would have to observe and measure these responding variables. Students also would need to note that *stream table* is an important term because it is where the investigation is being conducted, and it is a model of a natural stream system.

After discussing the focus or investigative question during the engagement stage, students may need to do or learn several other things, depending on the lesson. If they are going to conduct a controlled investigation, they need to record a prediction for the question in their science notebook. Before they write their prediction, you need to model how they can provide reasoning for their prediction by using *because*. For example, your modeling of a prediction for the earlier question might be, “I predict that greater water flow will cause more erosion and deposition in the stream table. I think this because __________.”

You also may need to model how to create a table and write observation notes, record quantitative (measured) data, or make a diagram or simple illustration of what students will be observing. Involve students in this process so that you are not telling them what they are going to be observing.
(Chapter 4 explains how to model creating tables, taking notes, drawing scientific illustrations, and making simple diagrams.)

If students need to plan a controlled investigation, they will do so in an extended version of this stage, which, depending on the grade level, might take the entire science session for that day. To help plan all the components of an investigation (for example, creating the question, then determining the variable that they will change or manipulate, the variables that they must keep the same or control, and the variables that they will measure and/or observe), students can use the Planning Your Own Scientific Investigation template shown in Chapter 3 and Appendix A. For class discussions of this planning, make lists of the components on wall charts so students have another scaffolding while discussing the planning as a class (see Figure 2–2).

As explained in Chapter 1, the Science Notebooks Program does not require students to write up their investigation plans in their science notebooks because this is low-level writing that uses up valuable time and energy that we would rather have them invest in developing higher-level thinking and writing skills. However, it is essential to their science education

![Wall chart for planning an investigation](image)

**FIGURE 2–2** Wall chart for planning an investigation
that students know how to plan and conduct investigations, and also learn about the different kinds of variables and how they can affect investigation outcomes. Using the planning template helps students learn these essential elements of an investigation, which will be important as they discuss, analyze, interpret, and write about the investigation outcomes.

**Stage Two: Active Investigation**
In the active investigation stage, your students’ minds are focused on a question as they begin to work with concrete materials to collect some type of data (observations and/or measured data). During this second stage, as students are working with concrete materials, they should do only minimal writing so they are not distracted from the science by the demands of the writing. If they are collecting quantitative (measured) data, they should record their results in their own notebook throughout this stage. If they are recording simple observation notes, they can do that after they have explored with the materials for a while. If they need to make detailed scientific illustrations, they can draw during the middle and end of this stage, depending on the lesson.

While students are investigating, visit the different groups. Facilitate discussion among team members. Ask questions, and if students have misconceptions, ask more questions to help them reflect about their ideas and thinking. Also model scientific thinking and ask students to speak and think like scientists (for example, by using scientific words such as data and evidence, and providing evidence for their claims).

Be sure to allow enough time during this active investigation stage for students to investigate with the materials and to discuss with the members of their investigation team what they are observing and discovering. Often, student misconceptions and inaccurate and/or inadequate content in the notebook writing are due to lack of time and purposeful talking during this stage. At the end of this second stage, students put away the materials and take their science notebooks to the discussion area, as described below.

**Stage Three: Shared Reflection**
We have found that whole-group discussions about science are most productive when students, even in the intermediate grades, leave their desks and sit together in an area that is designated for class discussions. Then they easily can talk in pairs and work together as a large group. They also can see the class data tables, graphs, word bank, and other graphic organizers more clearly as the teacher models and engages students in creating them.

During this reflective-discussion stage, have one set of concrete materials in the discussion area so that students can see the materials while the class reflects about what happened during the investigation and how the observations and data support the explanations the students are beginning to construct. When students are developing new understanding, they need
to make connections with the concrete materials so they can remember their experiences. After more experience, they can look at a visual replication instead, such as an illustration of the materials they have been using. With more experience and knowledge, they can move beyond the concrete materials and a picture, and understand a more abstract representation such as a diagram or a graphic organizer (for example, a flow map or Venn diagram).

This movement from concrete materials to visual representation to abstract organizers and thinking is a crucial element in teaching science and science writing. When students have trouble understanding a new concept, and then writing about it, it often is because they have spent too little time with the concrete materials or moved too quickly from communicating about the concrete experience to understanding that experience in a more generalized or abstract way. For example, in a unit about sound, students know from their experiences during their investigation that when they struck a short nail it made a high pitch. But they will not understand until they have had more concrete experiences that the shorter the nail is, the higher the pitch it will make. They also have not had enough experience to understand the more abstract principle: length affects both the pitch and vibration of objects. So, when students first talk and write about their experiences, they need to begin by describing what they actually have observed and experienced. Then, as they have more concrete experiences, they will be able to construct ideas and write about more abstract principles.

During this shared reflection stage, guide students by asking questions about their observations and data and how these help form answers to the question they have been investigating. Be sure to ask about data that are inconsistent with other test results as well as whether the data support the predictions they wrote before the investigation.

Also periodically, ask students to turn to the person next to them and talk about their thinking. All students—not just those who participate in whole-class discussions—need opportunities to talk about their thinking and to use scientific language. This, in turn, will help them develop scientific language skills they can use in their writing. (The role of this scientific discourse in developing science knowledge and scientific skills as well as writing skills is critical, but it is not the subject of this book.)

Sometime during this reflective discussion, you also can do the following:

- Add new words to the science word bank as students have a need to know them. Especially with English language learners, ask students to repeat words out loud with you as they see them. Hearing and seeing the words at the same time will help everyone learn the vocabulary.
- Repeat important words and language multiple times.
- Expect students to answer questions in complete sentences. This will improve both their oral and written expression.
Model the scientific language and thinking the students need to learn. For example, when students make claims, ask them what evidence they have to support their statements. Model how to use the frame “I think ______ . I think this because ______ .” (“I think thin wire has more resistance than thick wire. I think this because when we used thin wire, the bulb was dimmer. When we used thick wire, the bulb was brighter.”)

Model how to construct class data tables and graphs, involving students in the process.

Create graphic organizers if necessary (such as tables, T-charts, systems-parts maps, and flow maps) to represent what students have been learning.

Chapters 3, 4, and 5 explain in greater detail when and how you introduce and model these components of the science and writing instruction.

By the end of this third stage, the reflective discussion, students usually have developed an understanding of the answer to the focus or investigative question. They also may have unresolved questions about the results of their investigations and additional questions to investigate.

**Stage Four: Application**
In the last stage of the teaching-learning sequence, guide students in thinking about how the information might apply to the real world or lead into another investigation or research through the Internet or books. Students might refer to their notebooks at this point to give them some ideas during the discussion, but they do not write during this last stage of the teaching-learning sequence of the science session.

In the Science Notebooks Program, we highly value the thinking and planning in which students engage during this stage. But, as mentioned in Chapter 1, because elementary school students have a restricted amount of time and energy to devote to science writing, we focus their writing on the thinking involved in the investigation they have conducted and discussed in the first three stages. They will not write in their notebooks again until they engage in a separate shared-writing minilesson and independent writing session, which is explained in the next section.

**Science-Writing Session: Shared-Writing Minilesson and Independent Writing**
This separate twenty- to thirty-minute writing session includes a review of the science session that preceded it, a minilesson about writing various forms of expository and scientific text, and independent writing time during which students make entries in their notebooks. You will need to schedule this block later in the day of the science lesson or some time the next day. If you wait longer than this, you will lose needed momentum in both the science and writing instruction.
**Step One: Shared Review**
You can begin this writing session (see Figure 2–3) by involving your students in a review of what they had concluded at the end of the shared reflection stage of the science session. Bring one set of concrete materials to the discussion area to help students remember what they have experienced. As the class reviews the end of the earlier discussion, do not provide a summary of the reflective discussion. Instead, ask questions, including the focus or investigative question, so that students are actively involved in the brief discussion.

**Step Two: Shared Writing**
After the shared review, explain to students that you are going to help them learn how to write in a certain way to communicate what they have learned. Then involve them in a shared-writing experience or minilesson in which you model writing certain phrases or writing structures—in other words, the structure of the writing—and students then contribute their observations, evidence, and thinking that constitutes the content of the writing. (Chapters 4 and 5 explain this process for different types of scientific writing.) The following example of a shared-writing minilesson can serve as an introduction to this process.

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<table>
<thead>
<tr>
<th>Writing Session: Shared-Writing Minilesson and Independent Writing</th>
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<tbody>
<tr>
<td><strong>Steps</strong></td>
</tr>
<tr>
<td>Teacher</td>
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<tr>
<td>Students</td>
</tr>
</tbody>
</table>

**FIGURE 2–3** Science-writing session
In *Circuits and Pathways*, a unit published by Insights, fourth graders investigate this question: What happens to the brightness of a bulb when you change the length of wire in a closed circuit? You can begin the shared writing by modeling a strategy for writing a conclusion to an investigative question, starting with a topic or opening sentence. First, discuss a general answer to the question. Students probably will say, “The brightness of the bulb changes.” Then tell them that one way to begin a response is to use words from the question. If this is their first experience with this strategy, write a topic sentence on the overhead or board: “When you change the length of wire in a closed circuit, the brightness of the bulb changes.” If students have used this strategy, you would ask for several examples rather than writing your own.

Next, tell students that they need to support this opening statement by providing evidence from their investigation (in other words, from their data tables or the class data table or graph). Write the words *For example*, and say that these words can introduce the supporting evidence or data. Teach them that when they provide evidence in a conclusion, they usually can *summarize* the evidence by providing data just from the lower or lowest and higher or highest ends of the range of data (not including outliers, or data that are inconsistent with the rest of the class data).

Now ask students to tell you the data from the lower or lowest end of the range shown in the class table or graph. Add the data to what you already have modeled: “For example, with 10 cm wire, the bulb brightness was 9.” Before students provide the data from the other end of the range, model using a contrasting word such as *but* or *whereas* and add *only* to set up a contrast of the results: “But with the 30 cm wire, the bulb brightness was only 7.”

Point out that they now have provided enough evidence to make a concluding statement, then model using *therefore* as one way to begin that statement. Finally, ask students to state their conclusion based on the data and add their words to yours: “Therefore, the longest wire makes the bulb dimmer and the shortest wire makes the bulb brighter.”

If students have had enough experience with conducting controlled investigations with concrete materials and can recognize a cause-effect relationship between the length of wire and the brightness of a bulb, then ask them to write an inference about what is causing this difference. To model more structure, give them the phrase, “I think this is because.” Students then might state something like, “I think this is because the longest wire has more resistance so the bulb is dimmer. The shortest wire has less resistance so the bulb shines more brightly.”

**Step Three: Scaffolding**

Before students begin writing in their own science notebooks, remove the shared writing from the overhead or board. Replace it with just the
scaffolding you have modeled during the shared writing. In the Circuits minilesson, the scaffolding is:

- Words from the question (topic sentence)
- “For example,” (introduce data)
- “But” (introduce data from the other end of the range of data)
- “Therefore,” (introduce concluding statement)
- “I think this because” (introduce inferential thinking)

**Step Four: Independent Writing**

Using the scaffolding (if they need to), students write a conclusion to their investigations in their notebooks. The scaffolding prompts them to include the components of a conclusion and also introduces them to a text structure that can help them write a conclusion.

This structured approach to teaching different forms of scientific writing works well with most students. Those who are learning English or have less developed language or writing skills benefit from having the scaffolding because it helps them learn the writing skills as well as how to think and write scientifically. Those with more advanced language skills benefit because they need to learn to write scientifically. And those who have highly developed language skills and rich background knowledge benefit from having to focus first on their evidence before leaping into their inferential thinking, which may or may not be accurate.

When students have learned how to provide evidence for their thinking, they do not need to use any scaffolding. Nor do they need to provide the evidence before their inferences unless, by explaining their inferential thinking first, they forget to write about their observations and measured data that substantiate their claims. Students do, however, need to include all these components, and often others as well, in their conclusions. Regardless of which text structures students are learning, be sure to ask them regularly, “What is another way we could write this?” Doing so will help students realize that the structure of any writing frame is not the only way to produce strong writing. It is only a place to begin. (See Chapters 4 and 5 for more information about shared-writing minilessons, specific forms of scientific writing, and ways to help students write fluently and independently.)

**Audience for Science Notebook Entries**

Throughout the years of the Science Notebooks Program, one of the most frequent feedback responses from the hundreds of teachers who have participated in the program addresses the issue of audience. With whom are the students communicating when they write their entries? The most common answer is the classroom teacher. But if a teacher is the audience, then students tend to try to do what they think will please their teacher. Students also assume then that the audience knows what students have done and
discussed. This does not help students learn to write to an audience outside the classroom, which is an important writing skill. Furthermore, the standards for the notebook entries are often seen as those of the teacher.

What has worked extremely well in our program is to establish that other scientists are the audience. The standards of communication, therefore, are those of science. So, for example, when a student provides minimal information in an observation, you could ask, “What do you think another scientist would need to know if she or he were trying to understand more about what you observed?” Or say a student provides no evidence or only partial evidence for a claim. You might ask, “What do you think another scientist would need to know in order for you to convince him or her that your conclusion is reasonable?” After such queries, students can add information or reasoning to their entries.

Especially because we are thinking of students as young scientists who are communicating with adult scientists, talk with students about “making entries in their science notebooks.” Many science programs refer to this process as “notebooking.” But if we want students to think and act like scientists, we need to use appropriate language. Presumably, adult scientists do not say they are “notebooking” any more than they refer to their work as “sciencing.”

Content of Science Notebooks in the Elementary Grades

Science programs vary in what they expect students to include in their science notebooks. To determine the content, you first have to determine your purpose in having students write in notebooks. As explained in Chapter 1, Seattle’s Science Notebooks Program sees the notebooks as a means of teaching students to think scientifically and to learn expository writing structures that help them develop and communicate their scientific thinking and understanding. The program also advocates that teachers use the notebooks for formative rather than summative assessment and that they not score the notebooks. (Chapter 6 explains the rationale and research for this approach, how to assess the notebooks for formative assessment purposes, and how to communicate with students about their notebook entries.)

If you share this belief in the purpose of elementary science notebooks, then when you are deciding what type of entries students should make in their notebooks— in other words, the content of their notebooks—consider this fundamental question: How will writing these notebook entries help develop the students’ understanding of the science concepts and/or scientific skills and thinking? Their writing experience should focus their attention and energy on learning to write about their observations and test results, as well as explain their thinking and conceptual understanding. The process of learning how to write, and then writing independently, in these ways actually will help students develop their scientific understanding and their thinking and scientific skills.
With this in mind, avoid having children write about how they felt about doing the investigation, what their favorite object or organism or lesson was, what they learned (as prompted by the generic question, What did you learn today?), and what they did. None of these prompts will encourage most students to think and write scientifically. For example, writing about materials and how they set up and conducted an investigation—in other words, what they did—will not help students develop understanding of scientific content. As noted earlier in this chapter, students should thoroughly discuss and write notes on a class or group chart about how they are going to set up and conduct an investigation because planning an investigation is an important scientific skill. But students do not need to write about all the components of an investigation. Elementary students are better served by concentrating on learning higher-level writing and thinking skills.

Many science-writing programs set up lists of requirements for the content of each notebook entry, which often are tied to a rubric system for assessing notebook entries. Because the Science Notebooks Program has a different emphasis and also does not promote using a rubric system for scoring elementary science notebooks, the content of each entry varies. What students write depends on what they need to be thinking about, as well as what kinds of writing they need to be learning in order to communicate that thinking. (Chapter 7 explains how to plan the writing for a science unit, including when to have students learn the different forms of scientific writing.) The only generic notebook requirements are that students should do the following:

1. Date, in numerals, the first page of the entry.
2. Write a focus or investigative question for each lesson.
3. Write something about each science session.
4. Write legibly (not necessarily their “best handwriting”).

In this integrated science-writing approach, notebook entries are considered rough drafts. The writing process generally has four stages: prewriting, rough draft, editing or revision, and publishing. In the prewriting stage of a science notebook entry, students engage in discussions and create organizers (for example, class tables, T-charts, and graphs) to help them think about and organize what they will write (as explained in Chapters 4 and 5). They also participate in a shared-writing minilesson and independent writing session (as explained earlier in this chapter). In the rough draft phase of writing, students focus on the following three traits:

1. **content**, which addresses scientific content or conceptual understanding;
2. **organization**, which includes scientific thinking and the structure of different types of scientific writing (for example, observations, comparisons, and conclusions); and
3. **word choice**, which includes accurate use of scientific vocabulary.
If teachers or students choose to take an entry through the entire writing process—publishing an entry as a scientific article, for example—then students edit and revise the entry in terms of three other writing traits: sentence fluency (the flow of the language and variety of sentence structures), voice (a sense of scientific authority that a student expresses through the writing), and conventions (spelling, punctuation, and grammar). The point here is not that these last three traits are unimportant. However, at certain stages in the writing, and thinking, process, we need to focus students’ attention on certain traits. This also helps many reluctant writers learn to enjoy writing because they are so engaged in scientific work and thinking that is meaningful to them.

Neatness, handwriting, and presentation also would be important in a published piece. In a rough draft, however, the writing needs only to be legible to other readers. For example, if you teach students in the intermediate grades, allow them to choose whether they want to print or write their entries in cursive so they are not restricted by the handwriting itself.

Teachers in our science-writing program, especially in the primary grades, have difficulty letting go of the idea that the notebooks should be a product that looks good. However, as teachers learn to focus on developing students’ scientific thinking and teaching expository text structures that communicate higher-level science understanding, they change their assessment focus and concentrate on the content of the writing. (Chapter 6 includes information about how to assess student notebook entries through this lens.)

Physical Characteristics of Science Notebooks

What you choose to use for science notebooks is going to depend on the resources you have in your school or district. But here are some guidelines based on what we have tested and found to be most effective.

Size
Notebooks that are eight and one-half by eleven inches provide the best space. For example, when students need to compare two organisms, the larger paper allows them to draw and write an observation on a left-hand page, then draw and write about the other organism on the facing right-hand page. Having the illustrations on facing pages makes it easier for students to set up a comparison of the two (as explained in Chapter 4).

Students also can write more effectively about data when a table or graph is on a left-hand page and students write their analysis on the facing right-hand page (see Chapter 5 for writing about data). Keeping ongoing records of observations—of a plant, for instance—often requires using a table that is eleven by seventeen inches. This, too, enables students to see in one place the data they have collected over time (as explained in Chapter 25).
4). Students tape such a table to a notebook page before folding the table into the notebook, so the notebook has to be eleven inches on the side.

**Lined Pages**

Except for kindergartners, who use unlined pages, students need to write on lined notebook pages. Some teachers in primary grades like to have paper that is partly unlined and partly lined. In our experience, these types of pages restrict both the quality and quantity of the student writing. So does paper that is designed for handwriting instruction. Students should not be worrying about their handwriting when they are making thoughtful entries in their notebooks. The requirement is that notebook entries are legible. Consequently, teachers do not mention handwriting in discussing or assessing the notebooks unless a student is careless and has written illegible text.

**Binding**

The notebook pages should be bound in some way rather than loose because the science notebook represents an ongoing record of a student’s observations, data, thinking, and developing understanding. Sewn bindings work best, but spiral-bound notebooks work well, too, because they keep the pages organized and intact, and are sturdy enough to survive rough treatment.

**Science “Notebooks”**

We refer to these notebooks as *science notebooks* to distinguish them, in both teachers’ and students’ minds, from journals or logs. *Journals* often are associated with process writing and writing workshops in which students choose what they want to write and approach their writing in a particular way. *Science logs* tend to be ongoing records of the process of science, including questions, hypotheses, materials, procedures, and claims based on test results.

Using *science notebooks* in this science-writing program integrates the processes of learning how to think and write about science. Students do not choose, as they do with writing journals, the subject of an entry, and they learn disciplined forms of scientific writing through highly structured instruction. In addition, students do not record every aspect of their investigations in their notebooks, as they would in science logs, so that other scientists can replicate their experiments. Instead, these notebooks are meant to serve a different purpose: to focus student thinking and writing on targeted components of scientific investigations and scientific thinking in order to maximize the learning of scientific concepts, skills, thinking, and writing.
Important Points to Remember

1. Plan to have a science session and a science-writing session for each lesson in your science unit.
2. Model scientific skills, thinking, and language orally and in writing.
3. Help students recognize what an audience of adult scientists would expect and need to see in science notebook entries.
4. Understand that science notebooks are rough drafts, so students should focus on the following when they are writing their entries:
   ■ Content (science concepts and thinking)
   ■ Organization (scientific thinking and skills)
   ■ Word choice (scientific vocabulary and clarity of word use)
   ■ Legibility (readable; not necessarily good handwriting)
Appendix A  Blackline Masters for Graphic Organizers and Writing Frames

A–1  Teaching and Learning of Science and Scientific Writing
A–2  Science Session: The Teaching-Learning Sequence and Students’ Use of Science Notebooks
A–3  Writing Session: Shared-Writing Minilesson and Independent Writing
A–4  Planning Your Own Scientific Investigation
A–5  Observations
A–6  Compare and Contrast
A–7  Useful Words and Phrases in Scientific Writing
A–8  Components of a Scientific Conclusion
A–9  Data Analysis
A–10 Criteria for Exemplary Science Notebook Entries
A–11 Assessing Student Work and Planning Instruction
A–12 Science-Writing Reflection Groups: Protocol for Instructional Planning Meetings
A–13 Science-Writing Reflection Groups: Protocol for Assessing Notebook Entries
A–14 Notes About Lessons Learned
A–15 Planning for Lessons About Prior Knowledge, Initial Observations, and Comparisons
A–16 Planning for Lessons About More Focused or Ongoing Observations and Investigations
A–17 Planning for Lessons About Applications and Connections to the Real World
### Teaching and Learning of Science and Scientific Writing

#### Science Session

*Through inquiry, students learn:*

- science content—concepts and principles, or “big ideas”
- scientific thinking—critical reasoning, problem solving
- scientific skills—for example, observing, conducting investigations, using data

**Science notebooks:**

- used for observation notes, illustrations, data
- provide evidence for discussions

**Scaffolding:**

- scientific inquiry
- word banks
- graphic organizers

#### Science-Writing Session

*Using their science experiences and understanding as the content of their writing, students learn different forms of scientific writing, including:*

- observations
- cause and effect
- comparisons
- reasoning
- data analysis
- conclusions

**Science notebooks:**

- used for writing that communicates higher levels of scientific thinking and conceptual understanding

**Scaffolding:**

- word banks
- graphic organizers
- writing frames

## Science Session: The Teaching-Learning Sequence and Students’ Use of Science Notebooks

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<tbody>
<tr>
<td>Teacher</td>
<td>Models making tables, notes, data entries, illustrations, diagrams.</td>
<td>Works with groups: ■ asks questions ■ models language, thinking ■ addresses misconceptions.</td>
<td>Models making tables, graphs of class data, graphic organizers. Introduces new words to word bank. Models language, thinking.</td>
<td>Leads discussion to connect lesson with real world or further investigations.</td>
</tr>
<tr>
<td>Students</td>
<td>Write: ■ date ■ focus or investigative question ■ prediction with reasoning ■ table.</td>
<td>Record data. Take notes. Make illustrations, diagrams.</td>
<td>Use notebooks to provide data for class results, evidence for own reasoning, explanations, conclusions.</td>
<td>May use notebooks to provide ideas, questions.</td>
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<tbody>
<tr>
<td>Teacher</td>
<td>Questions students about shared reflection of conclusions from previous science session.</td>
<td>Models structure of specific writing form (e.g., comparison, conclusion).</td>
<td>Writes scaffolding for notebook entry (e.g., sentence starters, phrases, words).</td>
<td>Works with small groups or individuals who need extra support or more challenges. Asks questions, models language, rereads writing with students.</td>
</tr>
<tr>
<td>Students</td>
<td>Provide reflections, explanations.</td>
<td>Provide content of the writing.</td>
<td></td>
<td>Use scaffolding as they write their own notebook entries.</td>
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</tbody>
</table>
Planning Your Own Scientific Investigation

Use this form when you want to design and conduct your own investigation of a question that you and your group want to explore.

**Investigative question** (the question you want to investigate). Include both the changed (manipulated) variable and the measured/observed (responding) variable.

**Prediction, including your reasoning.** (You might write, I predict ____________ because ____________.) Include the variable you will change and what you will measure/observe.

**Procedure**

<table>
<thead>
<tr>
<th>List the one changed (manipulated) variable:</th>
<th>List the most important logical steps; include all the different variables and their amounts:</th>
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<table>
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<tr>
<th>List the variables you will keep the same or constant (controlled variables):</th>
<th>List the most important materials:</th>
</tr>
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</table>

<table>
<thead>
<tr>
<th>List the variable you will measure and/or observe (measured/observed or responding variable):</th>
<th>How often and/or how many times will you measure and/or observe it?</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Make a table for recording the data.</td>
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<tr>
<td></td>
<td>Repeat the tests/procedure at least 3 times.</td>
</tr>
</tbody>
</table>

After you have completed the investigation and talked with your group about the results, write a conclusion. Answer the question that you have been investigating, providing the data (results of your investigation) as evidence of your thinking. Also write about whether or not the results of the investigation support your prediction. If necessary, you might also explain what you think caused inconclusive or inconsistent data in your results (consider the variables in your tests).
Observations

Think of the four senses (not taste).
Size, shape, color, lines, patterns, texture, weight, smell/odor, sound, behavior . . .

I observed ______ .
I noticed ______ .

Connect it with what you know or have investigated.
It reminds me of ______ because ______ .

Observe and record cause and effect.
When ______ , it ______ .

Note any changes.
At first, ______ . But now ______ .

Be curious, and ask questions you might investigate.
I am curious about ______ .
It surprised me that ______ because ______ .
I wonder what would happen if ______ .
How does ______ affect ______ ?
Compare and Contrast

Start with how things are the same or similar. The _____ and the _____ are similar because they both _____ . In addition, they _____ .

Add more as needed. . . .

Explain how they are different. You can compare the same property or characteristic in the same sentence. Use and, but, or whereas to set up the contrast. They are different because the _____ , but the _____ . Also, the _____ , whereas _____ .

Add more as needed. . . .

Remember to ask, “Will it be clear to the reader what I mean when I use pronouns such as they and it? If not, how can I edit the sentence to make it clearer?”

### Useful Words and Phrases in Scientific Writing

<table>
<thead>
<tr>
<th>Questions</th>
<th>Observations</th>
<th>Contrasts</th>
<th>Sequence of Time, Cause and Effect, Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>What would happen if</td>
<td>I observed</td>
<td>____________, but ____________ .</td>
<td>First, ____________, Next, ____________,</td>
</tr>
<tr>
<td>_______________ ?</td>
<td>I noticed</td>
<td>____________, whereas ____________ .</td>
<td>Then, ____________, Finally, ____________,</td>
</tr>
<tr>
<td>How does [the changed</td>
<td>When ____________,</td>
<td>However,</td>
<td>If ____________, then ____________, So,</td>
</tr>
<tr>
<td>variable] affect [the</td>
<td>After ____________,</td>
<td>In contrast,</td>
<td>This leads to</td>
</tr>
<tr>
<td>measured, observed,</td>
<td></td>
<td>At first, ____________, But now, ____________</td>
<td>As a result,</td>
</tr>
<tr>
<td>responding variable]?</td>
<td></td>
<td></td>
<td>Consequently,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evidence</td>
<td>Reasoning</td>
<td>Adding Information, Evidence, Reasoning</td>
<td>Conclusions</td>
</tr>
<tr>
<td>____________ because</td>
<td>____________ because</td>
<td>Also,</td>
<td>Therefore, I think</td>
</tr>
<tr>
<td>____________ .</td>
<td>____________</td>
<td>In addition,</td>
<td>In conclusion, I think</td>
</tr>
<tr>
<td>For example,</td>
<td>I think this because</td>
<td>Furthermore,</td>
<td>Therefore,</td>
</tr>
<tr>
<td>For instance,</td>
<td>____________</td>
<td></td>
<td>In conclusion,</td>
</tr>
<tr>
<td>The evidence is</td>
<td>I think this means</td>
<td></td>
<td></td>
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<tr>
<td>The data show</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>The data provide evidence</td>
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</tr>
</tbody>
</table>

**Note to teachers:** Students can become too dependent on sentence starters and writing frames that teachers provide. To support students in becoming more independent writers, you can post a chart like this in the classroom, adding words and phrases as needed. Also teach students to use words from questions as appropriate in beginning their responses.

Components of a Scientific Conclusion

■ **Answer the investigative question in a general way**, using the words from the question in your answer if possible: What happens to the brightness of a bulb when you change the length of wire in a closed circuit? “When I change the length of wire in a closed circuit, the brightness of the bulb changes.”

■ **Provide evidence from your observations or tests. Include:**

  Qualitative data (for example, more/less; longer/shorter; brighter/dimmer): “The bulb was brighter with shorter wire and dimmer with longer wire.”

  Quantitative data (measured data): “For example, with 10 cm wire, the bulb brightness was 9. But with the 30 cm wire, the brightness was only 7.”

■ **Make a concluding statement(s) that is based on the evidence:**

  “Therefore, the shortest wire makes the bulb the brightest and the longest wire makes the bulb the dimmest.”

■ **Refer to your prediction.** Did your data support it? If they did not, how has your thinking changed? “The data did not support my prediction because I thought that the bulbs would have the same brightness. I didn’t think the length of the wire would make any difference. Now I know that the length does have an effect.”

■ **Make an inference about what you think caused these test results:** “I think this happens because longer wire has more resistance than shorter wire.”

■ **If you had data that were different from what other groups had, what do you think could have caused these results?** “I think my group got different results because we used a different type of wire than the others did. We should have kept that variable the same as everyone else.”

■ **What other questions do you have now that you want to investigate?** “What would happen if we used wires of different thicknesses?”

Data Analysis

**Start with a topic sentence** to say what the graph / table is about (as shown in the main title and the title for each axis/row or column).

**Summarize the data.** (Write about the important points in the graph or table; do not write about all the data.)

- **Qualitative data** (e.g., more/fewer; increase/decrease)
  - The larger wheels go farther than the smaller wheels do.
  - The distance increases as the wheels get larger.
  - For example, the 4.5 cm wheels went 145 cm, whereas the 11 cm wheels went 276 cm.

- **Specific quantitative data** (e.g., actual numbers, percentages)
  - Give examples from the greatest and least; do not include all the data in between.

**End with a conclusion** that answers the question you were investigating (investigative question). Include:

- The main inferences made from the data.
- Whether the data support your prediction and if your thinking has changed.

You may also need to include:

- **Outliers and inconsistent or inconclusive data** and what you think might have caused them (e.g., variables in the testing).
- How this information might be important in the real world.

Therefore, I think ______ .

The data ______ . My thinking ______ .

Some data were inconsistent. I think this happened because ______ .

This information could be important ______ because ______ .
## Criteria for Exemplary Science Notebook Entries

<table>
<thead>
<tr>
<th>Conceptual Understanding</th>
<th>Scientific Skills and Thinking</th>
<th>Expository Writing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Understanding of “big ideas” of unit</strong>&lt;br&gt;Demonstrates, through words and graphics, an accurate and quite full grasp of the major science concepts that were introduced&lt;br&gt;May demonstrate one or more of the following:&lt;br&gt;• Appropriately/accurately applies previous learning to new concepts and skills&lt;br&gt;• Extends the new concept or skill to new problems or new phenomena</td>
<td><strong>Use of scientific inquiry skills</strong>&lt;br&gt;Thorough and purposeful use of skills to advance learning. For example:&lt;br&gt;• Makes accurate and full observations, with complete records&lt;br&gt;• Collects and records data accurately, completely, and honestly&lt;br&gt;• Examines data and identifies results (for example, by comparing different data points)&lt;br&gt;• Shows understanding of fair tests or controlled investigations&lt;br&gt;<strong>Use of evidence to support explanations</strong>&lt;br&gt;Demonstrates understanding of relationship between data and explanation:&lt;br&gt;• Supports explanations with appropriate data&lt;br&gt;<strong>Use of critical thinking skills to draw inferences</strong>&lt;br&gt;Demonstrates understanding of relationships between data and inference:&lt;br&gt;• Draws reasonable inferences from data; supports inferences with reasoning</td>
<td><strong>Idea/content (development)</strong>&lt;br&gt;Has control of content:&lt;br&gt;• States information or idea clearly&lt;br&gt;• Develops information or idea fully with relevant details, evidence, and explanation&lt;br&gt;<strong>Organization (sequence)</strong>&lt;br&gt;• Uses different text structures to organize ideas/information effectively&lt;br&gt;• Logically sequences or groups details&lt;br&gt;• Uses appropriate transition words to show logical connections&lt;br&gt;<strong>Word choice</strong>&lt;br&gt;• Uses scientific vocabulary accurately&lt;br&gt;• Uses nonscientific vocabulary effectively to clarify and explain&lt;br&gt;These traits may be apparent:&lt;br&gt;<strong>Voice (authority)</strong>&lt;br&gt;• Has an engaged voice that shows confidence with scientific stance&lt;br&gt;• May include self-reflection&lt;br&gt;<strong>Sentence fluency (sentence structure and variety)</strong>&lt;br&gt;• Can use multiple types of clauses and structures to clarify and develop ideas</td>
</tr>
</tbody>
</table>


Assessing Student Work and Planning Instruction

1. Look briefly at each entry prior to the one you are assessing to give you a general idea of the quality of the student’s entries.
2. Before assessing the selected entry, think about the:
   - science concept(s)/ “big idea(s)” of the lesson/investigation and how it (they) related to the development of concepts in the unit;
   - scientific skills and thinking that may be involved in the lesson/investigation;
   - important structures and language in the expository writing;
   - question(s) to which the student may be responding in the entry.
3. Follow the Criteria for Exemplary Science Notebook Entries chart as you assess the entry.
   - Skim the entry. Then reread it carefully, considering each of these criteria. (Do not consider other criteria.)
   - Note strengths of each component first, then weaknesses. Determine further instruction for student or class.
   - Write constructive feedback on a sticky note and place it on the entry.

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
<th>Further Instruction</th>
</tr>
</thead>
</table>

Science-Writing Reflection Groups
Protocol for Instructional Planning Meetings

The facilitator’s role is to ensure that the protocol is followed.

For each lesson you are planning:

1. Reflect about the “big ideas”/concepts of the lesson and how they relate to the development of concepts throughout the unit.
2. Consider the scientific skills and thinking that may be involved in the investigation.
3. Think about the expository writing skills students will need in order to communicate their understanding and thinking in the lesson.
4. Consider the lesson’s focus/investigative question(s) and/or the reflective question(s) to which the students may be responding in the entry.
5. Discuss the challenges students could face in terms of points 1 through 4.
6. Determine what the teacher will need to model before the lesson and/or the writing.

At the end of the meeting, plan what student work each teacher will bring to the next meeting.

Unit Title ____________________________________________ Date _______________

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Notes</th>
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<table>
<thead>
<tr>
<th>Lesson</th>
<th>Notes</th>
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</table>

Science-Writing Reflection Groups
Protocol for Assessing Notebook Entries

The facilitator's role is to ensure that the protocol is followed.

1. Consider the specific concepts, scientific skills and thinking, and expository writing that pertain to
   the selected lesson and entry.
2. Briefly go over the Criteria for Exemplary Science Notebook Entries chart, which presents the gen-
   eral standards we expect students to meet in the notebook entries. Discuss the criteria in terms of
   the entry you will be assessing.
3. Silently, and fairly quickly, read through the first student sample without looking for anything in
   particular.
   ■ The teacher who provides the sample should not explain anything about the student or the
     entry.
4. Read the entry again, focusing on only the strengths in terms of the criteria.
5. Discuss the strengths of the sample:
   ■ Do not mention any weaknesses.
   ■ Do not discuss any other criteria (e.g., neatness, conventions—spelling, punctuation,
     grammar).
   ■ List the strengths on the Assessing Student Work and Planning Instruction form. All teachers
     can do this, or one teacher can volunteer to record these notes for the teacher whose student’s
     entry is being assessed.
6. Discuss the weaknesses of the sample in terms of the criteria.
   ■ List the weaknesses on the assessment form.
7. Discuss and plan further instruction and feedback that could build on the strengths and improve
   the weaknesses.
   ■ Make notes on the form regarding further instruction.
8. Give a completed form to the teacher whose student’s entry was assessed.

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## Notes About Lessons Learned

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>Date</th>
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</table>

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Notes—Lessons Learned About Content, Pedagogy, Writing, Modeling, etc.</th>
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</thead>
</table>

## Planning for Lessons About Prior Knowledge, Initial Observations, and Comparisons

<table>
<thead>
<tr>
<th>Focus of Lesson</th>
<th>Focus or Investigative Question Stems</th>
<th>Graphic Organizers*</th>
<th>Writing Forms or Frames*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>* ( ) indicate chapters</td>
<td>* ( ) indicate chapters</td>
<td></td>
</tr>
<tr>
<td>Accessing prior knowledge</td>
<td>What do you think you know about ______?</td>
<td>Observations organizer (3, 4, Appendix A)</td>
<td>Illustrations, diagrams (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Table (3, 4)</td>
<td>Notetaking (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>System-parts map (3)</td>
<td>Table, map as organizer (3, 4)</td>
</tr>
<tr>
<td></td>
<td>What do your senses tell you about ______?</td>
<td>I observed ______.</td>
<td>I observed ______.</td>
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<tr>
<td></td>
<td></td>
<td>I noticed ______.</td>
<td>I noticed ______.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Also, ______.</td>
<td>Also, ______.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In addition, ______.</td>
<td>In addition, ______.</td>
</tr>
<tr>
<td></td>
<td>What do you observe happening when ______?</td>
<td>Cause/effect:</td>
<td>Cause/effect:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>When I ______, then ______.</td>
<td>When I ______, then ______.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>After ______, then ______.</td>
<td>After ______, then ______.</td>
</tr>
<tr>
<td>Initial observations</td>
<td>What can you observe about ______?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>What do your senses tell you about ______?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>What do you observe happening when ______?</td>
<td></td>
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<tr>
<td></td>
<td>How can we measure ______?</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>What are some properties/characteristics of ______?</td>
<td></td>
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</tr>
<tr>
<td>Compare/contrast</td>
<td>How are ______ and ______ the same (similar) and different?</td>
<td>Box and T-chart (4)</td>
<td>Compare and Contrast frame (4, Appendix A)</td>
</tr>
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</table>
## Planning for Lessons About More Focused or Ongoing Observations and Investigations

<table>
<thead>
<tr>
<th>Focus of Lesson</th>
<th>Focus or Investigative Question Stems</th>
<th>Graphic Organizers*</th>
<th>Writing Forms or Frames*</th>
</tr>
</thead>
<tbody>
<tr>
<td>More focused or ongoing observations</td>
<td>What differences do you observe? How has _____ changed over time? How has _____ changed since _____? What properties affect _____? What roles do the _____ play in the system? What do you think would happen to the system if you _____?</td>
<td>Table (3, 4) T-chart (3, 4, 5)</td>
<td>Illustrations, diagrams (4) Notetaking (4) Table as organizer (4) Use words from question to begin response (4, 5) I noticed _____ I observed _____ In addition, _____ When I _____, then _____ After _____, then _____ At first, _____ But now _____ In the beginning, _____ Now, _____ days later, _____ The evidence is _____ Data Analysis frame (5, Appendix A) Components of a Scientific Conclusion list (5, Appendix A) Useful Words and Phrases (4, Appendix A)</td>
</tr>
<tr>
<td>Controlled investigation</td>
<td>What should you consider in planning your investigation about _____? What do you predict will happen and why? What would happen if _____? How does _____ affect _____? What story does the graph tell?</td>
<td>Planning Your Own Scientific Investigation template (3, Appendix A) Data Analysis frame (5, Appendix A)</td>
<td></td>
</tr>
</tbody>
</table>

## Planning for Lessons About Applications and Connections to the Real World

<table>
<thead>
<tr>
<th>Focus of Lesson</th>
<th>Focus or Investigative Question Stems</th>
<th>Graphic Organizers*</th>
<th>Writing Forms or Frames*</th>
</tr>
</thead>
</table>
| Application    | Can you make [something in particular happen]?
|                | What can you do to make [something in particular happen]?
|                | To [make this happen], I ______.
|                | I think this worked because ______.
| Connections to real world | How is our model similar and different from ______? |
|                | How can what we have learned about ______ help us ______? |
|                | Box and T-chart (4)
|                | T-chart (4)
|                | Compare and Contrast frame (4, Appendix A)
|                | We learned ______.
|                | This can help us when ______.
|                | Useful Words and Phrases (4, Appendix A)

* ( ) indicate chapters