

Science Notebooks in Middle School



Source: Special Collections Research Center, University of Chicago Library

A scientist's notebook

A student's notebook

INTRODUCTION

Scientists keep notebooks. The scientist's notebook is a detailed record of his or her engagement with scientific phenomena. It is a personal representation of experiences, observations, and thinking—an integral part of the process of doing scientific work. A scientist's notebook is a continuously updated history of the development of scientific knowledge and reasoning. The notebook organizes the huge body of knowledge and makes it easier for a scientist to work. As developing scientists, FOSS students are encouraged to incorporate notebooks into their science learning. First and foremost, the notebook is a tool for student learning.

Contents

- Introduction 1
- Notebook Benefits 2
- Getting Started 5
- Notebook Components 12
 - Focusing the Investigation.... 14
 - Data Acquisition and Organization..... 16
 - Making Sense of Data 18
 - Next-Step Strategies..... 22
- Using Notebooks to Improve Student Learning 25
- Derivative Products..... 28



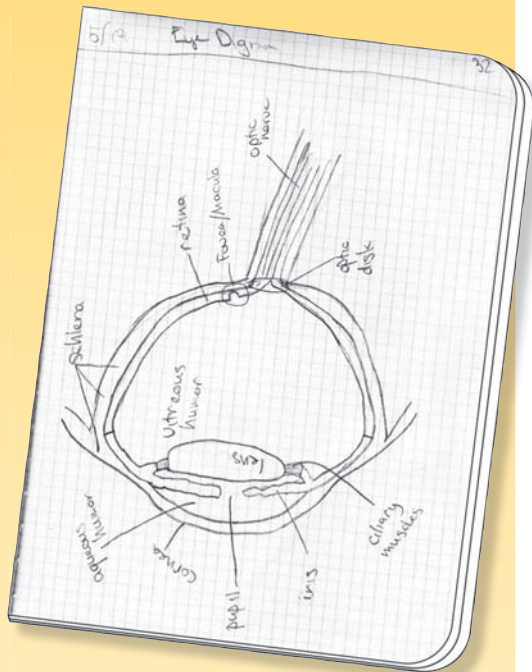
NOTEBOOK BENEFITS

Engaging in active science is one part experience and two parts making sense of the experience. Science notebooks help students with the sense-making part by providing two major benefits: documentation and cognitive engagement.

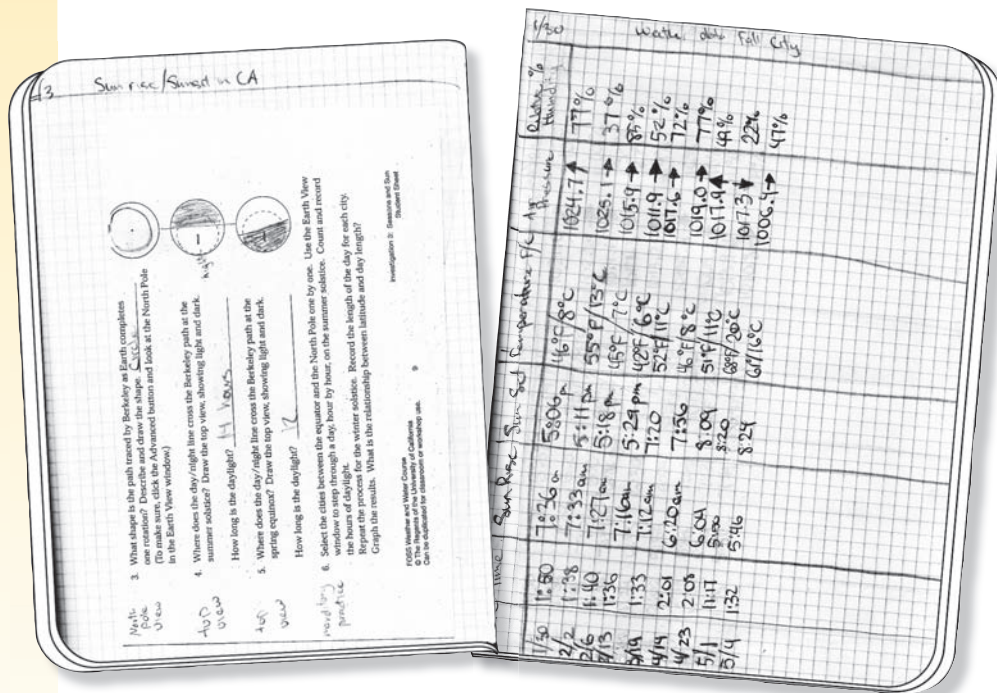
Benefits to Students

Science notebooks centralize students' data. When data are displayed in functional ways, students can think about the data more effectively. A well-kept notebook is a useful reference document. When students have forgotten a fact or relationship that they learned earlier in their studies, they can look it up. Learning to reference previous discoveries and knowledge structures is important.

Documentation: an organized record. As students become more accomplished at keeping notebooks, their work will become better organized and efficient. Tables, graphs, charts, drawings, and labeled illustrations will become standard means for representing and displaying data. A complete and accurate record of learning allows students to reconstruct the sequence of learning events and relive the experience. Discussions about science among students, students and teachers, or students, teachers, and families, have more meaning when they are supported by authentic documentation in students' notebooks. Questions and ideas generated by experimentation or discussion can be recorded for future investigation.



From the Human Brain and Senses Course

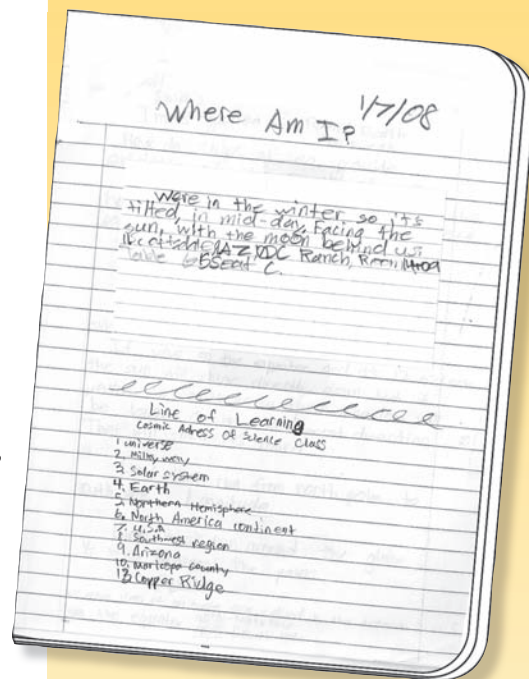


From the Weather and Water Course

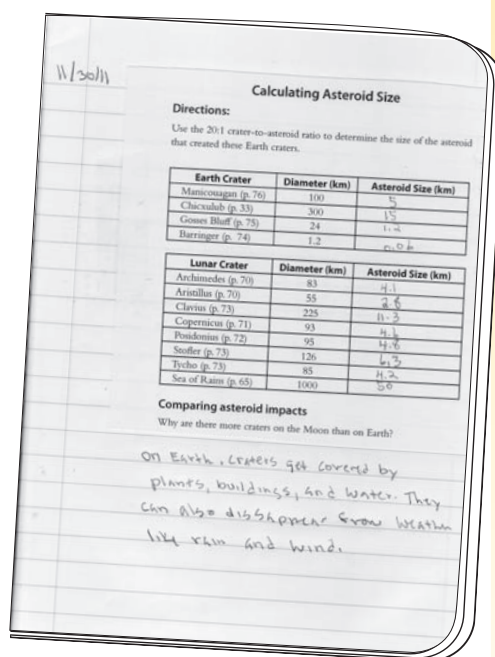
Cognitive engagement. Once data are recorded and organized in an efficient manner in science notebooks, students can think about the data and draw conclusions about the way the world works. Their data are the raw materials that students use to forge concepts and relationships from their experiences and observations.

Writing stimulates active reasoning. There is a direct relationship between the formation of concepts and the rigors of expressing them in words. Writing requires students to impose discipline on their thoughts. When you ask students to generate derivative products (summary reports, detailed explanations, posters, oral presentations, etc.) as evidence of learning, the process will be much more efficient and meaningful because they have a coherent, detailed notebook for reference.

When students use notebooks as an integral part of their science studies, they think critically about their thinking. This reflective thinking can be encouraged by notebook entries that present opportunities for self-assessment. Self-assessment motivates students to rethink and restate their scientific understanding. Revising their notebook entries helps students clarify their understanding of the science concepts under investigation. By writing explanations, students clarify what they know and expose what they don't know.



From the Planetary Science Course



From the Planetary Science Course

Benefits to Teachers

In FOSS, the unit of instruction is the course—a sequence of conceptually related learning experiences that leads to a set of learning outcomes. A science notebook helps you think about and communicate the conceptual structure of the course you are teaching.

Assessment. From the assessment point of view, a science notebook is a collection of student-generated artifacts that exhibit learning. You can informally assess student skills, such as using charts to record data, in real time while students are working with materials. At other times, you might collect student work samples and review them for insights or errors in conceptual understanding. This valuable information helps you plan the next steps of instruction. Students' data analysis, sense making, and reflection provide a measure of the quality and quantity of student learning. The notebook itself should not be graded, though certain assignments might be graded and placed in the notebook.

Medium for feedback. The science notebook provides an excellent medium for providing feedback to individual students regarding their work. Productive feedback calls for students to read a teacher comment, think about the issue it raises, and act on it. The comment may ask for clarification, an example, additional information, precise vocabulary, or a review of previous work in the notebook. In this way, you can determine whether a problem with the student work relates to a flawed understanding of the science content or a breakdown in communication skills.

Focus for professional discussions. The student notebook also acts as a focal point for discussion about student learning at several levels. First, a student's work can be the subject of a conversation between you and the student. By acting as a critical mentor, you can call attention to ways a student can improve the notebook, and help him or her learn how to use the notebook as a reference. You can also review and discuss the science notebook during family conferences. Science notebooks shared among teachers in a study group or other professional-development environment can effectively demonstrate recording techniques, individual styles, various levels of work quality, and so on. Just as students can learn notebook strategies from one another, teachers can learn notebook skills from one another.

GETTING STARTED

A middle school science notebook is more than just a collection of science work, notes, field-trip permission slips, and all the other types of documents that tend to accumulate in a student’s three-ring binder or backpack. By organizing the science work systematically into a bound composition book, students create a thematic record of their experiences, thoughts, plans, reflections, and questions as they work through a topic in science.

The science notebook is more than just formal lab reports; it is a record of a student’s entire journey through a progression of science concepts. Where elementary school students typically need additional help structuring and organizing their written work, middle school students should be encouraged to develop their organizational skills and take some ownership in creating deliberate records of their science learning, even though they may still require some pointers and specific scaffolding from you.

In addition, the science notebook provides a personal space where students can explore their understanding of science concepts by writing down ideas and being allowed to “mess around” with their thinking. Students are encouraged to look back on their ideas throughout the course to self-assess their conceptual development and record new thoughts. With this purpose of the science notebook in mind, you may need to refine your own thinking around what should or should not be included as a part of the science notebook, as well as expectations about grading and analyzing student work.



Rules of Engagement

Teachers and students should be clear about the conventions students will honor in their notebook entries. Typically, the rules of grammar and spelling are fairly relaxed so as not to inhibit the flow of expression during notebook entries. This also helps students develop a sense of ownership in their notebooks, a place where they are free to write in their own style. When students generate derivative products using information in the notebooks, such as reports, you might require students to exercise more rigorous language-arts conventions.

In addition to written entries, students should be encouraged to use a wide range of other means for recording and communicating, including charts, tables, graphs, drawings, graphics, color codes, numbers, and artifacts attached to the notebook pages. By expanding the options for making notebook entries, each student will find his or her most efficient, expressive way to capture and organize information for later retrieval.

Enhanced Classroom Discussion

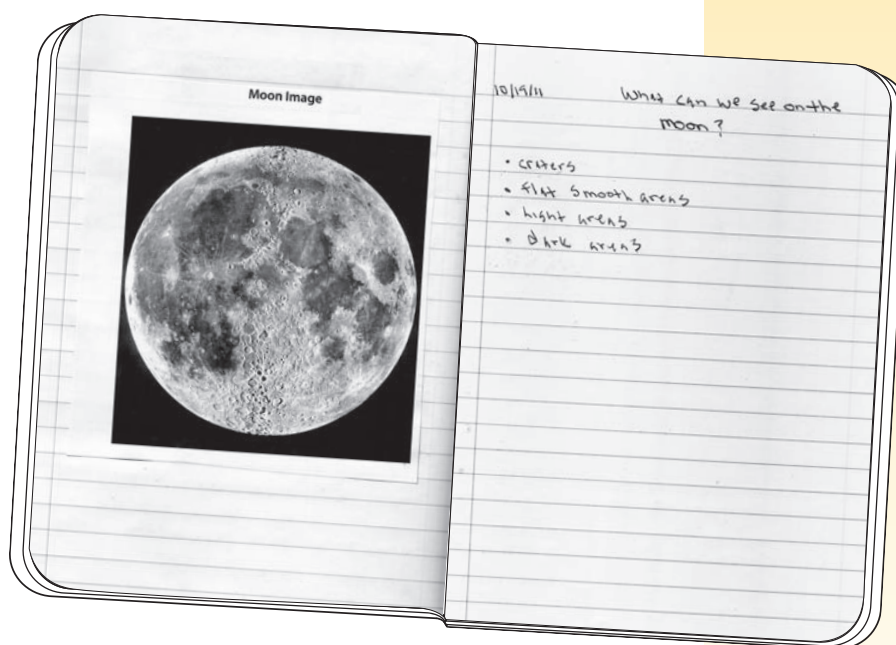
One of the benefits of using notebooks is that you will elicit responses to key discussion questions from all students, not just the handful of verbally enthusiastic students in the class. When you ask students to write down their thoughts after you pose a question, all students have time to engage deeply with the question and organize their thoughts. When you ask students to share their answers, those who needed more time to process the question and organize their thinking will be ready to verbalize their responses and become involved in a class discussion.

When students can use their notebooks as a reference during the ensuing discussion, they won't feel put on the spot. At some points, you might ask students to share only what they wrote in their notebooks, to remind them to focus their thoughts while writing. As the class shares ideas during discussions, students can add new ideas to their notebooks under a line of learning (see next-step strategies). Even if some students are still reticent, having students write after a question is posed prevents them from automatically disengaging from conversations.

Notebook Structure

FOSS recommends that students keep their notebooks in 8" × 10" bound composition books. At the most advanced level, students are responsible for creating the entire science notebook from blank pages in their composition books. Experienced students determine when to use their notebooks, how to organize space, what methods of documentation to use, and how to flag important information. This level of notebook use will not be realized quickly; it will likely require systematic development by an entire teaching staff over time.

At the beginning, notebook practice is often highly structured, using prepared sheets from the FOSS notebook masters. You can photocopy and distribute these sheets to students as needed during the investigations. Sheets are sized to fit in a standard composition book. Students glue or tape the sheets into their notebooks. This allows some flexibility between glued-in notebook sheets and blank pages where students can do additional writing, drawings, and other documentation. Prepared notebook sheets are helpful organizers for students with challenges such as learning disabilities or with developing English skills. This model is the most efficient means for obtaining the most productive work from inexperienced middle school students.



From the Planetary Science Course

Science Notebooks in Middle School

To make it easy for new FOSS teachers to implement a beginning student notebook, Delta Education sells copies of the printed *FOSS Science Notebook* in English for all FOSS middle school courses. Electronic versions of the notebook sheets can be downloaded free of charge at www.FOSSweb.com.

Each *FOSS Science Notebook* is a bound set of the notebook sheets for the course plus extra blank sheets throughout the notebook for students to write focus or inquiry questions, record and organize data, make sense of their thinking, and write summaries. There are also blank pages at the end to develop an index of science vocabulary.

The questions, statements, and graphic organizers on the notebook sheets provide guidance for students and scaffolding for teachers. When the notebook sheets are organized as a series, they constitute a highly structured precursor to an autonomously generated science notebook.

Developing Notebook Skills

Students will initially need more guidance from you. You will need to describe what and when to record, and to model organizational techniques. As the year advances, the notebook work will become increasingly student centered. As the body of work in the notebook grows, students will have more and more examples of useful techniques for reference. This self-sufficiency reduces the amount of guidance you need to provide, and reinforces students' appreciation of their own record of learning.

This gradual shift toward student-centered use of the notebook applies to any number of notebook skills, including developing headers for each page (day, time, date, title, etc.); using space efficiently on the page; preparing graphs, graphic organizers, and labeled illustrations; and attaching artifacts (sand samples, dried flowers, photographs, etc.). For instance, when students first display their data in a two-coordinate graph, the graph might be completely set up for them, so that they simply plot the data. As the year progresses, they will be expected to produce graphs with less and less support, until they are doing so without any assistance from you.

Organizing Science Notebooks

Four organizational components of the notebook should be planned right from the outset: a table of contents, page numbering, entry format, and an index.

Table of contents. Students should reserve the first three to five pages of their notebook for the table of contents. They will add to it systematically as they proceed through the course. The table of contents should include the date, title, and page number for each entry. The title could be based on the names of the investigations in the course, the specific activities undertaken, the concepts learned, a focus question for each investigation, or some other schema that makes sense to everyone.

Page numbering. Each page should have a number. These are referenced in the table of contents as the notebook progresses.

Entry format. During each class session, students will document their learning. Certain information will appear in every record, such as the date and title. Other forms of documentation will vary, including different types of written entries and artifacts, such as a multimedia printout. Some teachers ask their students to start each new entry at the top of the next available page. Others simply leave a modest space before a new entry. Sometimes it is necessary to leave space for work that will be completed on a separate piece of paper and glued or taped in later. Students might also leave space after a response, so that they can add to it at a later time.

Index. Scientific academic language is important. FOSS strives to have students use precise, accurate vocabulary at all times in their writing and conversations. To help them learn scientific vocabulary, students should set up an index at the end of their notebooks. It is not usually possible for students to enter the words in alphabetical order, as they will be acquired as the course advances. Instead, students could use several pages at the end of the notebook blocked out in 24 squares, and assign one or more letters to each square. Students write the new vocabulary word or phrase in the appropriate square and tag it with the page number of the notebook on which the word is defined. By developing vocabulary in context, students construct meaning through the inquiry process, and by organizing the words in an index, they strengthen their science notebooks as a documentary tool of their science learning. As another alternative, students can also define the word within these squares with the page references.

Date	Title	Page
11/11	Land forms	5
11/11	Land forms Tour	6
11/15	Grand Canyon Rocks	9
11/16	mile 20 Sketch/Obs.	10-11
11/16	mile 52 Sketch/Obs.	12-13
11/16	Rock Correlation (part 3)	15
11/19	Rock Correlation Questions (part 2)	17
11/23	Sorting Earth Materials (part 2)	18
11/29	Wentworth Scale (Rock particle size) (part 2)	19
12/2	Stream Table	20, 21, 22
12/2	GC Model, GC Food? s, Mal: media table	23, 24
12/3	Sediments in the Ches Basin	25
12/7	Physical Weathering Sand Comp. Sorting	26, 27, 28
12/7	Chemical Weathering (part 1)	29, 30, 31
12/15	Inv. 3 Deposition part 2 Sandstone	32, 33, 34
1/3	Part 2 Shale	35, 36, 37
1/7	Part 3 Limestone	38, 39, 40
1/12	Part 4: Soils	41, 42, 43
1/19	Part 4: Fossils & Part environments part 1	44, 45, 46
1/26		47, 48

Table of contents

M	matter 19, 91	N	
	melt 65, 66		
	mixture 82		
	molecules 91		
O	oxygen 17	P	particles 12 - periodic table 13 particles 20, 25, 83
Q		R	reaction 8, 93

A science notebook index

NOTEBOOK COMPONENTS

Four general types of notebook entries, or components, give the science notebook conceptual shape and direction. These structures don't prescribe a step-by-step procedure for how to prepare the notebook, but they do provide some overall guidance. The general arc of an investigation starts with a question or challenge, proceeds with an activity and data acquisition, continues to sense making, and ends with next steps such as reflection and self-assessment.

All four components are not necessary during each class session, but over the course of an investigation, each component will be visited at least once. It may be useful to keep these four components in mind as you systematically guide students through their notebook entries. The components are overviewed here and described in greater detail on the following pages.

Focusing the investigation. Each part of each FOSS investigation includes a focus question, which students transcribe into their notebooks. Focus questions are embedded in the teacher step-by-step instructions and explicitly labeled. The focus question establishes the direction and conceptual challenge for that part of the investigation. For instance, when students investigate the origins of sand and sandstone in the **Earth History Course**, they start by writing,

➤ *Which came first, sand or sandstone?*

The question focuses both students and you on the learning goals for the activity. Students may start by formulating a plan, formally or informally, for answering the focus question. The goal of the plan is to obtain a satisfactory answer to the focus question, which will be revisited and answered later in the investigation.

Data acquisition and organization. After students have established a plan, they collect data. Students can acquire data from carefully planned experiments, accurate measurements, systematic observations, free explorations, or accidental discoveries. It doesn't matter what process produces the data; the critically important point is that students obtain data and record it. It may be necessary to reorganize and display the data for efficient analysis, often by organizing a data table. The data display is key to making sense of the science inquiry.

Making sense of data. Once students have collected and displayed their data, they need to analyze it to learn something about the natural world. In this component of the notebook, students write explanatory statements that answer the focus question. You can formalize this component by asking students to use an established protocol such as a sentence starter, or the explanation can be purely a thoughtful effort by each student. Explanations may be incorrect or incomplete at this point, but students can remedy this during the final notebook entry, when they have an opportunity to continue processing what they've learned. Unfortunately, this piece is often forgotten in the classroom during the rush to finish the lesson and move on. But without sense making and reflection (the final phase of science inquiry), students might see the lesson as a fun activity without connecting the experience to the big ideas that are being developed in the course.

Next-step strategies. The final component of an investigation brings students back to their notebooks by engaging in a next-step strategy, such as reflection and self-assessment, that moves their understanding forward. This component is the capstone on a purposeful series of experiences designed to guide students to understand the concept originally presented in the focus question. After making sense of the data, and making new claims about the topic at hand, students should go back to their earlier thinking and note their changing ideas and new findings. This reflective process helps students cement their new ideas.

WARNING — This set contains chemicals that may be harmful if inhaled. Read contents and do not inhale except under adult supervision.

Name: Emily Period: 1 Date: _____

MYSTERY-MIXTURE SUMMARY

Well	Substances	Description of fizzing	Other observations	Large-scale reactions
1	Ascorbic acid + calcium carbonate $C_6H_8O_6 + CaCO_3$	Slow, little bubbles	Cloudy, milky color	
2	Ascorbic acid + sodium bicarbonate $C_6H_8O_6 + NaHCO_3$	Big bubbles first, looks like spore	Clears up	
3	Ascorbic acid + sodium carbonate $C_6H_8O_6 + Na_2CO_3$	Little bubbles medium bubbling	Clears up	
4	Calcium chloride + sodium bicarbonate $CaCl_2 + NaHCO_3$	Looks like spit, very small bubbles	Not clearing up	
5	Citric acid + calcium carbonate $C_6H_8O_7 + CaCO_3$	Slow, small bubbles, keeps fizzing	Cloudy	
6	Citric acid + sodium bicarbonate $C_6H_8O_7 + NaHCO_3$	Big bubbles lots	Hissing sound colder	Gets cold nothing on bottom
7	Citric acid + sodium carbonate $C_6H_8O_7 + Na_2CO_3$	Fizzes a lot medium to big bubbles	Clears up a bit	Not cold has stuff on bottom
8	Mystery mixture	Fizzes a lot big bubbles	Colder	Gets cold nothing on bottom

Identify the two substances in the mystery mixture and explain how you identified them.
 I think it is citric acid and sodium bicarbonate.
 It's bubbling, looks and sounds more like the mystery.
 I can eliminate 1-3 because of the evaporation reports.
 It's not too yellow and the mystery mixture isn't. I can eliminate 4 because the bubbles aren't. I can eliminate 5 because the bubbles aren't. I can eliminate 6 because the bubbles aren't. I can eliminate 7 because the bubbles aren't. I can eliminate 8 because the bubbles aren't.

A student organizes and makes sense of data in the Chemical Interactions Course.

Focusing the Investigation

Focus question. The first notebook entry in most investigations is the focus question. Focus questions are embedded in the teacher step-by-step instructions and explicitly labeled. You can write the question on the board or project it for students to transcribe into their notebooks. The focus question serves to focus students and you on the inquiry for the day. It is not always answered immediately, but rather hangs in the air while the investigation goes forward. Students always revisit their initial responses later in the investigation.

Quick write. A quick write (or quick draw) can be used in addition to a focus question. Quick writes can be completed on a quarter sheet of paper or an index card so you can collect, review, and return them to students to be taped or glued into their notebooks and used for self-assessment later in the investigation.

In the **Diversity of Life Course**, you ask,

➤ *What is life?*

For a quick write, students write an answer immediately, before instruction occurs. The quick write provides insight into what students think about certain phenomena before you begin instruction. When responding to the question, students should be encouraged to write down their thoughts, even if they don't feel confident in knowing the answer.

Knowing students' preconceptions will help you know what concepts need the most attention during the investigation. Make sure students date their entries for later reference. Read through students' writing and tally the important points to focus on. Quick writes should not be graded.

Planning. After students enter the focus question or complete a quick write in their notebooks, they plan their investigation. (In some investigations, planning is irrelevant to the task at hand.) Planning may be detailed or intuitive, formal or informal, depending on the requirement of the investigation. Plans might include lists (including materials, things to remember), step-by-step procedures, and experimental design. Some FOSS notebook masters guide students through a planning process specific to the task at hand.

Lists. Science notebooks often include lists of things to think about, materials to get, or words to remember. A materials list is a good organizer that helps students anticipate actions they will take. A list of variables to be controlled clarifies the purpose of an experiment. Simple lists of dates for observations or of the people responsible for completing a task may be useful.

Step-by-step procedures. Middle school students need to develop skills for writing sequential procedures. For example, in the **Chemical Interactions Course**, students write a procedure to answer these questions.

- *Is there a limit to the amount of substance that will dissolve in a certain amount of liquid?*
- *If so, is the amount that will dissolve the same for all substances?*

Students need to recall what they know about the materials, develop a procedure for accurately measuring the amount of a substance that is added to the water, and agree on a definition of “saturated.” To check a procedure for errors or omissions, students can trade notebooks and attempt to follow another student’s instructions to complete the task.

Experimental design. Some work with materials requires a structured experimental plan. In the **Planetary Science Course**, students pursue this focus question.

- *Are Moon craters the result of volcanoes or impacts?*

Students plan an experiment to determine what affects the size and shape of craters on the Moon. They use information they gathered during the open exploration of craters made in flour to develop a strategy for evaluating the effect of changing the variable of a projectile’s height or mass. Each lab group agrees on which variable they will change and then designs a sound experimental procedure that they can refer to during the active investigation.

Data Acquisition and Organization

Because observation is the starting point for answering the focus question, data records should be

- clearly related to the focus question;
- accurate and precise;
- organized for efficient reference.

Data handling can have two subcomponents: data acquisition and data display. Data acquisition is making and recording observations (measurements). The data record can be composed of words, phrases, numbers, and drawings. Data display reorganizes the data in a logical way to facilitate thinking. The display can be a graph, chart, calendar, or other graphic organizer.

Early in a student's experience with notebooks, the record may be disorganized and incomplete, and the display may need guidance. The FOSS notebook masters are designed to help students with data collection and organization. You may initially introduce conventional data-display methods, such as those found in the FOSS notebook masters, but soon students will need opportunities to independently select appropriate data displays. As students become more familiar with collecting and organizing data, you might have them create their own records. With practice, students will become skilled at determining what form of recording to use in various situations, and how best to display the data for analysis.

Narratives. For most students, the most intuitive approach to recording data is narrative—using words, sentence fragments, and numbers in a more or less sequential manner. As students make a new observation, they record it below the previous entry, followed by the next observation, and so on. Some observations, such as a record of weather changes in the **Weather and Water Course** or the interactions of organisms in miniecosystems in the **Populations and Ecosystems Course**, are appropriately recorded in narrative form.

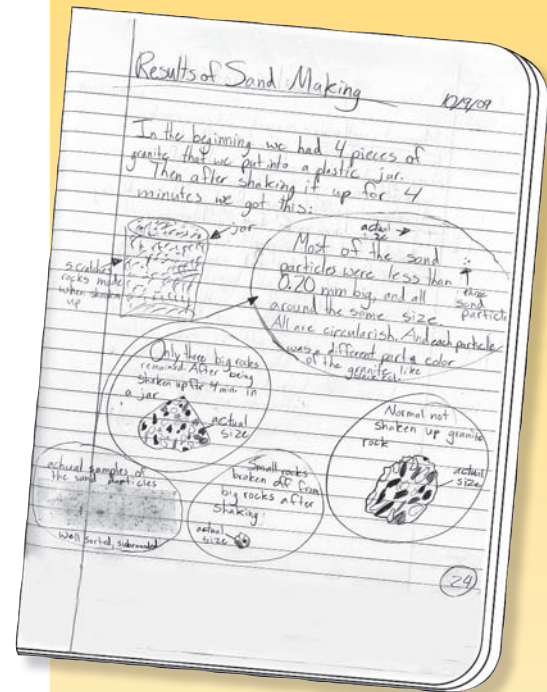
Drawings. A picture is worth a thousand words, and a labeled picture is even more useful. When students use a microscope to discover cells in the *Elodea* leaf and observe and draw structures of microorganisms in the **Diversity of Life Course**, a labeled illustration is the most efficient way to record data.

Charts and tables. An efficient way to record many kinds of data is a chart or table. How do you introduce this skill into the shared knowledge of the classroom? One way is to call for attention during an investigation and demonstrate how to perform the operation. Or you can let students record the data as they like, and observe their methods. There may be one or more groups that invent an appropriate table. During processing time, ask this group to share its method with the class. If no group has spontaneously produced an effective table, you might challenge the class to come up with an easier way to display the data, and turn the skill-development introduction into a problem-solving session.

With experience, students will recognize when a table or chart is appropriate for recording data. When students make similar observations on a series of objects, such as rock samples in the **Earth History Course**, a table with columns is an efficient way to organize observations for easy comparison.

Artifacts. Occasionally an investigation will produce two-dimensional artifacts that students can tape or glue directly into a science notebook. The mounted flower parts in the **Diversity of Life Course** and the sand samples card from the **Earth History Course** can become a permanent part of the record of learning.

Graphs and graphic tools. Reorganizing data into logical, easy-to-use graphic tools is typically necessary for data analysis. Graphs allow easy comparison (bar graph), quick statistical analysis of frequency data (histogram or line plot), and visual confirmation of a relationship between variables (two-coordinate graph). The **Force and Motion Course** offers many opportunities for students to collect data and organize the data into graphs. Students collect data from cars rolling down ramps, graph the data, and use the resulting graph to discuss whether cars traveling downhill maintain a constant velocity or accelerate. Other graphic tools, such as Venn diagrams, pie charts, and concept maps, help students make connections.



Drawing and artifact from the Earth History Course

Making Sense of Data

After collecting and organizing data, the student's next task is to answer the focus question. Students can generate an explanation as an unassisted narrative, but in many instances you might need to use supports such as the FOSS notebook masters to guide the development of a coherent and complete response to the question. Several other support structures for sense making are described below.

Development of vocabulary. Vocabulary is better introduced after students have experienced the new word(s) in context. This sequence provides a cognitive basis for students to connect accurate and precise language to their real-life experiences. Lists of new vocabulary words in the index reinforce new words and organize them for easy reference.

Data analysis. Interpreting data requires the ability to look for patterns, trends, outliers, and potential causes. Students should be encouraged to develop a habit of looking for patterns and relationships within the data collected. Frequently, this is accomplished by creating a graph with numerical data. In the **Populations and Ecosystems Course**, students review field data acquired by ecologists at Mono Lake to determine how biotic and abiotic factors affect the populations of organisms found in the lake.

Graphic organizers. Students can benefit from organizers that help them look at similarities and differences. A compare-and-contrast chart can help students make a transition from their collected data and experiences to making and writing comparisons. It is sometimes easier for students to use than a Venn diagram, and is commonly referred to as a box-and-T chart (as popularized in *Writing in Science: How to Scaffold Instruction to Support Learning*, listed in the Bibliography section).

In this strategy, students draw a box at the top of the notebook page and label it “similar” or “same.” On the bottom of the notebook page, they draw a *T*. At the top of each wing of the *T*, they label the objects being compared. Students look at their data, use the *T* to identify differences for each item, and use the “similar” box to list all the characteristics that the two objects have in common. For example, a box-and-*T* chart comparing characteristics of extrusive and intrusive igneous rocks in the **Earth History Course** might look like this.

similar	
extrusive	intrusive

Students can use the completed box-and-*T* chart to begin writing comparisons. It is usually easier for students to complete their chart on a separate piece of paper, so they can fill it in as they refer to their data. They affix the completed chart into their notebooks after they have made their comparisons.

Claims and evidence. A claim is an assertion about how the natural world works. Claims should always be supported by evidence—statements that are directly correlated with data. The evidence should refer to specific observations, relationships that are displayed in graphs, tables of data that show trends or patterns, dates, measurements, and so on. A claims-and-evidence construction is a sophisticated, rich display of student learning and thinking. It also shows how the data students collected is directly connected to what they learned.

Frames and prompts. One way to get students to organize their thinking is by providing sentence frames for them to complete.

- *I used to think _____, but now I think _____.*
- *The most important thing to remember about Moon phases is _____.*
- *One new thing I learned about adaptation is _____.*

Prompts also direct students to the content they should be thinking about, but provide more latitude for generating responses. For students who are learning English or who struggle with writing, assistive structures like sentence frames can help them communicate their thinking while they learn the nuances of science writing. The prompts used most often in the FOSS notebook masters take the form of questions for students to answer. In the **Weather and Water Course**, students answer the quick-write question

➤ *What causes seasons?*

After modeling an Earth/Sun system and reviewing solar angle and solar concentration, students revisit their quick write to revise and expand on their original explanations.

- *I used to think seasons were caused by _____, but now I know _____.*

Careful prompts scaffold students by helping them communicate their thinking but do not do the thinking for them. As students progress in communication ability, you might provide frames less frequently.

Conclusions and predictions. At the end of an investigation (major conceptual sequence), it might be appropriate for students to write a summary to succinctly communicate what they have learned. This is where students can make predictions based on their understanding of a principle or relationship. For instance, after completing the investigation of condensation and dew point in the **Weather and Water Course**, a student might predict the altitude at which clouds would form, based on weather-balloon data. Or upon examining the data graphed in the **Force and Motion Course**, students might predict the time it will take a cart to travel 200 centimeters down a slope that is different from the experimental slopes they have tried. The conclusion or prediction will frequently indicate the degree to which a student can apply new knowledge to real-world situations. A prediction can also be the springboard for further inquiry.

Generating new questions. Does the investigation connect to a student's personal interests? Does the outcome suggest a question or pique a student's curiosity? The science classroom is most exciting when students are generating their own questions for further investigation based on class or personal experiences. The notebook is an excellent place to capture students' musings and record thoughts that might otherwise be lost.

Science Notebooks in Middle School

Next-Step Strategies

The goal of the FOSS curriculum is for students to develop accurate, durable knowledge of the science content under investigation. Students' initial conceptions are frequently incomplete or confused, requiring additional thought to become fully functional. The science notebook is a useful place to guide reflection and revision. Typically students commit their understanding in writing and reflect in three locations.

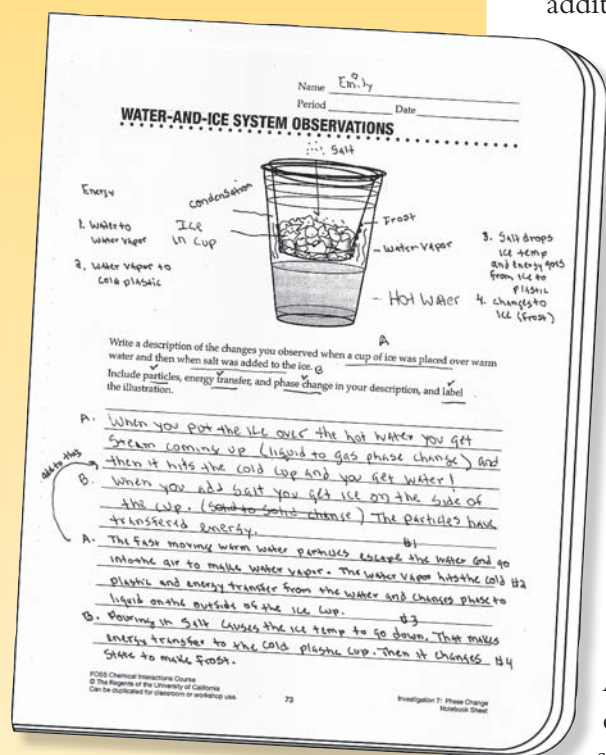
- Explanatory narratives in notebooks
- Response sheets incorporated into the notebook
- Written work on I-Checks

These three categories of written work provide information about student learning for you *and* a record of thinking for students that they can reflect on and revise. Scientists constantly refine and clarify their ideas about how the natural world works. They read scientific articles, consult with other scientists, and attend conferences. They incorporate new information into their thinking about the subject they are researching. This reflective process can result in deeper understanding or a complete revision of thinking.

After completing one of the expositions of knowledge—a written conclusion, response sheet, or benchmark assessment—students should receive additional instruction or information via a next-step strategy. They will use this information later to complete self-assessment by reviewing their original written work, making judgments about its accuracy and completeness, and writing a revised explanation. You can use any of a number of techniques for providing the additional information to students.

- Group compare-and-share discussion
- Think/pair/share reading
- Whole-class critique of an explanation by an anonymous student
- Identifying key points for a class list
- Whole-class discussion of a presentation by one student

After one of the information-generating processes, students compare the “best answer” to their own answer and rework their explanations if they can no longer defend their original thinking. The revised statement of the science content can take one of several forms.



A student's revised work for the Chemical Interactions Course

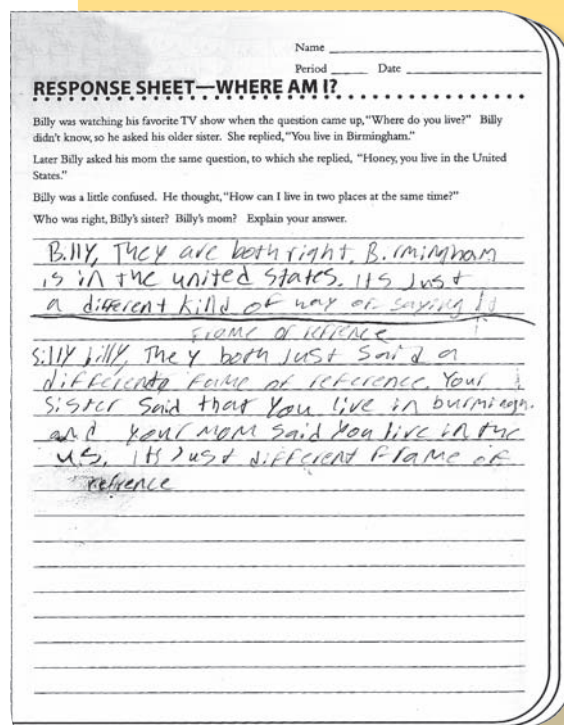
Students might literally revise the original writing, crossing out extraneous or incorrect bits, inserting new or improved information, and completing the passage. At other times, students might reflect on their original work and, after drawing and dating a line of learning (see below), might redraft their explanation from scratch, producing their best explanation of the concept.

During these self-assessment processes, students have to think actively about every aspect of their understanding of the concept and organize their thoughts into a coherent, logical narrative. The learning that takes place during this process is powerful. The relationships between the several elements of the concept become unified and clarified.

The notebook is the best tool for students when preparing for benchmark assessment, such as an I-Check or posttest. Students don't necessarily have the study skills needed to prepare on their own, but using teacher-guided tasks such as key points and traffic lights will turn the preparation process into a valuable exercise. These same strategies can be used after a benchmark assessment when you identify further areas of confusion or misconceptions you want to address with students. Here are four helpful next-step, or self-assessment, strategies.

Line of learning. One technique many teachers find useful in the reflective process is the line of learning. After students have conducted an investigation and entered their initial explanations, they draw and date a line under their original work. As students share ideas and refine their thinking during class discussion, additional experimentation, reading, and teacher feedback, encourage them to make new entries under the line of learning, adding to or revising their original thinking. If the concept is elusive or complex, a second line of learning, followed by more processing and revising, may be appropriate.

The line of learning is a reminder to students that learning is an ongoing process with imperfect products. It points out places in that process where a student made a stride toward full understanding. And the psychological security provided by the line of learning reminds students that they can always draw another line of learning and revise their thinking again. The ability to look back in the science notebook and see concrete evidence of learning gives students confidence and helps them become critical observers of their own learning.



A line of learning used with the Planetary Science Course

Traffic lights. In the traffic-lights strategy, students use color to self-assess and indicate how well they understand a concept that they are learning. Green means that the student feels that he or she has a good understanding of the concept. Yellow means that the student is still a bit unsure about his or her understanding. Red means that the student needs help; he or she has little or no understanding of the concept. Students can use colored pencils, markers, colored dots, or colored cards to indicate their understanding. They can mark their own work and then indicate their level of understanding by a show of hands or by holding up colored cards. This strategy gives students practice in self-assessment and helps you monitor students' current understanding. You should follow up by looking at student work to ensure that they actually do understand the content that they marked with green.

Three C's. Another approach to revision is to apply the three C's—confirm, correct, complete—to the original work. Students indicate ideas that were correct with a number or a color, code statements needing correction with a second number or color, and assign a third number or color to give additional information that completes the entry.

Key points. Students do not necessarily connect the investigative experience with the key concepts and processes taught in the lesson. It is essential to give students an opportunity to reflect on their experiences and find meaning in those experiences. They should be challenged to use their experiences and data to either confirm or reject their current understanding of the natural world. As students form supportable ideas about a concept, those ideas should be noted as key points, posted in the room, and written in their notebooks. New evidence, to support or clarify an idea, can be added to the chart as the course progresses. If an idea doesn't hold up under further investigation, a line can be drawn through the key point to indicate a change in thinking. A key-points activity is embedded near the end of each investigation to help students organize their thinking and prepare for benchmark assessment.

USING NOTEBOOKS TO IMPROVE STUDENT LEARNING

Notebook entries should not be graded. Research has shown that more learning occurs when students get only comments on written work in their notebooks, not grades or a combination of comments and grades.

If your school district requires a certain number of grades each week, select certain work products that you want to grade and have students turn in that work separate from the notebook. After grading, return the piece to students to insert into their notebooks, so that all their work is in one place.

It may be difficult to stop using grades or a rubric for notebook assessment. But providing feedback that moves learning forward, however difficult, has benefits that make it worth the effort. The key to using written feedback for formative assessment is to make feedback timely and specific, and to provide time for students to act on the feedback by revising or correcting work right in their own notebook.

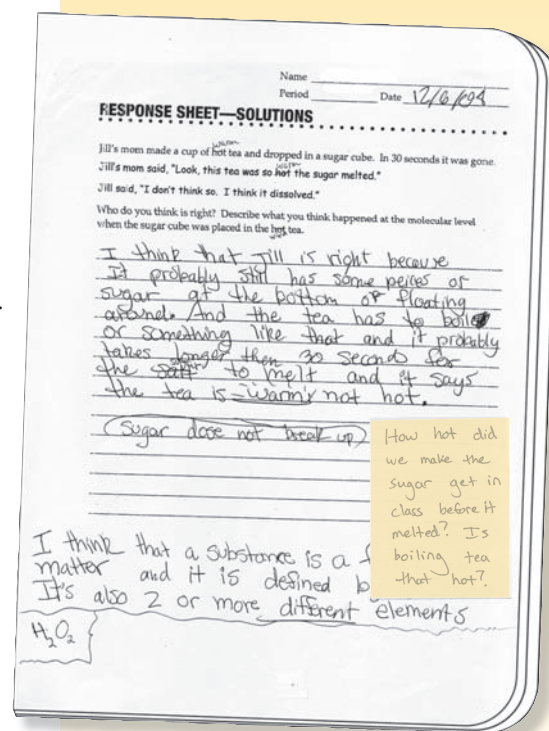
Teacher Feedback

Student written work often exposes weaknesses in understanding—or so it appears. It is important for you to find out if the flaw results from poor understanding of the science or from imprecise communication. You can use the notebook to provide two types of feedback to the student: to ask for clarification or additional information, and to ask probing questions that will help students move forward in their thinking. Respecting the student’s space is important, so rather than writing directly in the notebook, attach a self-stick note, which can be removed after the student has taken appropriate action.

The most effective forms of feedback relate to the content of the work. Here are some examples.

- *You wrote that seasons are caused by Earth’s tilt. Does Earth’s tilt change during its orbit?*
- *What evidence can you use to support your claim that Moon craters are caused by impacts? Hint: Think of our experiments in class.*

Nonspecific feedback, such as stars, pluses, smiley faces, and “good job!”, or ambiguous critiques, such as “try again,” “put more thought into this,” and “not enough,” are less effective and should not be used. Feedback that guides students to think about the content of their work and gives suggestions for how to improve are productive instructional strategies.



Feedback given during the Chemical Interactions Course

Science Notebooks in Middle School

Here are some appropriate generic feedback questions to write or use verbally while you circulate in the class.

- *What vocabulary have you learned that will help you describe _____?*
- *Can you include an example from class to support your ideas?*
- *Include more detail about _____.*
- *Check your data to make sure this is accurate.*
- *What do you mean by _____?*
- *When you record your data, what unit should you use?*

When students return to their notebooks and respond to the feedback, you will have additional information to help you discriminate between learning and communication difficulties. Another critical component of teacher feedback is providing comments to students in a timely manner, so that they can review their work before engaging in benchmark assessment or moving on to other big ideas in the course.

In middle school, you face the challenge of having a large number of students. This may mean collecting a portion of students' notebooks on alternate days. Set a specific focus for your feedback, such as a data table or conclusion, so you aren't trying to look at everything every time.

To help students improve their writing, you might have individuals share notebook entries aloud in their collaborative groups, followed by feedback from a partner or the group. This valuable tool must be very structured to create a safe environment, including ground rules about acceptable feedback and comments.

A good way to develop these skills is to model constructive feedback with the class, using a student-work sample from a notebook. Use a sample from a previous year with the name and any identifying characteristics removed. Project it for the class to practice giving feedback.

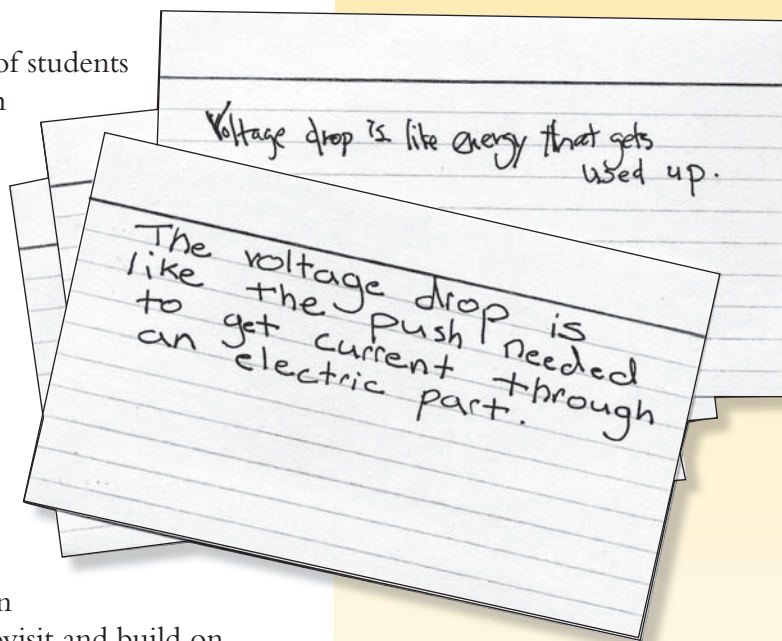
Formative Assessment

With students recording more of their thinking in an organized notebook, you have a tool to better understand the progress of students and any misconceptions that are typically not revealed until the benchmark assessment. One way to monitor student progress is during class while they are responding to a prompt. Circulate from group to group, and read notebook entries over students' shoulders. This is a good time to have short conversations with individuals or small groups to gain information about the level of student understanding. Take care to respect the privacy of students who are not comfortable sharing their work during the writing process.

If you want to look at work that is already completed in the notebook, ask students to open their notebooks to the page that you want to review and put them in a designated location. Or consider having students complete the work on a separate piece of paper or an index card. Students can leave a blank page in their notebooks, or label it with a header as a placeholder, until they get the work back and tape it or glue it in place. This makes looking at student work much easier, and the record of learning that the student is creating in the notebook remains intact.

When time is limited, you might select a sample of students from each class, alternating the sample group each time, to get a representative sample of student thinking. This is particularly useful following a quick write.

Once you have some information about student thinking, you can make teaching decisions about moving ahead to a benchmark assessment, going back to a previous concept, or spending more time making sense of a concept. Benchmark assessments can also be used as formative assessment. You might choose to administer an I-Check, score the assessment to find problem areas, and then revisit critical concepts before moving on to the next investigation. Students can use reflection and self-assessment techniques to revisit and build on their original exam responses.



Quick writes for the Electronics Course written on index cards

DERIVATIVE PRODUCTS

On occasion, you might ask students to produce science projects of various kinds: summary reports, detailed explanations, end-of-course projects, oral reports, or posters. Students should use their notebooks as a reference when developing their reports. You could ask them to make a checklist of science concepts and pieces of evidence, with specific page references, extracted from their notebooks. They can then use this checklist to ensure that all important points have been included in the derivative work.

The process of developing a project has feedback benefits, too. While students are developing projects using their notebooks, they have the opportunity to self-monitor the organization and content of the notebook. This offers valuable feedback on locating and extracting useful information. You might want to discuss possible changes students would make next time they start a new science notebook.

Homework is another form of derivative product, as it is an extension of the experimentation started in class. Carefully selected homework assignments enhance students' science learning. Homework suggestions and/or extension activities are included at the end of each investigation. For example, in the **Human Brain and Senses Course**, after being introduced to the properties of lenses and how these properties affect the function of their eyes, students can write about the role of light in vision, considering radiant, transmitted, and reflected light. In the **Electronics Course**, students can calculate the flow of current in home appliances, using the information they have learned in class. Homework should be done on a separate paper, graded, and then inserted into the science notebook.