Scientific Content and Process Connections

Learning science is something students do, not something that is done to them. (National Research Council 1996, 20)

Connections to the National Science Education Standards

How do science notebooks connect to the National Science Education Standards?

In a move to begin looking at the process of science differently, experts from across the country came together to examine what scientists do. The results of their work are the National Science Education Standards. "The Standards are the 'next word,' not the 'final word,' in our attempts to improve science programs" (Bartels 2000, 21). The Standards provide insight into the learning of scientific concepts and encourage teachers to provide students with opportunities to investigate and question the world around them.

In order for students to learn science, they need to be engaged in meaningful investigations with materials. The National Science Education Standards provide teachers with an understanding of what it looks like and means to provide students with meaningful science experiences. The Standards establish the students' knowledge base within eight scientific content categories:

1. unifying concepts and processes in science
2. science as inquiry
3. physical science
4. life science
5. earth and space science
6. science and technology  
7. science in personal and social perspectives  
8. history and nature of science  

"The national standards challenge educators to move beyond 'science as a process,' in which students learn skills (observing, inferring, and hypothesizing) and to combine these skills with scientific knowledge, scientific reasoning, and critical thinking to construct a richer understanding of science" (Bybee 1997, 11). Science notebooks provide a context in which students can use the skills Bybee talks about to construct a richer understanding of science. Science notebooks also promote five of the eight standards categories: scientific content (physical, life, and earth and space), science as inquiry, and unifying concepts and processes in science. This chapter examines the relationship between science notebooks and each of these categories.

**Physical, Life, and Earth and Space Content Standards**

**How do science notebooks address the physical, life, and earth and space content standards?**

The important but abstract ideas of science ... all begin with observing and keeping track of the way the world behaves.  
(National Research Council 1996, 126)

Scientific content refers to the information students study within physical, life, and earth and space sciences. It is through content that students learn and practice the process of scientific inquiry. By utilizing notebooks in writing, discussing, and reflecting, students begin to focus on the scientific content they know as well as how they know it—an important step in developing students' metacognitive thinking. Students begin constructing their understandings of scientific ideas as they determine what information needs to be recorded in their notebooks and the best way to organize it. During discussions, students question one another's thinking, causing them to refer back to the evidence they collected in their notebooks to support their ideas. Reflecting in notebooks is another time when students may focus on the content they are learning. In reflecting on what worked and why it worked, students are developing conceptual understanding. Research shows that student learning is enhanced when students are asked to write within the content areas (Reeves 2000). Notebooks provide students with one context for writing within the content of science and may be used as a tool to create other forms of informational writing. Chapter 6, "Literacy Connections," provides more
information on other forms of informational writing that may come from science notebooks.

**What evidence is there that students are learning content by using science notebooks?**

Observing how students use their notebooks during an investigation and discussion can provide insight into student understanding of the content being studied. Notebooks represent the path of student knowledge—where they began and where they are currently. Students are provided with the opportunity to construct understanding while they draw, describe, create charts, and reflect. Their understanding of content is strengthened along with their recording skills.

The appearance or length of an entry may not reflect the content that is present. Some students may record very little in their notebooks or organize their information in a manner that appears to be disorganized; however, they may have a strong understanding of the content being studied. On the other hand, there are some students who may write pages upon pages in beautiful handwriting and actually say little in terms of content.

The notebooks become tools for students to help explain their thinking and justify their ideas using the evidence gathered. As students work through an investigation, they begin to make connections to prior experiences. Their notebooks become reference tools during discussions as they refer to the books to find evidence to support their thinking. In the following vignette the teacher describes how third-grade students came to an understanding of content by utilizing their notebooks in their discussions with others.

The students had been exploring pitch for some time and had several different experiences that allowed them to think about the connection between pitch and length of an item, such as metal bars or hollow tubes. Students were struggling with one of the investigations, a water xylophone, consisting of glass bottles with various amounts of water that needed to be put in order from highest to lowest pitch. I called the students to the floor to discuss this particular investigation. Students began by sharing their ideas with a partner before sharing them with the group. The first student to share with the group explained that the bottles needed to go in order from the least amount of water to the greatest and showed a picture he had drawn in his notebook to represent this. He went on to explain that the one with the most water had the highest pitch. Another student quickly disagreed
and said she thought that the bottle with the smallest amount of water had the highest pitch.

In order to explore this further, we pulled the bottles out to demonstrate. The two students took turns tapping the bottles and the class agreed that each one seemed to be correct. How could this be? Another student started searching through his notebook. "I found that shorter items usually have a higher pitch, so I think the bottle with less water should have a higher pitch. This is so confusing." Students were quick to join the discussion, referring to evidence in their notebooks to support their thinking.

I listened to the conversation and realized that students had a good understanding of pitch and length, as evident by their discussion, but were getting confused with the water xylophone. From the demonstration, I realized that the two students were tapping the bottles at different locations, one above the water line and the other below. This would affect the pitch. Rather than telling students the answer, I decided to leave the water xylophone out for further investigation. We would revisit this conversation after they had more time to work with the water xylophone.

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**Thinking point:** How will you look for evidence of content understanding when your students use their science notebooks?

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**Science as Inquiry**

**How do science notebooks address science as inquiry?**

Science as inquiry “involves asking a simple question, completing an investigation, answering the question, and presenting the results to others” (National Research Council 1996, 122). As students work within an investigation, they record findings and questions in their science notebooks. Often, questions arise based on the information they have recorded. As they look back through their notebook entries, students may find that new ideas conflict with their current thinking. This conflict becomes a question and serves as a starting point for an inquiry. From that question, students plan and conduct an investigation. Based on previous data, they form a hypothesis, decide upon materials, and devise a way to find an answer. All of this is recorded in their notebooks, along with the work of the investigation. Throughout the investigation, students use their notebooks in discussions with others. When sufficient information has
been gathered, students synthesize their thoughts and present their results to others through formal written or oral presentations.

Also included in this standard is the expectation that students learn how scientists conduct, document, and communicate their work. Students utilize their notebooks throughout an investigation, just as scientists do. Using science notebooks in this manner helps students develop an understanding of how scientists work and the importance of this basic, yet essential, tool to their work.

**What evidence is there that students are using science as inquiry in their science notebooks?**

Science as inquiry, sometimes referred to as the inquiry process, is the overarching process that students utilize to formulate an understanding of scientific content. Within science as inquiry there are five main categories, which the Exploratorium Institute for Inquiry groups as (1) observing, (2) hypothesizing, (3) planning investigations (including predictions), (4) interpreting findings and drawing conclusions, and (5) communicating (Exploratorium Institute for Inquiry 1998). This process may not be as linear as many believe, as students enter it at various stages, and evidence of science as inquiry is scattered throughout their notebooks. Understanding what the process skills may look like allows the teacher to be aware of where students are in the inquiry process.

Students’ observations are recorded in a variety of ways, using drawings, lists, explanations, charts, and tables. Within their observations are wonderings and questions that lead them to new investigations. They formulate a hypothesis for their question based on successes and failures with past experiences. Using their notebooks in conversations with others becomes a natural process and a way to think about ideas. Through their work and discussions, students develop a plan for their inquiry. This plan may not be orderly and probably evolves as students work through their inquiry. Finally, students interpret their findings and present them to others either informally or formally.

In the vignette that follows, a teacher describes how a group of second-grade students utilized their notebooks as they worked through a small-group inquiry.

After exploring air resistance, students looked back through their notebooks and shared questions they had recorded while working with parachutes. I recorded these questions on the board where all the students could see them. Students then selected a question they were interested in pursuing and formed groups based on their selections. A group of three students had
decided to explore how the size of the parachute affected the speed of descent.

As students began planning their inquiry, they realized that they needed to examine the parachute they used in the original investigation, as no one knew exactly how big it was and they had nothing in their notebooks about this. After looking at their original parachutes, they decided it was a regular dinner napkin and jotted this down in their notebooks. They decided that they would cut napkins to make smaller parachutes and one person suggested that they tape some napkins together to make a really big parachute. They put these ideas down in their notebooks and then called me over. Realizing that they had not formed a hypothesis yet, I asked them what they thought would happen when they tested the parachutes. They thought the smaller parachute would descend faster and referred to the times their parachute did not open, which caused it to come down very quickly. I suggested they record this in their notebooks so they could reference it later.

The group quickly began cutting and taping napkins to make different-sized parachutes and then started testing them to see what would happen. Realizing they needed a way to organize their tests, one student suggested they name each parachute so they could write about it in their notebooks. They busily went about dropping and counting how long it took each parachute to reach the ground and then recording the results in their notebooks. After testing five different-sized parachutes, one of the students commented that he didn’t see much of a difference. Another student pointed out that she didn’t see a big difference between each parachute, but when she looked at the results of the biggest parachute and the results of the smallest parachute, the smaller one came down faster. The students then decided to drop those two parachutes at the same time to see which one hit the ground first.

As the small groups wrapped up their inquiries, we came back together as a whole class to share our findings. The class listened intently as each group shared what they had learned in a short presentation. Many groups showed the parachutes they had made to the group and used evidence from their notebooks to support their findings.

**Thinking point:** How will you look for evidence of science as inquiry when your students use their science notebooks?
Unifying Concepts and Processes

How do science notebooks address unifying concepts and processes?

In elementary science, students are learning to make sense of the unifying concepts and processes. These are the skills that allow students to create a bigger picture by examining the information they have gathered through small units of study. For example, by using the unifying concepts and processes, students are able to apply information they learned about four various insects to identify characteristics that are common to all insects.

Science notebooks are authentic tools that students use to work with the ideas presented within this category and bring together their science experiences. Within notebooks, students begin to make sense of the concepts included in the National Science Education Standards: “systems, order, and organization”; “evidence, models, and explanation”; and “constancy, change, and measurement.” As students work in a content area, their notebooks allow them to build connections between the unifying concepts and processes and the content being studied.

The first concept deals with system, order, and organization. Through examining notebook entries, students are able to begin thinking about the various components of the systems they are working with and the connections that exist between them. A sense of order begins to emerge, allowing students to bring organization to the concept with which they are working and to the ideas represented within their notebooks.

The second concept focuses on evidence, models, and explanation. While working in science, students are gathering evidence of their thinking in their science notebooks. Through observation or experimentation, students gather evidence as drawings, explanations, and/or data to use in support of their scientific explanations. Models help students make sense of how things work. Models are represented in notebooks as plans, equations, drawings, and so on. Students use models to support their scientific explanations. When forming hypotheses or conclusions, students base their explanations on information recorded in their notebooks.

Constancy, change, and measurement require students to look at materials over time. By keeping notebooks, students are able to look at an object through various stages of an inquiry and note changes that take place or aspects of the material that remain constant. Notebooks allow students to keep track of measurements and determine what would be considered appropriate based on past experiences. Notebooks provide students with a quick and easy means to access information over time, allowing them to have the experiences necessary to gain an understanding of concepts.
What evidence do notebooks provide that students are making sense of the unifying concepts and processes?

Students' understanding grows with time and is represented within their entries. They begin to make connections between concepts and refer to past experiences to help explain new ideas. Evidence becomes an important component of their entries, and during discussion they ask each other on what evidence their ideas are based. Change is represented in their entries and they realize the importance of dating each entry in order to reference the time that has elapsed. It is the concepts presented in this standard that allow students to begin making connections between ideas and applying them to other situations.

In the following vignette a teacher describes how first graders utilized their notebooks in examining the system of balance.

I challenged my students to create a balanced system using a craft stick, pencil, wire, and clothespins. The pencil was to balance on its sharpened tip on the end of the craft stick. From past experiences, they knew that the clothespins, or counterweights, could be used to make an object balance. I saw some students look back at their notes to see how they had balanced cardboard figures, while others started immediately with the materials. Soon all of them were wrapping the wire around the pencil and attaching the clothespins at various points to see if they could get the pencil to balance. As some students began creating the balanced system, other students observed what they were doing differently and it wasn't long before everyone had managed to create a balanced system. I gave them a few minutes to make sure they had recorded their systems in their notebooks before calling them to the floor for a group discussion. We examined the various systems that were created and discussed what would happen if we made changes to them. I wanted students to think about the systems and how important each part was to the system, a unifying concept.

Thinking point: How will you look for evidence that your students are using the unifying concepts and processes when they use their science notebooks?

In order to meet Bybee's challenge of taking students beyond learning "science as a process," teachers must employ methods that replicate the work of scientists. Notebooks are essential tools to scientists and therefore need
to be considered as essential to the learning of elementary science. Notebooks, while developing literacy, help students make connections to the larger scientific concepts that they will build on throughout the rest of their education.

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