From "Adding Inquiry" to "Doing Science"

Embracing the tensions in teaching inquiry-based science

By Diana Weller and Carla Finkelstein

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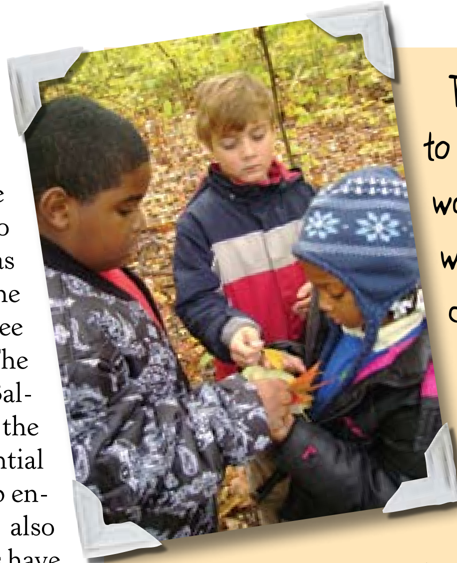
The first week of our tree unit, I took my second graders outside with clipboards and instructions to write what they noticed and what they wondered about trees. Altogether, they generated almost two dozen questions. "How come the roots don't show?" "How do trees eat?" "Why are they all so different?" "How do the nests get there?" I was excited by my students' enthusiasm for generating their own questions, but I was anxious about what to do next. Could I address all of their questions during this unit? Should I? If I chose just one of their questions to explore in depth, what might I be giving up by following that path?

—Diana's reflective journal, July 2010

Our school's second-grade science curriculum has always focused on trees and their role in our ecosystem during the first half of the year. Curricular goals have largely emphasized what students ought to "know" by the end of the semester, such as identifying the parts of a tree, describing the process of photosynthesis, and creating a tree guide about trees found in our school yard. The Green School, a public charter school in Baltimore City, was founded by teachers with the mission of providing project-based, experiential education for elementary children to develop environmental literacy and stewardship. We also promote a science program in which students have opportunities to think and work like scientists. To that end, we discussed in the summer of 2009 including more inquiry in our science curriculum and chose to dedicate the following year's professional development (PD) to science and inquiry. At the time, we did not realize how much tension would fill this journey, as we came to learn that "inquiry" was not a simple add-on to our current curriculum but rather involved rethinking what it meant to engage children in doing science.

In partnership with an NSF-funded research project investigating learning progressions in science inquiry, we sought to balance teaching science content with processes and reasoning, and to navigate how to be authentically responsive to children's inquiry without compromising content goals. With the new goal of including more inquiry, we wanted to take more of our lead from the students' interests. That is, to truly engage students in scientific inquiry practices, we would have to create ongoing opportunities to listen to children and to hear what questions they had and wanted to pursue (Hammer and van Zee 2006). Then, in helping them answer their questions, we would also want to support students' scientific practices of reasoning, explanation, and argumentation.

At our school, we have always seen the value in going deep with content—for example, spending an entire semester with first graders investigating the local watershed—but the new focus on responsiveness seemed even more time-intensive. Would this be possible? We worried: What might this new focus do to our curriculum goals? Could we guarantee that the students would learn the science content? In this article, Carla—the school's staff developer—and Diana, second-grade teacher—present one teacher's journey over the course of a school year in navigating these tensions.



The next day, I announced to my second graders that we would begin our inquiry journey with an interesting question about trees that many of them shared: Why do leaves change color? There was a collective pause. It seemed that none of them knew "the answer" to this question. As students turned and talked with a partner, I listened in and heard them connecting this question to their prior experiences and knowledge, and to what they had observed during our previous week's science walks. Stephen explained, "I think the tree stops giving life to the leaves, and then they fall off the tree and change color." Sara stated, "Seasonal effect is making the oil in the leaf move to the orange or red part. We have oils in our hands; it has oils like the oils in our hands." Anya offered, "The water is going out of the leaves. That's why it changes color. The water goes out of the leaves because it needs to save water for winter." I was amazed at my students' willingness to take risks in offering theories and explaining why their ideas had merit. I saw that these seven-year-olds' ideas had logical reasoning behind them, even though they were often lines of reasoning I, as an adult, would never have thought of myself.

Initial Ideas

Diana helped the class identify common threads in their thinking, which led them to numerous possible ideas:

Why do leaves change color?

- The wind
- The leaves are sick
- The roots send something up the tree that changes the leaves
- The season is changing
- They have less water
- There is oil in the leaf
- The tree stops giving life to the leaves
- The leaves are too cold
- The leaves are trying to keep warm

Over the next couple of weeks, Diana continued to engage students in discussing, drawing, and writing about their ideas. She challenged them to challenge each other in supporting, justifying, or abandoning theories, and to hold each other accountable for ideas that made sense. We noticed students who usually struggled academically who were developing more confidence and independence in sharing their ideas and participating eagerly with their classmates. In PD meetings and informal hallway conversations, Diana shared with Carla the class's evolving ideas. We noticed that the list was condensing, as students combined ideas to try to come up with a more comprehensive and coherent explanation for why leaves change color. We also noticed that students were seeking to explain not only *why* leaves change color but *how* as well:

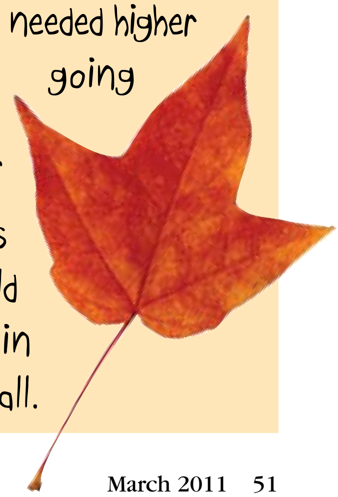
- The season is changing. The leaves have less water, and that makes them lose their green color.
- The season is changing. The leaves are too cold, and they are trying to keep warm.
- Leaves have two layers, green on top and red, yellow, or brown underneath. In autumn, the top leaf layer blows away.

Revising Ideas

At this point in the unit, Diana noticed students pushing each other for evidence for their ideas, saying things like, "I don't *see* green leaf layers on the ground. Where do they go if they blow off?" or "It rained last night. How come the leaves aren't changing back to green?" Up to this point, we had mostly provided opportunities for students to use their own prior knowledge and reasoning to generate and revise ideas. Now, Diana thought, would be a good time for students to wrestle with the question, "How could we find out?" She would have them design and run an experiment, an experience they had not yet had and which might provide a more structured opportunity for observation. We decided to select one of the class's ideas for children to test in small groups: "Leaves change color because they have two layers, a top green layer and an underneath red or brown layer; in autumn, the top layer blows off because it's windy in autumn." We chose this idea both because it seemed easily testable and because it had been generating a lot of animated discussion among the students.

Students excitedly set up fans (with teacher supervision), taped leaves to desks or paper, and made plans for recording their observations. Each small group of five to six students determined its own procedure to follow based on the plan it had made. Diana and her undergraduate science methods course interns circulated among the groups, helping to facilitate conversations and monitoring students' use of materials. Unfortunately, the results of the experiments were inconclusive; students disagreed about what had happened, and some even thought they saw leaves change color from green to brown as they flapped in the wind created by the fans they had set up in the classroom.

This is a place where in my former life as a science teacher I would a have felt as though we had found nothing, and the experiment was a failure. Was this a dead end, or was there any value in what we had done? I realized that a huge part of scientists' work involves learning from "failed" experiments, so I chose to share this decision-making task with my students. The following lesson I asked, "We haven't found our answer yet to our big question. What should we do next?" Some of them suggested new experiments—maybe we needed higher wind power if we were going to be able to observe the top layer blowing off the leaf other students wondered how we could determine if a leaf, in fact, has layers at all.



Many students had closely investigated their leaves during the experiment and wanted to know more about their parts and functions. They argued for exploring this further with tools such as magnifying lenses and microscopes.

Although my students offered several reasonable next steps, I felt a tension between continuing to seek the "correct answer" and moving on to other areas of study. We'd spent weeks on this investigation and students still didn't "know" why leaves change color. Could I afford to linger longer in this topic? If not, would I be letting students walk away with "wrong" ideas?

Next Steps

At our next whole-staff science PD, Diana shared student work and posed her continuing dilemma. One colleague asked, "It seems important for us to revisit: What do we want our students to know in science?" This sparked an aha moment for Diana. She realized that she wanted her students to know how to participate in scientific reasoning—which they were doing—and to understand tree parts and functions. Her students were now asking to look more closely at leaves to understand what might be going on inside of them. Within *their* questions and *their* interests, Diana heard opportunities to investigate some of the science concepts that were most important to her. She realized that looking more closely at leaves and other tree parts could now happen through more "traditional" instructional activities such as observation and informational text reading, while remaining responsive to students' inquiry.

The next lessons involved students closely examining leaves with magnifying lenses, as well as reading informational text diagrams displaying leaf parts. Unlike in previous years where students passively followed directions for this work, these students were actively engaged in examining diagrams to learn names and functions of the leaf parts, and rubbing and dissecting leaves to look for layers or multiple colors. Diana alternated this work with sharing sessions that connected the reading and observations back to the students' big question; she asked them to share "noticings" or observations that supported the two-layer idea, observations that refuted that theory, and any new observations or wonderings.

Figure 1.

Student work sample.

Looking at the functions that students identified on their leaf charts shows me that they were thinking a lot about water moving in the tree, how the tree makes food, and about air or oxygen as it relates to a tree. To me the lightbulb had turned on. If you put all of these possible functions together, you are thinking about photosynthesis. They had done all of the hard work, hypothesizing what was going on in the leaves. I now could define their thinking for them.

After reading about and discussing photosynthesis, I asked students to draw their thinking about this process (Figure 1).

Looking back at these student diagrams and descriptions of photosynthesis, I see a richness in understanding that I had not seen in previous years. I feel that all of the science talks prior to our reading helped them understand the text and relate it to their own experiences with trees. I imagine that it was easier for them to comprehend what was going on inside of a leaf after dissecting leaves and discussing the complexity of its many parts. Some students saw the process as a formula, others as a recipe. The diagrams they created demonstrated a deep understanding of the phenomena and did not look like copied versions of the diagram from the text.

Trusting in Inquiry

By the end of the tree investigation, Diana examined the paths she had taken and realized that she reached the same curricular goals she had in previous years but with a richness and depth in conceptual understanding she had not seen before. By trusting student inquiry to guide us and empowering children to be inquisitive about the world around them, the students in turn were able to ask and answer their own big questions about trees, while Diana provided the structure of being their tour guide for this scientific journey. ■

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TEACHER TAKE-AWAYS

I didn't have to relinquish all content goals; I could choose pathways from among student ideas that connected to important scientific concepts.

Time will always be a tension. Extended conversation can be worth the time in that students will offer and wrestle with important scientific ideas, but the struggle to balance content coverage will remain.

I came to see science processes (habits of argumentation and reasoning) as part of the substance of science—not as a choice between favoring content or process.

Connecting to the Standards

This article relates to the following *National Science Education Standards* (NRC 1996):

Teaching Standards

Teaching Standard B:

Teachers of science guide and facilitate learning.

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academies Press.