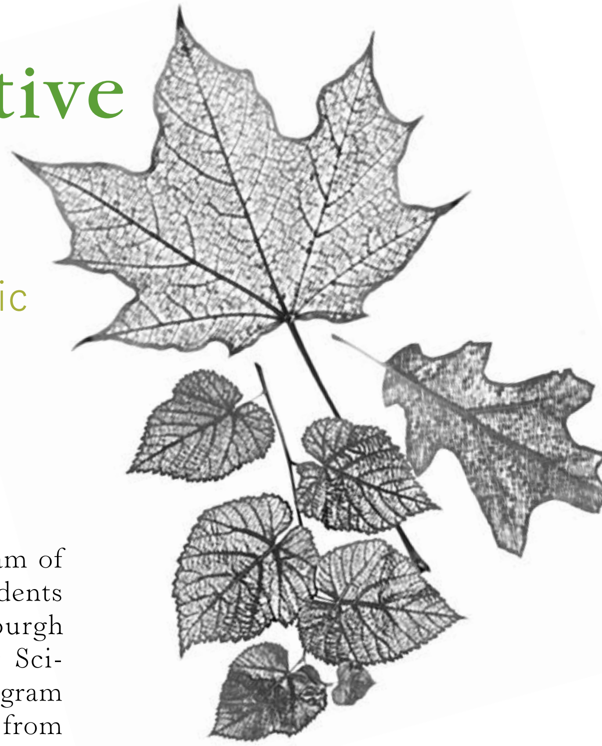
Developing Investigative Skills Purposefully



Thoughtful planning transforms general skills into tools for understanding authentic scientific inquiry.

By Stephen L. Pellathy, John Paul, Jennifer L. Cartier, and Claudia Wittfeldt

Walk into a fourth-grade science class just after the start of the year in Pittsburgh's Public School District, and you will likely find students busy doing rubbings of a variety of materials. Burlap, denim, lace, screening, fencing, and other materials produce different patterns. Getting a quality rubbing requires skill, attested to by the students' hard work. But are students learning an *investigative* skill? And why are they doing rubbings in science class?

Investigative skills involve considerably more than just the general skills (e.g., texture rubbings, weight or length measurements, etc.) that they employ. To be *investigative,* skills must be (1) learned in the context of a big idea or central theme; (2) used purposefully; and (3) employed to obtain data or information. When used in this manner, general skills are transformed into investigative ones, making hands-on activities more like authentic scientific inquiry.

We are members of a team of educators and university students participating in the Pittsburgh Partnership for Energizing Science in Urban Schools, a program in which graduate students from the natural sciences and mathematics work with teachers to help them modify existing curricula to relate to central big ideas in science. As part of our work on this project, we have addressed the issue of helping students develop investigative skills within the context of an introductory science unit for fourth graders. The unit focuses on data-collection techniques and is a component of the district's required curriculum. It contains four hands-on investigations, each involving a different technique: rubbing, carbon printing, chromatography, and reflecting. At first glance, these investigations seem unrelated; however, if students engage with them focused on the three criteria above, the sequence of activities becomes meaningful.

In this article, we discuss the investigations involving rubbings and carbon printing. We describe how we successfully transformed these general skills into investigative skills used in meaningful science explorations. Moving from burlap rubbings to investigating venation patterns takes a game plan, as does transitioning from rubbings to using carbon printing to identify fingerprint patterns. In sharing our approach, we offer a model to transform the skills learned in a science classroom from general to investigative ones.

Identifying the Big Idea

At the core of the process is identifying the big idea of the unit. A big idea in science is a concept, theory, or relationship that can be used to explain phenomena in many contexts. It is not specific to a single system. In our unit, the big idea was the following: "Investigative techniques enable scientists to gather data that is not possible to obtain by use of the senses alone. The choice of technique depends on the properties of the object being investigated and the particular pattern or feature of interest." To develop this big idea, we first read the unit thoroughly and listed the main learning goals (that is, what patterns or ideas should students know at the end of this unit?). Next, we considered what central concept, theory, or relationship might unify these individual learning goals. We consulted our state standards as well as the *Atlas of Science Literacy* (AAAS 2001) to help us formulate our big idea. Throughout our partnership work, we have learned that a given unit may have multiple big ideas—the goal is not to identify *the* big idea but rather to organize the unit around *a* big idea instead of leading students through a series of unconnected experiences.

Establishing a Roadmap

The second step in planning is to create a roadmap for the unit. To begin, first identify the important patterns that students should notice when they are doing each task and describe how these patterns will connect to the big idea of your unit. Then plan how you will make explicit bridges connecting to the big idea. For example, in the rubbings lesson, it was important for students to notice the pattern that some textures are not visible to the naked eye, but become much more pronounced when viewed by way of a rubbing. The instructional materials for the original unit suggested that students make rubbings of objects around the classroom. However, this task did not contribute to their recognition of a pattern (since each student selected his or her own object). Therefore, we replaced this task with a leaf-sorting activity in which students first used visual data and then rubbing data to identify categories of leaves. This enabled them to recognize how the rubbing technique made new information about the venation patterns visible.

Supporting Tools

Once the roadmap is established, the next step is to design or implement instructional tools to support it. Such tools may include vocabulary word walls, graphs, pictures, and concept maps. For example, while students shared their fingerprint types with each other in our carbon printing investigation, a large chart was used to record the distribution of fingerprint types in each class. In this way, each class could see every other class' distribution, opening up discussions about why the average number of each type was the same or different.

We note that there is no *best* tool to support a given activity. The main feature of any tool to consider is whether or not it enables students to organize their data so that patterns are clear, communicate their ideas with one another, and better understand the connection between an activity and the overall big idea of the unit. One strategy that the teachers in our partnership found useful was to modify familiar tools (like concept maps or data tables) within lessons and revisit them throughout the unit. Repetition helped students make connections between investigations as well as to the overall big idea.

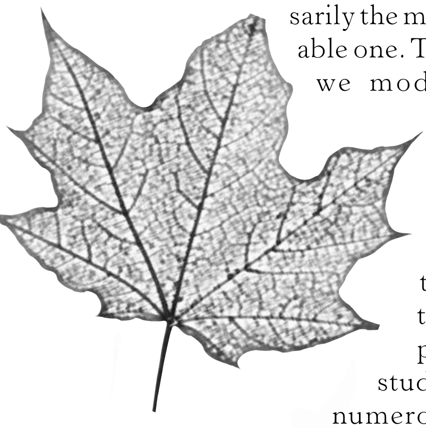
The Investigations

Once the planning is done, it is time to teach the investigations. Keep in mind that skills in these activities require additional focus, explanation, and context to become true scientific investigation skills. Our goal in the first and second investigations was to present rubbing and carbon printing as *scientific* investigative skills that would help the students to explore patterns in naturally occurring phenomena. To accomplish this goal, we needed to make explicit connections to the big idea throughout the unit, emphasizing that students were using various techniques to gather evidence of patterns that occur in nature.

Rubbings

In the rubbings task, students began by placing paper over screening, burlap, lace, and other textured objects. They used a pencil to rub the image onto the paper. When students made rubbings of various objects, they noticed that the quality and pattern of the rubbing was dependent on characteristics of the object they were using.

Usually, the pattern that is revealed when students create a rubbing is readily apparent with a quick observation of the object. So how can the skill of rubbing become more scientific? One approach was to show how rubbings can help us focus on a particular aspect of an object, not necessarily the most noticeable one. To that end, we modified the existing activity to help us highlight leaf venation patterns. We provided students with numerous leaves of three different tree species that had markedly different venation patterns. Because this unit was taught in the fall, the leaves varied in their color (even within a species) from green to yellow to orange and red. First, the students collected data by grouping some of the leaves based on whatever classification scheme seemed most appropriate (e.g., they placed leaves of similar color or similar size together). Next, we mixed the leaves back up and had the students make rubbings of some of the leaves. Then, we asked the students to group the rubbings (rather than the leaves themselves). With color no longer a variable, the students grouped the rubbings based on the venation patterns. In subsequent discussion, we pointed out that an important pattern (venation) that helps group leaves is less obvious while paying attention to other patterns, such as color. Thus, rubbings helped us concentrate on a particular pattern of interest and collect the data accordingly (e.g., how many leaves were *palmate* [radiating from a point], etc.).



Carbon Printing

To build a bridge to the next investigation—carbon printing—and to demonstrate that we use rubbings for a specific purpose, students made rubbings of their fingerprints by placing a piece of paper over their fingertip and attempting to make a rubbing just as they did with the leaves. Did this work well? Of course not! Clearly the rubbings technique, although great for revealing leaf venation patterns, was not appropriate for seeing fingerprints. Rubbings are great for showing texture, and fingerprints do have texture, but a fingerprint's texture is too fine to be seen through that technique. So, we asked students for some ways that we could see fingerprints better. Students suggested that ink or paint would work, which led us to introduce the idea of carbon printing. We emphasized that carbon printing was a technique similar to what they may have seen on TV (but less messy!). Then students tried making carbon prints of their fingertips.

Students used the edge of their pencil tips to make a dark patch of carbon on a piece of paper. Then they pushed their fingertip against the patch slowly with a slight side-to-side rolling motion. Next they placed a piece of clear tape over the fingertip that is covered in carbon. The tape lifts the pattern from their finger. Finally, they placed the tape onto white paper, and labeled which finger was used to make the print. This process was repeated for each finger.

Once students captured their own fingerprint patterns on paper, a whole range of extensions were available to us. We asked, "How do the fingerprints on your hand differ? What general patterns can you identify (e.g., loop, whorls, ridges)?" and "Can we group fingerprints based on these patterns?" Carbon printing was a great technique to see fingerprint patterns and compare them. For example, it was possible to determine the most common fingerprint type in the room when students held up a print of their thumb, something that was not possible when they only held up their thumbs! We also discussed how fingerprints allow us to identify individual people, because everyone's fingerprint is different. Thus, carbon printing is an appropriate technique to gather data on how the fingerprints of various people or groups of people differ.

Assessment

The activities described in the rubbings and carbon printing investigations lend themselves to three kinds of assessments: 1) hands-on skills (How well did a student accomplish the mechanics of the investigation?), 2) understanding of the learning goals of the investigations (Can a student explain why we use these techniques and how they are different?), and 3) integration and extension of the central concepts of the investigations (How well can a student apply what they have learned to new and challenging situations?). We focused most of our attention on the latter two assessments, because these assessments tie explicitly to the understanding of our big idea.

Assessing the hands-on skills of actually doing the rubbings and carbon printing was simple: we looked at student work and determined if they had satisfactorily completed the tasks. All science includes an aspect of meticulous and careful execution of a set of tasks, so assessing if students can accomplish the mechanics behind these tasks is important. However, these are skills that can be honed through repetition and practice, and a student's fluency with these particular tasks will ultimately be of minor significance when compared to the benefits of understanding why they were doing them. Thus, we spent more effort assessing if students had achieved our learning goals for the investigations. Accordingly, we wanted to know if students could identify why they used a particular tool (e.g., a pencil), what the tool and task helped them see better, and what kinds of information did the technique we used allow them to gather. We assessed their understanding through classroom-guided discussion and simple worksheets.

Similarly, to assess students' ability to integrate and expand on the themes of the investigation, we presented students with a new set of tools, techniques, and things that we wished to study. For example, we wished to learn about the differences in the wing venation patterns of insects. We then presented the students with potential tools (e.g., microscope, magnifying glass, pencil and paper, binoculars, etc.) and developed a list of possible techniques (through question and answer) that could be used to study the wing patterns. We also brainstormed about what we might like to learn about the insect wings; the data we wanted to collect. Students who tried to apply only the techniques we had used earlier found the wings too small and delicate to successfully reveal the patterns. These students had learned a technique or two, but did not understand the bigger picture regarding choosing appropriate tools and techniques for a successful scientific investigation. Students who chose tools that were most appropriate (using a microscope and magnifying glass, and drawing what they saw) were deemed to have successfully understood our central learning goal: scientific investigation requires the appropriate tools and techniques to reveal hidden patterns.

With planning, teachers can create deeper connections between hands-on activities and the big ideas that provide coherence throughout an instructional unit, making the science experiences more meaningful.

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Connecting to the Standards

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

Content Standards

Grades K-4

Standard A: Science as Inquiry

- Understandings about scientific inquiry

Teaching Standards

Standard A

- Teachers of science plan an inquiry-based science program for their students.

Resources

American Association for the Advancement of Science (AAAS). 2001 *The atlas of science literacy, volume one*. Washington, DC: Author.

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