Making Sense of Data

Giving students freedom in collecting data helps them develop lasting understanding and solid problem-solving skills.

By Amy Palmeri

Scientists communicate findings in many ways—spoken and written words, charts, graphs, field notes, models, diagrams, images, artifacts. These various representations help scientists organize and disseminate their work, but more important, the chosen format can either contribute to or constrain understanding of their findings.

In classrooms, representational tools and strategies are often considered means to an end rather than tools to make sense of data in a meaningful way. We give students data to graph, telling them what type of graph to use. We give students prototypical examples of living things or types of matter but ask them to sort these into groups whose categories are already provided. We ask students to interpret data organized in tables, stripped of complexity. When and how,

then, do we ask students to collect, organize, and make sense of their own data?

Rather than explicitly teaching students how to record or document data, organize data, or infer, interpret, and communicate ideas emerging from data, I agree with the image of science learning that is advocated in *Taking Science to School,* which suggests that students can benefit from opportunities to determine for themselves the utility and quality of the approaches they use (NRC 2007). The process of making sense of data requires students to (1) identify which pieces of data are relevant, (2) choose which aspects of the data need to be further refined or more clearly defined, and (3) create tools for measuring, quantifying, or describing data systematically (Lehrer and Schauble 2002). In this article, I share three examples of such opportunities from my classroom of prospective early childhood teachers (preK–4). Although the students I work with are adults, the approaches described have been successfully used by my students as they complete field experience in K–3 classrooms.

Moon Observation

The goal of this five-week Moon observation project was for students to notice objects in the sky and to generate conjectures seeking to explain patterns of change in the sky noticed through students' observations. The content goals were integrally tied to key abilities necessary to do scientific inquiry including asking questions, gathering data, using data to construct reasonable explanations, and communicating both the process and the understandings.

I began by asking students to identify trends in the appearance of the Moon (i.e., how the image of the Moon changes and why they think this change occurs). In class, we generated a list of things students might note as they observe the Moon. Students suggested shape, size, color, and brightness, and I suggested noting the weather, time, and location.

Many times, students start looking for the Moon only after the Sun goes down, so they may be less likely to see the Moon. To avoid this problem, I provided students with data they could use to determine when they might be most likely to see the Moon—a chart showing moonrise and moonset times (see Internet Resources).

Gaps or inconsistencies in the data—for example, bad weather preventing Moon observations or explanations that the Moon could not be seen because the sky was cloudy when in reality the Moon was not out at the time of the observation—can be used to help students make sense of the messiness of real/authentic data. I purposefully do not define or control variables at the beginning of the inquiry, so that it becomes something of a necessity to the students, rather than something learned in the abstract. Students can also be challenged to fill in the gaps or reconcile inconsistencies in the data by being encouraged to ask questions and generate conjectures to refine and explain the observations.

For the first couple of weeks, students focused on recording their own data in Moon logs. After this initial period, students were asked to post their data (size, shape, color, and brightness of the Moon, weather, and time of observation) around the room on large easel sheets. It was soon obvious that there was little uniformity in the form or descriptive language used in the data, and students found it difficult to talk with each other about or interpret the collective data. For example, students variously described the color of the Moon on a given night as pale yellow, light yellow, yellow, and bright white. Students quickly realized that one person's "pale yellow" may or may not mean the same thing as another person's "light yellow." Students were challenged to unify the ways in which different individuals recorded data, thus the need to control variables. When it came to discussing the size of the Moon, students created tools allowing them to measure the apparent size of the Moon using standard objects (a piece of paper from a three-hole punch, a dime, quarter, Ping-Pong ball, etc.) held at arm's length. Similarly, after noting the various ways individuals drew the Moon (e.g., some chose to color the illuminated part, others the nonilluminated portion), students proposed that we consistently color only the illuminated part of the Moon.

The Moon observation study helped students develop strategies for collecting, representing, and making sense of observational data. Students made decisions about what data to collect and how to collect and record data, generated shared procedures to enable pooling of the data, and raised questions about the Moon and how the image of it changes across time.

As a result of these explorations of student-generated data, students began to ask more specific questions about the Moon. For example, after sequencing drawings of the Moon on a given night by time of observation, students noticed that the illuminated portion of the Moon shifted its position during the course of the evening, and they began to wonder why. Discussing and analyzing their own observations and data allowed questions about content to naturally arise.

Animal Classification

To help my students learn about the variety of organisms that make up the animal kingdom, I asked them to collect and organize a data set composed of lists of animals. In addition to addressing life science content focused on the characteristics of organisms and the environments in which animals can be found, such an exercise gives students opportunity to use the process skill of classification.

Each of my students asked 15 friends or family members to each generate a list of the first 20 animals that come to mind. The nature of the data collected (lists of animals) requires one to organize the data—the lists do not provide one with much insight about a general conception of animals. Students then created ways of representing the concept of *animal* as reflected in their data. Because the lists generated capture a narrow window into the wide array of animals that make up the animal kingdom, the data and conceptions of animals that emerge from the data provide a wonderful impetus for exploring the concept of animals in greater depth.

My students listed and tallied numbers of specific animals mentioned, and they generated a variety of ways to sort the animals, such as number of legs (e.g., 0, 2, 4, 6, 6 or more), type of outer covering (e.g., fur, scales, feathers, skin), where one is likely to find the animal (e.g., zoo, jungle, desert, water, pets), or type of animal (e.g., mammal, insect, bird, invertebrate). Many of their approaches are similar to how children might sort the animals and enable them to tap into their varying degrees of prior knowledge about animals.

My students found these varied ways of organizing data useful in helping them represent the image of animals reflected in their data. However, they found some organizational approaches potentially problematic: If they expect categories to be mutually exclusive, they must reconsider the costs and benefits of overlapping versus mutually exclusive categories (e.g., should they place a gorilla in the zoo or jungle category?). In doing this same task with children, my students have found they use overlapping categories as well and that in reconciling this, the children enter into debates regarding the merits of certain ways of grouping animals.

Generating authentic data in this way is beneficial because it creates an opportunity to explore many different organizational strategies and the benefits and limitations of some strategies in terms of helping one develop a deeper and more robust concept of animals. Thus, classifying the data and critiquing various organizational strategies leads to greater understanding of both the skills needed to engage in scientific inquiry and content related to animals as living things. For example, after students generated a concept of *animal* reflected in their data, some recognized that the data were biased toward vertebrates in general and mammals in particular. They began to question whether other organisms, like insects or worms, are animals. I was able to gain insight into the scope and depth of my students' prior knowledge about the variety and classification of animals as I saw the ways in which they sorted their data and listened to the questions they raised about the data. These insights helped frame how I introduced a more formalized study of animals, taking my students' initial thoughts and questions into account.

As the teacher, based on the way some students organized their data (e.g., mammals, birds, or insects), I can create a situation in which my students learn more about the scientific classification of animals. I could just as easily select organizational strategies focused on characteristics of different animals to create a context in which my students learn more about the form and function of various body structures and how organisms adapt to and interact with their environments.

Plant Growth Learning

To explore life cycles and characteristics of organisms, my students observed and documented the growth of an amaryllis bulb. *Hippeastrum* spp. bulbs, commonly (but inaccurately) called "amaryllis," are toxic plants that can cause illness if ingested. Consult a safe plant list when choosing bulbs to grow in an early elementary classroom.

CAUTION

The project focused on plant growth, growth rate, and features, but these were explored using the process skills of observation and measurement (naming and noting the timing and growth pattern within and across different parts of the plant).

Students took daily measurements and made drawings illustrating emerging plant features. Over the course of the project, students consistently measured and noted the height, in centimeters, of the tallest part of the plant. This was necessary at the beginning of the project, as students were not able to identify whether the initial growth was leaves or stem. As plant parts differentiated and could be labeled, students continued to measure the tallest part of the plant, but many also measured and noted the tallest leaf and stem. Students also counted the number of leaves, stems, buds, and flowers as indicators of growth. Students regularly shared observations and measurements, making variation across individual plants apparent. As they began to name parts of the plant, we confirmed that we were naming parts consistently and accurately.

Many of my students chose to represent plant growth using a standard graph of change in plant height over time. Because they were dealing with authentic data, students often finished their graphs and puzzled about an aspect of the graph that did not make sense. Specifically, they sought to explain why their graph showed a typical S-shaped growth curve, but at some point the data plotted on the graph suggested that the plant had decreased in height. Applying their knowledge of growth, they were compelled to look back at other data to explain why, given the graph, it appeared that the plant had decreased in height.

They reflected on their criteria for measuring (the tallest part of the plant) and their careful drawings of the plant at various times and explained this glitch in the data by describing how the form of the plant changes as the bud (which grows nearly upright from the stem) begins to tilt downward as it opens and the flowers emerge (a peculiarity of this plant).

In this example, students were encouraged to think about other dimensions of growth and to consult a range of data to make sense of and explain an anomaly in the graphical representation. The variety of measures and the ongoing sharing and discussion of the data enabled students to develop a robust understanding of the concept of growth: They questioned whether height is the only or best indicator of growth and they sought to find relations between how quickly a plant increases in height and the number of leaves, stems, and buds that form. As we shared data, I asked clarifying questions—Is this the only way to measure growth? Why might two different plants vary so much in height?—further supporting students' conjectures, and data-based explanations. In reflecting on their work with elementary school children, my students have found their students to be more readily open to considering the concept of growth in more multidimensional ways than they often felt that they were willing to do.

Assessment

When engaged in the examination of authentic questions, teachers have many opportunities to formatively assess students' content understanding as they simultaneously facilitate and support students' data collection and analysis skills. For example, in the animal example, a teacher is able to identify and then challenge learners who present a narrow understanding of animals.

I also created final projects that reflected the aspects of scientific inquiry that are at the heart of the explorations. On the Moon project, students represented and explained an aspect of the Moon image that changed during the course of the observation period. For the animal project, students created a representation of the concept of animals based on their data—often narrow—and then compared this representation to the variety of animals in the animal kingdom. In the plant growth project, students created representations of an aspect of their plant that they found intriguing and used their data to explain their understanding of the plant and its growth. Criteria for evaluating these open-ended final projects focus primarily on the following questions:

- How well do students describe and explain the phenomenon they are representing?
- To what extent do they draw on their data (or other data generated and shared during the project) to describe, quantify, or explain the phenomenon?
- To what extent does their data support their explanations regarding this change?
- What is the strength of their argument?
- When appropriate, to what extent does the explanation align with accurate scientific ideas?

The focus on process provided insight into students' abilities to engage in scientific inquiry, and their conclusions gave insight into both the depth and scope of their understanding of content.

Final Thoughts

Providing opportunities for students to grapple with collecting and organizing data, struggle with how to represent and communicate ideas emerging from the data, and consider the alignment of these ideas with the science content being learned is reflective of authentic inquiry and supports the development of scientific understanding. The aforementioned examples show how students can learn powerful ways of documenting inquiry while at the same time make use of this documentation to support the development of key scientific understandings. ■

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References

Lehrer, R., and L. Schauble. 2002. *Investigating real data in the classroom: Expanding children's understanding of math and science.* New York: Teachers College Press.

National Research Council (NRC). 2007. *Taking science to school: Learning and teaching science in grades K–8.* Washington, DC: The National Academies Press.

Internet Resource

Complete Sun and Moon Data for One Day
http://aa.usno.navy.mil/data/docs/RS_OneDay.php

Connecting to the Standards

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

Teaching Standards

Standard A:

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

Content Standards

Grades K–4

Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry

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