Draw-a-Scientist/Mystery Box *Redux*

Two classic activities are tweaked to help students understand the nature of science.

By Ann Cavallo

- *Wash your hands often to reduce the risk of contracting the flu.*
- *Earth is approximately 4.5 billion years old.*
- *The atom is composed of smaller particles.*

Today's students hear a constant stream of such statements from news media, parents, and teachers; statements purportedly originating from scientists. But, have your students ever wondered about the scientists who make such profound statements? Do they wonder how scientists find out such things? How do scientists decide which findings to report to the rest of the world? Who are these scientists anyway, and what exactly do they do?

Students will have responses to these questions when they have the opportunity to experience the nature and processes of science for themselves. With this purpose, I use the sequence of activities described here with students at the very start of the school year. The activities are designed to help students better understand the nature of science (NOS) and to help establish the format and level of critical thinking that will be used in inquiry-based science throughout the year. The described activities have been successfully implemented with students in grades four through six to help them reflect upon and better understand NOS.

The mechanism for students' development of thinking is science inquiry. The activities described here are offered as a way to jump-start the mechanism for inquiry-based science learning in the classroom and throughout the students' lifetime.

Who Are Scientists?

On the first day of school, I give students a blank sheet of paper. On one side I ask them to draw a scientist, as done in the Draw-a-Scientist test (Mason, Kahle, and Gardner 1991). On the other side of the paper I ask students to make a list of three words/short phrases that respond to the question "What is science?"

When students are finished, we first discuss their creations, prompted by questions that may reveal stereotypes they hold about scientists. Students respond to a show of hands to my questions, including, "How many of you drew a male scientist?" "How many drew a scientist with messy or no hair?" "How many drew their scientist wearing glasses or goggles?" "Who drew their scientist with strange clothes (e.g., pants too short)?" "Who drew their scientist wearing a pocket-protector?" "How many drew a lab coat on their scientist?" "How many drew test tubes or other physical science materials—and what were they?" We have a lively discussion about the prevailing image of a scientist as a lonely, perhaps a bit "mad," white, elderly male, with glasses, messy hair, and unstylish clothing. We discuss how this view of scientists is often supported by the media. I then ask students questions such as, "How many drew a female scientist?" "Who drew a scientist of an ethnicity other than their own?" "How many drew the scientist with animals or other life science materials?" "Did anyone draw their scientists with other people?" "Did anyone draw a child as a scientist?" "Did anyone draw themselves as a scientist?" "Why or why not?" Using the students' responses to these and related questions, we work toward expanding our views to include everyone, including children and adults, individuals of diverse ethnicities and gender, and most importantly, the students themselves as scientists.

In doing this activity, I find that many stereotypes of scientists prevail. In one study where I used the Draw-a-Scientist test with 150 students, only five drew their scientists as female. Therefore, to help expand students' views of scientists, we look to past and present scientists of diverse ethnic, ability, and gender compositions. One of my favorite examples is the true story (circa 1944) of Vivien Thomas (an African American male), Alfred Blalock (a white male), and Helen Brooke Taussig (a hearing impaired, white female) who worked together, each overcoming various obstacles, to conduct research and then successfully perform the first heart surgery on an infant to remedy a condition called "blue baby" syndrome. We discuss or I assign the students to research each individual's life story and scientific accomplishments. Students find, for example, that Helen Taussig was originally denied acceptance into medical school; and Vivien Thomas was at first not allowed in the operating room because of his race, but Alfred Blalock insisted upon his presence. This landmark research and surgery would not have succeeded without the entire team working together. Real-life stories such as this help expand students' views of scientists and their work and to realize science is for all.

Students then turn their paper over and we construct a list on the board of all of the words they used to respond to the question, "What is science?" The words or phrases students typically offer include *discovering, experimenting, exploring, concluding, predicting, finding out something about the world,* and *collecting information/data*. Students are asked to read and find what is in common among the words (i.e., what kinds of words are these, grammatically speaking?). The students respond that these words are action words or verbs—all describe something we actively do. Thus the lesson learned from this list is that science is an active process. We use all of these actions to learn about the world and how things work. We then discuss that, to be true to the discipline of science in our class, we use the active process of science to learn about the world and how it works. In our science class, we will use the following (adapted from Camins 2001):

- Observing: Using the senses to get information
- Communicating: Talking, drawing, acting
- Comparing: Pairing, one-to-one correspondence
- Organizing: Grouping, seriating, sequencing
- Relating: Cause and effect, classification
- Inferring: Classification, if/then reasoning, developing scientific laws
- Applying: Developing strategic plans, inventing.

What Do Scientists Do?

This next investigation is based on the well-known activity called Mystery Boxes, which originated from the Science Curriculum Improvement Study (SCIS) (Knott and Their 1993). Before the activity, I purchase 10 jewelry-type boxes at a local craft store. In each box I place one or a few of one kind of item, such as a pencil eraser in one box, three toothpicks in another box, and a pinch of rice in another box. I then number each box and tape each closed with clear packing tape. With students working in groups, I distribute one mystery box to each group of students. I then set the scientist teams to work with the following instructions.

- Without opening the box, make and write observations about what is in the box.
- Draw a conclusion of what you believe the item in the box to be, based on your observations.
- Report your observations and conclusions to your colleagues.

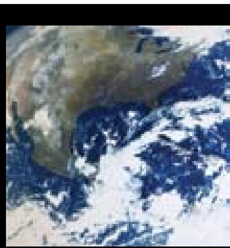
The groups work together to make specific observations and discuss what they predict is the item in the box. The students find they can only use their sense of hearing to make observations, though many try to use their senses of smell, touch, and sight (trying with marginal or no success to feel or see through the box). The students record their observations and conclusions in a table (Figure 1), which I display on overhead transparency or large poster paper.

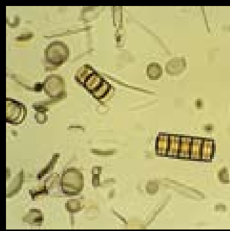
I then call each scientist team up to the front to present their research to the class of scientists by either selecting a spokesperson or working as a group to report the team's findings. The teams state their observations and conclusions about their box and field questions from the audience (e.g., "Our object made a clicking noise when it moved, so we think it's a paper clip."). A student question to the research group is typically something like, "How do you know it is a paper clip and not a nail or something like that?" The group would answer with more detail, such as

Figure 1.

Mystery box observations.

Box Number	Observations	Conclusions
1	Small, lightweight, rolls, we do not it is think spherical—perhaps cylinder shape	Push pin
2	Single unit, lightweight, about ¼ size of box, fights movement	Wrapped piece of candy
3	Light, not crowded, rolls to every corner, round, size is less than box	Beads
4	Not round, flat, obstacle in the way, long, hard to get from one end to other	Paper clip
5	Flat, slides, lightweight, metal, solid, small, two objects	Two dimes
6	Small, light, single object, flat, wide	Plastic or wood rectangle
7	Light, single object, small, muffled sounding, no smell, shake hard, slides	Cotton swab
8	Flat, takes large incline to move, has weight, about a gram, sounds metal	Washer
9	Rolled, slides, more than one object (likely two), very light	Ball bearing
10	Small marble size, seems circular, rough edges, hollow, tumbles, seems hollow at one end, not the other	Eraser for pencil





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that the object sounded like it was sliding and not rolling or that when they turned the box onto its side it sounded like a flat object.

Once all teams have presented, my questions begin. I first ask them difficult questions that all scientists need to confront, such as, "Are you willing to stake your international reputations on your findings and your life's work by publishing your results in a scholarly journal?" "How sure are you that there is indeed a paper clip and not something else in the box?" Most students say that they would not be ready to publish their work yet, because they are not absolutely sure. I ask the groups to describe the "experiments" they conducted on their boxes. The students describe that they shook the box multiple times, they rocked it back and forth slowly and then quickly, they had each person in the group try it, they worked through disagreements, and they decided together on what they would conclude was in the box. I ask the groups what other predictions they first made about the item in the box, of which I find they have many to share. For example, at first they may have thought the object was a safety pin, but after shaking the box, believed a safety pin would make a different sound than a paper clip because it is heavier/thicker on one end than the other.

I then ask the class, "How could we put forward our conclusion of what is in the box with more certainty and conviction without opening the box?" "What would we need to do to obtain more data that adds to what our team concluded, to be closer to explaining what the object might be?" One idea students offer is to take an empty box that is the same as the original box, place the object we think may be in the closed box in the new, empty box (e.g., paper clip) and compare the sounds and movements made between the two boxes. I applaud their thinking and we discuss that scientists do exactly that—they make models to try to imitate/replicate the phenomena they are studying and add insight to their findings. Students often offer the suggestion that we "switch boxes" that is, we give our box to another research team and let them independently conduct experiments. We then compare their findings with our own. The more often the box is tested and leads to the same result, the more support we have for our initial conclusion. If the findings of other research teams do not match our conclusions, it is time to rethink our research and conclusions. Perhaps with more testing we may even change our theory from what we first thought was in the box. Again, the processes they describe are compared to how scientists work in the real world.

Students also often suggest that we take the mass of an empty box plus the mass of the object we think is in the box to see if the masses are equal to that of the unknown box. We discuss the need to measure the mass of the items several times to calculate an average mass, because only one value would not be representative enough of the item (e.g., the mass of each paper clip could slightly differ). When students suggest using a scale/balance to find the mass of the objects, we discuss scientists' use of instruments to help them extend the observations they are able to make with their senses alone. I ask them to name some other instruments scientists use and the sense that is being extended. The students usually name the microscope or telescope to extend our vision and mention the possibility of using motion detectors or instruments that may measure sound waves. Such examples provide only a glimpse of the interesting and lively discussions that emerge from our Mystery Box investigation.

After all student teams have presented and discussed their mystery box findings, they invariably ask what is really in each box. I compare this question to scientists' work in university and industrial settings. "Do we (scientists) really know what a black hole is like?" "Are we absolutely sure, without a doubt, what an atom is like?" "How can we truly know?" "Could some finding be brought forth tomorrow that would change our current thinking about some scientific theory?" "Has a shift in scientific theory/understanding ever happened in the past?" These questions provide the opportunity for me to introduce examples from the history of science, such as the Earth-centered versus Sun-centered view of the solar system. When I cite these examples, students begin to realize that new discoveries change how we think and what we currently know. The examples also lead students to better understand that science is dynamic and tentative, rather than fixed and static and that through continued inquiry, scientific understandings we hold today may be different in the future (Flick and Lederman 2006).

Still the students prevail in wanting to know what is in the boxes. So, I reuse the boxes from year to year and keep the previous classes' observations and conclusions reported in Figure 1. I post the findings made by the students' contemporaries in other classes for comparison. With this information, we can now discuss which of their predictions garners more support based on previous findings and which boxes need more research due to inconsistent conclusions. At the end, I may read them the list of what was actually in the boxes (purely for their amusement), but we still do not open them. I ask them, by knowing what it is, they now know more about the object, but do they actually know for sure what it looks like or is? For example, if I tell them a pencil eraser is in Mystery Box 3, do they know everything about it (e.g., its unique dents, marks, color)? No doubt the more information we have about something, the more confidence we have in our conclusions, which is how theories are determined to become scientific laws. However, gaps in our knowledge are always present, and though changes may be more subtle, even scientific laws as we now know them can change.

Connecting to the Standards

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

Science Teaching Standards

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

Standard B: Teachers of science guide and facilitate learning

Content Standards

Grades K–8

Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Standard G: History and Nature of Science

- Science as a human endeavor
- Nature of science
- History of science

Evaluating Learning

To evaluate learning, students are given the mystery boxes again or new mystery boxes. They review the processes they engaged in during the mystery boxes activity and this time document each science process they used, writing, for example: research questions, predictions, experimental design, observations, inferences, conclusions, and additional research questions. Students record their data on an expanded table like that shown in Figure 1 (p. 39), with added headings and columns for each of the science processes. I have students work on this exercise individually or in groups and provide differing levels of guidance depending on their age and experience. Alternatively, I often conduct this exercise aloud with the class, simply as an informal way for me to review and to gauge the class's understanding of the scientific processes gained from the activity.

In addition, I ask students to draw scientists again at the end of the school year. This time, it is hoped students will draw a broader, less stereotypical image of scientists and even draw themselves engaged in science investigations with a group of their friends. Our students need to view themselves as scientists every day and realize that they already have the skills and thought processes necessary to be successful in the field. If teachers provide opportunities for their students to experience science as an active process, they will further refine and extend their skills and thinking abilities to become the future scientists our society so desperately needs. ■

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