THE CASE OF THE MISSING MUSIC

An outreach activity sparks interest in science and density.

By Mark Mechelke and Allissa Dillman

From Scooby Doo and Nancy Drew and the countless other detectives that fill children's bookshelves and television programs, it is clear that children are fascinated with solving crimes. As a chemistry professor who performs outreach activities at local elementary schools, I exploited this interest in mysteries as a method to spark curiosity in science. I developed an outreach activity in which students solve a mystery using density and fingerprint analysis. As they do so, they use science processes and also begin to develop some key understandings about properties of materials, namely that *density* is a characteristic property of a substance that can be used to identify it. While the experience described here is done with fourth-grade students, I have conducted the activity successfully with children in grades four to six, and each time I have found it to be an excellent way motivate students in science.

Density Background

To appreciate the activity, students must first understand the concept of *density* and how a density column works. Density is the amount of material (its mass) divided by how much space it takes up (its volume). Essentially it is how much weight is packed into a volume. To introduce these concepts, I begin with a demonstration using water, vegetable oil, and ice. "What happens when you place ice in water?" I ask. *(The ice floats because it is less dense than water.)* "What happens when you place ice in vegetable oil?" (*The ice sinks because ice is denser [more dense] than vegetable oil.)* Students may confuse weight (or how "heavy" something is) with density.

Figure 1.

The Case of the Missing Music worksheet.

Objective: To use density columns and fingerprint analysis to solve a crime.

The Crime: Two CDs, *Rocking to the Oldies Parts 1 and 2*, were stolen from my house.

Victim's Statement: I recently invited six friends over for a cooking party. We spent the evening talking about chemistry and making a chocolate cake from scratch. To add to the atmosphere of the party, I placed my favorite CD, *Rocking to the Oldies Part 1*, in my CD player. The evening went by quickly. We made the cake as a team. Friends A and B were responsible for adding the flour. Friends C and D were in charge of adding the baking soda. Friends E and F spent almost all of their time making the chocolate frosting from powdered sugar. The cake was delicious. When my six friends left at about 11 p.m., I realized that not only was my *Rocking to the Oldies Part 1* CD missing, but the case to my *Rocking to the Oldies Part 2* CD was on the floor, and that CD was missing also. How can I ever throw a rocking cooking party again without my two CDs? One of my six friends must have taken the CDs. Please help me get my CDs back!

The Evidence: Two pieces of evidence were found at the crime scene. An unknown white powder was found near the CD player, and fingerprints were found on the empty CD case.

Police Report on How to Solve the Crime:

1. The identity of the unknown white powder found at the scene of the crime must be identified. This will be accomplished using a density column. Different solids have different densities. *Density* is a measurement of how much something weighs per unit volume. It is anticipated that the powder left at the crime scene is either flour, baking soda, or powdered sugar. The powder should help to narrow down the suspects in the following manner:

Suspects	Powder Used to Make Cake
Friends A and B	Flour
Friends C and D	Baking Soda
Friends E and F	Powdered Sugar

2. Once the suspect list has been narrowed down to two of the friends, one of the fingerprints found on the CD case will be lifted and compared against the fingerprints of all of the suspects. The fingerprint will ultimately determine the culprit.

(To illustrate the difference, have two items that are identical in mass but very different densities. One should float, the other sink. Demonstrate that while they are the same mass, one will float. For example, take a large marshmallow. Note the mass and size [perhaps by measuring its dimensions and calculating the volume]. Then squish the marshmallow into a tiny ball. It should still have the same mass, but now it is much smaller in volume.)

Next, I ask students what will happen when water is placed in vegetable oil. *(The water sinks.)* I illustrate this point by pouring water into a clear glass containing vegetable oil. I then tell the students that what I've made is an example of something called a *density column*. Density columns are made from liquids that have different densities. The liquids form layers, and these layers can be used to determine the relative densities of solids. In a density column, solids will sink until they hit a layer that is denser (more dense) than the solid itself.

I demonstrate this idea by placing ice in the cup containing vegetable oil and water. What happens to the ice? *(Ice is more dense than vegetable oil and less dense than water, therefore it sits at the interface between the two layers.)*

At the end of the density column demonstration, I mention that density columns are used in forensic laboratories to analyze different types of soil that might be found at a crime scene. Soils can consist of a variety of different components. For example, a type of soil called *loam* consists of a mixture of clay, sand, and silt. These components have different densities. A density column performed on loam will separate these three components into different layers of the column. This type of analysis allows forensic scientists to match soil samples found at a crime scene with, for example, the type of soil found in a suspect's backyard. Then, I tell the students that *we* are going to use density columns to help solve a crime, The Case of the Missing Music, and I distribute a handout (see Figure 1) so that they can read along when I describe the crime.

The Case

Two CDs were stolen from my house! Six friends recently came over for a cooking party, and I put my favorite CD (*Rocking*

Figure 2.

Density Column worksheet.

1. You are going to be working as a group of four during this part of the activity. Each of you is responsible for making one density column and for testing one of the solids.

2. To make a density column, pour 10 mL of corn syrup, 10 mL of glycerol, 10 mL of dish soap, and 10 mL of isopropyl alcohol—in that order—into a graduated cylinder. You should see four distinct layers.

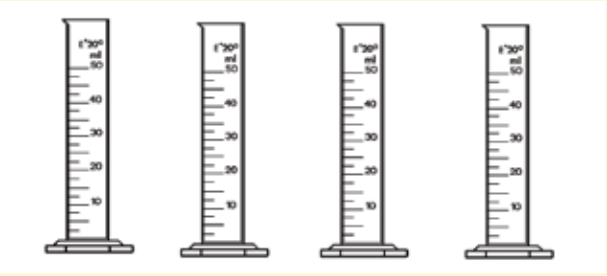
Question 1: Which liquid is the most dense?

_____

Question 2: Which liquid is the least dense?

_____

3. The first solids you need to test are the three known white powders—flour, baking soda, and powdered sugar. Add these solids one at a time so that everyone can record the results. On the graduated cylinders shown on this worksheet, draw in the four layers of the density column (at 10 mL, 20 mL, 30 mL, and 40 mL) and then clearly mark with a pencil where each solid sits in the column.



4. Once you have added and recorded the data for all of the known white powders, add the unknown powder into the last density column. Clearly mark with a pencil where the unknown powder sits in the column.

Flour Baking Soda Powdered Sugar Unknown

Question 3: What powder is the most dense?

_____

Question 4: What powder is the least dense?

_____

Question 5: What is the unknown powder?

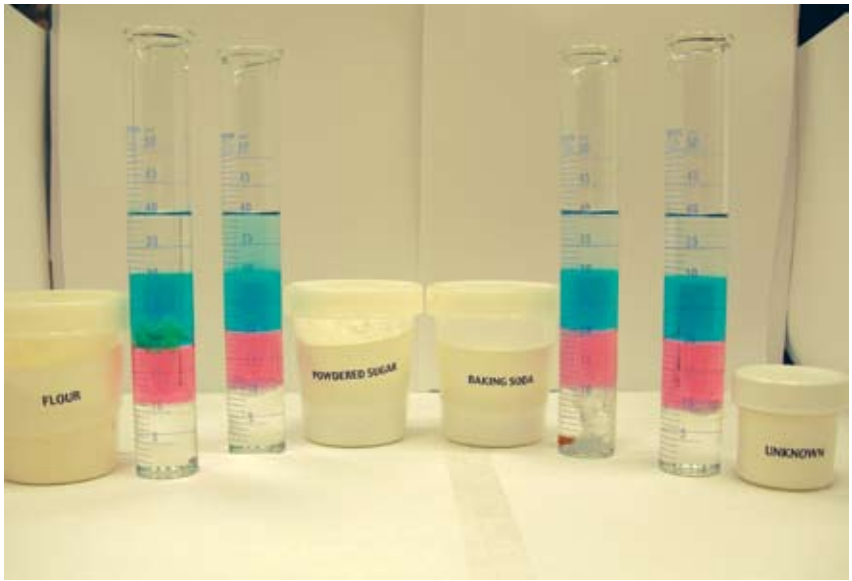
_____

Question 6: Who are the two major suspects in the investigation?

_____

to the Oldies Part 1) into the CD player. We spent the evening talking about chemistry and making a chocolate cake together from scratch. Two friends (A and B) added the flour; two friends (C and D) added the baking soda; and two friends (E and F) made chocolate frosting from powdered sugar. The cake was delicious. When my friends left, however, I realized my *Rocking to the Oldies Part 1* CD was missing, and the case to *Rocking to the Oldies Part 2* was on the floor, and that CD was missing, too! One of my friends must have taken the CDs! Two pieces of evidence were found at the crime scene: An unknown white powder was found near the CD player, and fingerprints were found on the empty CD case.

Help me find the culprit!



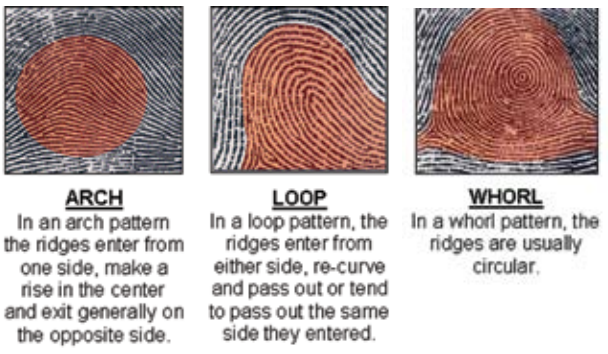
PHOTOGRAPH COURTESY OF THE AUTHORS

Determining the identity of an unknown powder using density columns helps narrow the suspect list.

Figure 3.

Fingerprint worksheet.

1. Fingerprints have three basic pattern types. There are loops, whorls, and arches. Pictures of these three pattern types are shown below.



Source: Federal Bureau of Investigation *(www.fbi.gov/hq/cjisd/takingfps.html).*

2. The fingerprints of all six suspects (friends A, B, C, D, E, and F) are shown below. Identify them as either loops, whorls, or arches. (These are to be added by the teacher.)

Friend A	Friend B	Friend C
_____	_____	_____
Friend D	Friend E	Friend F
_____	_____	_____

3. Place your right thumb on an ink pad and make a fingerprint of your thumb in the square below. Two boxes are provided in case your first fingerprint attempt does not work.

Trial 1 | Trial 2 (only if Trial 1 did not work)

4. Is your right thumbprint a loop, whorl, or arch?

_____

5. Lift a fingerprint off of the CD case by using a magnetic wand, magnetic fingerprinting powder, and tape. Place the lifted fingerprint in the box below. Again, two boxes are provided in case your first fingerprint lift attempt does not work.

Trial 1 | Trial 2 (only if Trial 1 did not work)

6. Is the lifted fingerprint a loop, whorl, or arch?

_____

7. Based on the information above, who stole the two CDs?

_____

Part One: Identifying the Unknown Powder

In the first part of the experiment, students use a density column to identify the unknown powder found at the crime scene. To make the density column, students pour 10 mL each of corn syrup, glycerol, dish soap (such as Dawn), and isopropyl alcohol into a 50 mL graduated cylinder. Students should wear chemical splash goggles when working with liquids.

To make this work in the classroom, we have students push their desks into groups of four. Each group of four is given one small bottle of corn syrup, glycerol, dish soap, and isopropyl alcohol. Red food coloring was added to the glycerol to add color to the density column. The corn syrup is added first because it is the densest liquid, followed by the glycerol, dish

soap, and isopropyl alcohol, which is the least dense. Students record their data and observations on the Density Column Worksheet (Figure 2, p. 40).

First, students test the three known solids: flour, baking soda, and powdered sugar. Reinforce the idea that these are the ingredients of the cake that the suspects were baking. Each student in the group tests one of the solids in the column, so designate who is going to test the flour, baking soda, powdered sugar, and the unknown powder. The unknown powder will be tested after the data for the three known solids has been recorded.

When the tests are conducted, students will observe that baking soda is the most dense and sinks to the bottom of the graduated cylinder. Powdered sugar initially comes to rest just below the dish soap/glycerol layer, but after approximately five minutes, it slowly settles to the bottom of the glycerol layer. The flour lies on the bottom of the dish soap layer, just above the glycerol.

Next, students test the unknown white powder found at the scene of the crime (I use powdered sugar as the unknown white powder). Once students determine that the unknown is powdered sugar, they will have narrowed the suspect list down to two people, friends E and F. Make sure the students fill out the worksheet as they complete the experiment, stressing how recording observations is a key part of performing good science. Once the suspect list has been narrowed down to two friends, students can move on to Part Two and lift a fingerprint found on the CD case and compare it against the fingerprints of all of the suspects. The fingerprint will ultimately determine the culprit.

Part Two: Fingerprints

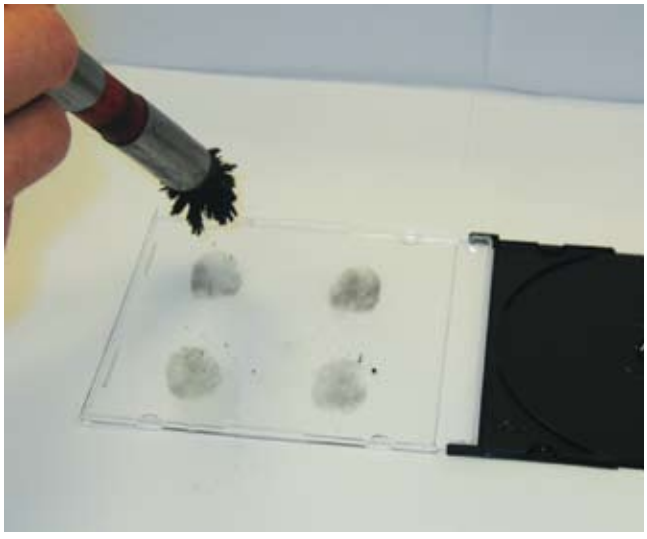
First, discuss the basic fingerprint patterns: loops, whorls, and arches (see Figure 3, p. 41, for examples). A loop pattern looks like the loop when you are tying a shoelace. Loops occur in about 65% of all fingerprint patterns encountered. A whorl pattern looks like a whirlpool. Whorls occur in approximately 30% of all fingerprint patterns encountered. An arch pattern looks like an arch. Arches occur in approximately 5% of all fingerprint patterns encountered.

Distribute the Fingerprint Worksheet (Figure 3), and have the students identify the fingerprints for friends A through F as loops, whorls, or arches. When I conduct this activity, I have colleagues generate fresh prints for the worksheet using an ink pad from an office supply store. Using fresh prints ensures that the fingerprint samples look alike. Ideally, all three types of fingerprint patterns (loops, whorls, and arches) should be represented. Friend E (the culprit) is my fingerprint, the one that students will lift from the CD case. (Be sure to put your thumbprints on the cases before class.) It works best to have four thumbprints on each CD case. That

Magnetic Fingerprinting Wands

The magnetic wands are made by duct-taping a cow magnet onto an approximately 20 cm wooden dowel. Place a plastic sheath (e.g., disposable test tubes such as VWR 17×100 mm culture tubes [see Internet Resources]) over the magnet before use, otherwise the magnetic powder will stick to the magnet and you will not be able to get it off. Wrap four or five layers of duct tape approximately 2.5 cm up from the bottom of the casing. This will knock the magnetic powder off the sheath when you remove the magnet, allowing you to recycle the powder.

Cow magnets work best for making the magnetic wands. Their shape allows you to connect them to a dowel and also allows you to protect the magnet with a plastic sheath (in this case a plastic test tube). The strength of the magnet is also important. It has to be strong enough to pick up enough magnetic powder to make a brush but weak enough so that some of the powder can be distributed over the fingerprint. The cow magnets can be purchased online or at farm supply stores. The 3-inch Alnico cow magnets work well. (See Internet Resources at end of article for links to suppliers that carry the necessary materials.)



PHOTOGRAPHS COURTESY OF THE AUTHORS

Dusting for fingerprints with a magnetic wand.

way, each group of four students then needs only one CD case for each student to have a turn at lifting a fresh fingerprint. (To make a good thumbprint, rub your nose with your thumb and then firmly place your thumbprint on the CD case.)

Lifting Fingerprints

Once students can distinguish between the basic fingerprint patterns, have them create their own right thumbprint using an ink pad in the box provided on the Fingerprint Worksheet and identify their fingerprint pattern. When they have added their print to the worksheet, they are ready to lift a thumbprint from the CD case.

Give each group of four students an empty CD case with your thumbprint (Friend E) on the inside cover. To lift the fingerprint, the students will use black magnetic fingerprinting powder (see Internet Resources) and a magnetic wand in plastic sheath (see p. 42 for instructions on how to make the wand). This setup is good for classrooms because the quality of the print lifted is usually good, and the powder can be reused over and over; a 16-ounce bottle should last indefinitely.

To lift the print, have the students pour a small amount of magnetic powder on top of the latent fingerprint (enough to cover it) and place the magnetic wand above the powder. The wand will pick up the powder and make a broom, where the wand is the handle and the powder is the brush. The students then use the broom to gently sweep the surface of the CD case over and around the fingerprint. The fingerprint should turn darker as some of the magnetic powder adheres to the oil of the print. Once the print is dark, students place the magnetic powder back in its container by pulling the magnet out of the plastic sheath while holding it over the bottle. At this point, students carefully place a piece of transparent tape over the print. Students then smooth down the tape tightly, leaving one corner up so that it can easily be taken off. When the tape is removed, the fingerprint pattern should be fixed on its surface. The students place the lifted fingerprint in the box provided on the worksheet. What pattern is the lifted fingerprint? The students should now be able to solve The Case of the Missing Music.

A Case When Crime Pays

During the course of this activity, students gain an understanding of density as a property of a substance. They are also exposed to the field of forensic science during the course of the experiment through the introduction of fingerprint analysis and fingerprint lifting. All of the students were able to complete the activity in one hour, and both the density columns and the fingerprinting were a big success. The students' understanding of all of the concepts was assessed by their ability to physically perform the experiment and requiring them to answer questions throughout the activity. Students became forensic scientists and were motivated and eager to learn that science can be the key to unlocking the mystery of "who done it?" ■

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 science program for their students.

Standard B:
Teachers of science guide and facilitate learning.

Standard E:
Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning.

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Resources

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

Internet

Forensic Examination of Soil Evidence
www.interpol.int/public/Forensic/IFSS/meeting13/Reviews/Soil.pdf

Taking Legible Fingerprints
www.fbi.gov/hq/cjisd/takingfps.html

Fingerprint Patterns
www.virtualsciencefair.org/2004/fren4j0/public_html/fingerprint_patterns.htm

Fingerprint Patterns
www.reachoutmichigan.org/funexperiments/agesubject/lessons/handouts/print_patterns.html

Magnetic Latent Print Powders
www.securityandsafetysupply.com/department-supplies/fingerprints-2.html

Alnico Cow Magnets
www.hobbylinc.com/htm/mgu/mgu07239.htm

Plastic Test Tubes
http://vwrlabshop.com/product.asp_Q_pn_E_0013292