"It's ELEMENTary, My Dear Watson"

A Crime Scene Investigation With a Technological Twist

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As students enter the science classroom, they walk around the yellow crime scene tape that marks off a set of muddy footprints on the floor (Figure 1). Looking in the secured crime scene area, students may notice computer cords with empty spaces where the computers used to be, large pieces of broken glass on the floor, and red "blood" drops on a sheet of paper on the floor next to the glass. Students become more animated as they sit down at their desks and read the message projected from the document camera:

(Middle School Associated Press):

After school yesterday, there was a break-in at the middle school. The police and school authorities are investigating the theft of several computers and science probes from a science classroom. Police have asked students at the school, all of whom are currently considered suspects, for help with the investigation. According to an anonymous source, soil, glass, hair, and blood were found at the scene.

Students whisper excitedly, and there is a sense of anticipation for the day's lesson. "Do you see these tracks?" the teacher asks, pointing to the shoeprints of soil, as students stand up to look. "They weren't here yesterday when I left. The school yard has several different soil types. If we can determine the soil type in these prints, we may figure out which direction the suspect came from and focus our search on people who live in that direction. The police have asked for our help. All of you are suspects!" she says with a wink.

The Crime Scene Labs

The Crime Scene Labs is a technology-enhanced unit with seven laboratory stations. Probes at many of the stations facilitate students collecting and analyzing their own data (some lessons are adapted from Volz and Sapatka 2000). The labs are designed to build 21st-century skills and model reform-based practices (NRC 1996). The crime scene allows science concepts to be introduced or reviewed in a high-interest, real-world format.

Students will rotate through station labs, investigating the properties of soils, glass fragments, students' hair, and "blood." As described here, the labs are designed for a four-day period, but they may be extended or condensed according to a teacher's objectives and time constraints. A middle school science teacher might select to use the entire Crime Scene Labs unit as an introduction to basic chemical properties of matter, as Halloween-inspired science activities, or as an introductory unit at the beginning of the school year to build technology and laboratory skills. (Visit *http://21ctl.fi.ncsu.edu/msms/crimescenelabs.html* to see all of our technology-enhanced middle school crime scene labs.)

On the first day, the class reviews a satellite map of the school site and heads out to collect soil (alternately, you can supply soil samples). Next, it is time for students, working in teams of four, to begin rotating through the stations. Each station takes 15 to 20 minutes to complete. In addition to the seven lab stations described here, you may want an extra station or two to allow students to progress at different rates, to reinforce more difficult concepts (repetition), or to differentiate learning (Jones 2007). Additional stations could include computer simulations, videos, worksheets, or related websites, depending on your objectives.

FIGURE 1 Key teaching materials and equipment for labs

Setup: Crime scene tape, four baggies of soils, four different-colored glass pieces (sanded), suspect hair on slide, artificial "blood" splatter on paper, staff person to be "criminal," hairs for Station 7, addresses and completed lab sheets for other school staff suspects, print out of Google map, lab station names, and directions

Station 1: pH probe (or pH paper), distilled water, and beaker

Station 2: Conductivity probe (or LED, battery, and wire), distilled water, and beaker

Station 3: Soil chart from *http://soils.usda.gov/education/resources/lessons/texture*

Station 4: Light probe, shoebox, flashlight, and tape

Station 5: Graduated cylinder and digital/triple beam balance

Station 6: Dropper, meter stick, hot chocolate mix, corn syrup, and beaker

Station 7: Light microscope, slide with suspect hair, and extra slides

More info: Detailed lab instructions, data sheets, and a possible grading rubric for each lab may be found online at *http://21ctl.fi.ncsu.edu/msms/crimescenelabs.html.*

Setting up whodunit

This can be done two ways. One way is to have all students be suspects. Students would clear their names by collecting data and comparing it to a data sheet listing the perpetrator's information, filled out by the teacher ahead of time and posted somewhere in the room. The second way would be to provide a set of 5 to 10 suspect data sheets and have students rule them out. A "perpetrator" (a student or a provided suspect) would be selected ahead of time, depending on how you set up the activity, as well as a story line.

If suspects are provided, students' interest is piqued if the suspects are school personnel, such as the coach, media specialist, principal, or custodian. Students will be filling out data sheets (Figure 2) as they complete the labs; you should supply a completed data sheet for each of the suspects (if they are being provided), and a second sheet with the perpetrator's data should be sealed in an envelope and taped to the board for students to compare their own data to when they've completed all the labs. All of the suspects' names (or the names of all students in the class) should be written on the board or projected for everyone to see, and eliminated as suspects are ruled out.

We recommend that the situation turns out not to be a crime after all, but a custodian or media specialist who has taken the computers for repair, or a student who borrowed equipment, or a principal who has borrowed the equipment for a parent night. More details can be woven in, such as the person dropped a vase and cut a finger, bleeding on the paper and forgetting to clean up one piece of glass.

FIGURE 2 Data sheet

Clue	Suspect data			
Soil	**Color (circle one):** brown gray red black **Size (circle one):** medium sand fine sand silt clay **pH:** **Conductivity (µS/cm):** **Water absorption (mL):**			
Hair	**Color (circle one):** blonde brown red black gray **Appearance (circle one):** healthy damaged **Texture (circle one):** straight curly wavy			
Station	**Collected data**			
Is It Basic?	**pH:**			
Shocking!	**Conductivity (µS/cm):**			
Sticky or Gritty?	**Color (circle one):** brown gray red black **Size (circle one):** medium sand fine sand silt clay **Water absorption (mL):**			
Rose-Colored Glasses?	**Sample A** Light intensity (lux):		**Sample B** Light intensity (lux):	
The Plunge	**Sample A** Mass (g): Volume (mL): Density (g/mL):		**Sample B** Mass (g): Volume (mL): Density (g/mL):	
"Blood" Splatter	**Height:** **Diameter:**	**Height:** **Diameter:**	**Height:** **Diameter:**	**Height:** **Diameter:**
Hairy Situation	**Color (circle one):** blonde brown red black gray **Appearance (circle one):** healthy damaged **Texture (circle one):** straight curly wavy			

Day 1: Digging for evidence and setting the stage

Students begin by examining a digital map of the school yard (Google Maps has great satellite images; see Figure 3) to determine where different soil types might be located. You can project a map for the class to look at together, or students can research the images themselves, online. To increase student interest, a Google map of the school district can be printed out, as well. If students are suspects, have students put their names on the map according to where they live. Or, the names of the suspects (key school personnel) should be plotted.

Then, student teams head outside to the school grounds with shovels and gallon-sized baggies to collect soil samples (see Figure 4). (It is a good idea to have soil already collected in case of rain, and to test soils in advance. We put the soil samples into gallon baggies to compare to the "suspect soil"; baggies can be used for all of the class sections.) Students are asked to find soils that look like the soil on the floor of the classroom, but ideally there is an assortment of soil types (clay, silt, and sand). Ahead of time, find locations to dig on campus (within view) and send students in teams to various locations. Students can share soil samples when they return to the classroom. Blowing a whistle is a good way to get students' attention outdoors and the signal that it is time to come inside.

FIGURE 3 Sample Google map; in this example, red clay can be found in the baseball field, white sand in the soccer field, etc.

Safety: Be sure to check for student allergies (bees, poison ivy, etc.) before taking students outside, and scan the school area ahead of time to ensure there is no harmful contamination (dog droppings, dangerous garbage, etc.) at the targeted soil-collection sites. Specific sites should be designated by flags or cones. Make sure students only dig with shovels and wear safety goggles while doing so. Some safety experts suggest microwaving the soil before allowing students to handle it in the lab to kill any harmful bacteria that may exist. Also, make sure students do not disturb vegetation or leave large holes that could cause injury to others.

Back inside, draw students' attention to the evidence that is at hand, which could be displayed under the document camera: a clear zip-top baggie of crime scene soil marked "suspect soil," pieces of colored glass, hairs found at the scene, and the splatter of "blood" on the paper found near the broken glass on the floor. If there is time, you can prompt students to consider the evidence at the crime scene and generate questions: Does the soil on the floor look like any of the soils from the school grounds? Where might the glass on the floor have come from? What characteristics does the glass have? Do students think the hair is from a human, animal, or clothing (fiber)? Do they think the red liquid on the floor is blood or Kool-Aid? Keeping students in suspense will create anticipation and excitement for the next class. At the start of the lab period, put this evidence at each of the appropriate lab stations (or have extras already located at the appropriate stations).

FIGURE 4 The teacher helping students collect soil

PHOTO COURTESY OF THE AUTHOR

Days 2–4: Crime scene stations

Before beginning, each student receives a blank data sheet (see Figure 2). Laminated station labels (e.g., "Station 1: Is It Basic?") and directions for each lab are located at each lab station. The first three lab stations deal with the properties of soil: There is a pH test with a pH probe, a conductivity test with a conductivity probe, and a water absorption and "feel" test. If your school does not have probeware, pH paper can be used and simple conductivity meters can be made with an LED (lightemitting diode), battery, and wire (see *http://atlantis.coe.uh.edu/texasipc/units/energy/conductivity.pdf*). Stations 4 and 5 investigate glass density and how light passes through glass. Station 6 is where students drop "blood" from different heights to see if they can match the splatter pattern found at the crime scene. Station 7 looks at the differences between hair and fiber and the characteristics of each. (Safety note: Chemical splash goggles must be worn at all stations except Station 7.) It is helpful to instruct students to move clockwise to the next station when it is open, to ensure smooth movement of teams. A timer or bell can also help ease student movement through stations.

Station 1: Is It Basic? (pH test)

At this station, students add 100 mL of water to a tablespoon of soil and stir (the pH probe only works in liquids). Students then use the pH probe to determine how acidic or basic the soil is.

Teacher's notes: Acids and bases

Soils that are basic have compounds called bases. Bases neutralize acids. For example, taking milk of magnesia, $Mg(OH)_2$, helps an upset (acid) stomach feel better. An acid is a compound that has H^+ (hydronium) in it, such as hydrochloric acid (HCl), the acid in our stomachs. Different soils have different pH levels. On the pH scale, 0 to 6 is an acid, 7 is neutral (water), and 8 to 14 is a base.

Station 2: Shocking! (conductivity tests)

This station allows students to determine differences in soil type based on how much electricity may be passed through the soil when soil is added to water. Again, students add water to the soil to enable the probe to work, and then insert the probe to take a reading. The more ionic material contained in the soil, the higher the conductivity will be. Samples that are almost entirely sand and do not contain minerals and nutrients will have a conductivity of 0.

Teacher's notes: Ions

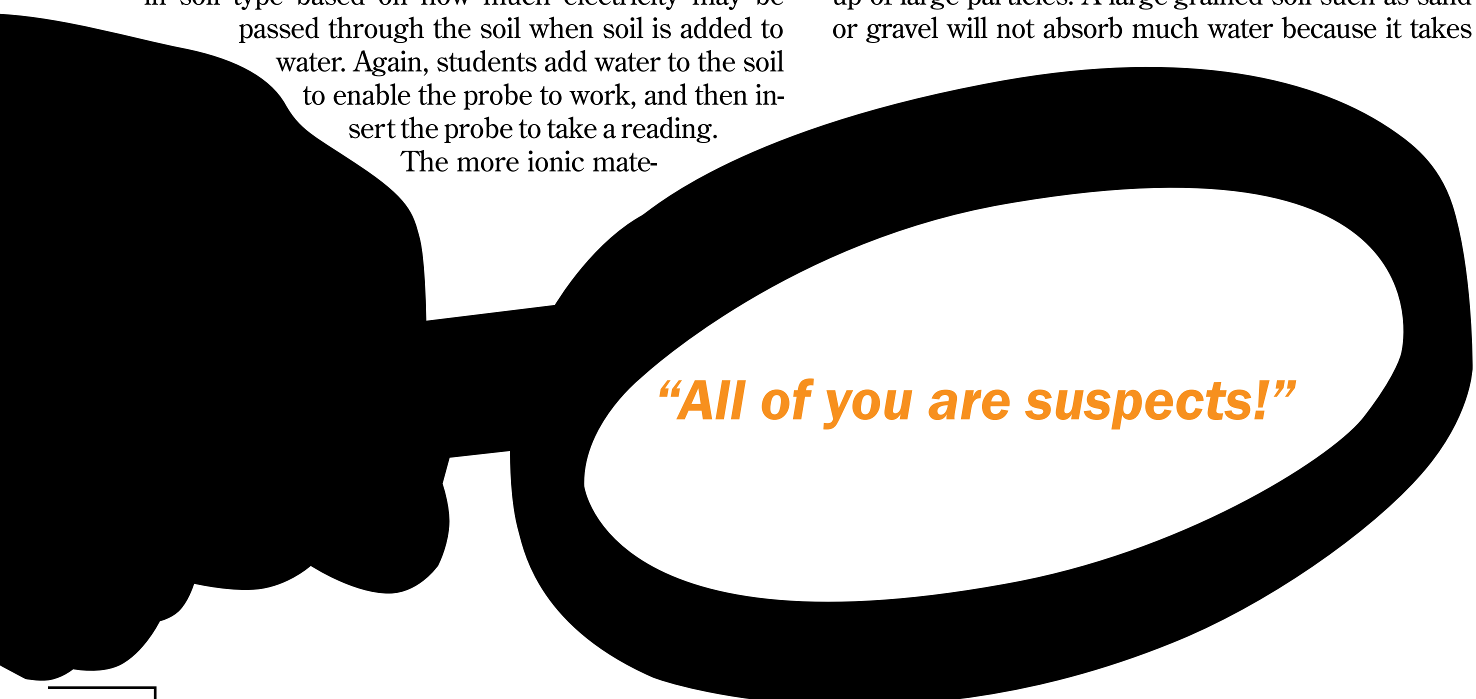
Ions are elements with a charge. For instance, when added to water, salt (NaCl) "dissolves" into Na+ and Cl- ions. The conductivity probe measures these ions by giving off an electrical current and measuring the amount of electricity that comes back to the probe. The more ions a compound breaks into, the more it conducts a current. When soil is added to water, the ions in the soil break down, allowing students to measure differences in conductivity of different soil types. Clay has lots of iron in it (Fe+2). Sand at the ocean, which has a high salt content, will dissolve into Na+ and Cl-, and therefore have high conductivity.

Station 3: Sticky or Gritty? (soil classification)

Water absorption and the "feel" test allow students to determine the size of the particles making up the soil sample. Students place a tablespoon of soil in their palm, add a few drops of water, and then try to roll the mixture into ball and snake shapes.

Teacher's notes: Mixtures

Soils, which are formed when rock breaks down through weathering, are a mixture of compounds. Most soils are a mixture of sand, silt, and clay. Soils that are sticky are made up of small particles. Soils that are gritty are made up of large particles. A large-grained soil such as sand or gravel will not absorb much water because it takes



little effort for the water to pass among the grains. A small-grained soil such as clay absorbs a large amount of water because it takes much more time and energy for the water to find its way through the tiny grains. The "feel" test was developed by the United States Department of Agriculture and may be found at *http://soils.usda.gov/education/resources/lessons/texture.*

Station 4: Rose-Colored Glasses? (light intensity)

To measure the reflectivity of light, students attach a light sensor (using tape or a ring stand with clamps) to one side of a cardboard box with a quarter-sized hole made on each side. Students place the piece of glass to be analyzed on the other side (with tape) and close the box lid (see Figure 5). Students hold a flashlight to the glass, shining the light through the glass toward the light sensor (which measures in units of light intensity called *luxes*). By testing samples of the colored glasses, students can potentially find the identity of the glass, or at least rule out possibilities. Note: Plastics may be used in place of glass, but 5 × 5 cm (2" × 2") colored glass pieces with the edges filed down work the best. If a light sensor is not available, this station can be skipped.

Teacher's notes: Compounds and mixtures

Glasses are made from different oxide compounds (e.g., SiO_2, Al_2O_3, CaO). A compound is a mixture of two or more elements in fixed proportions. A mixture is two or more elements not in fixed proportions, and not chemically bonded. Colored glass mixes paint or dyes into glass. Different colored glasses will absorb some of the colors of light, except what gets reflected (bounced off) or refracted (bent).

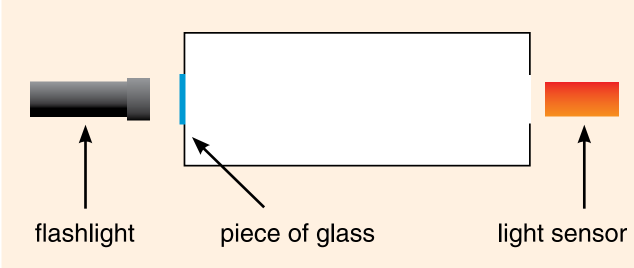
Station 5: The Plunge (glass density)

Most labs have students calculate the densities of different glasses by measuring the sides of an object to find its volume and then massing it. But what happens if the object is an irregular shape? By placing pieces of the glass in a graduated cylinder full of a known volume of water, students can discover the volume by comparing the volume of water before and after adding the glass (displacement). Note: You may use a triple-beam balance or a digital balance for mass. If you have neither, a dual-range force sensor from a variety of vendors can be used to weigh objects.

Teacher's notes: Density

Glass, which can change shape when heated, is called an "amorphous" solid. Different types of glasses are

FIGURE 5 Light-box setup



made up of different mixtures, which therefore have differing densities, ranging from less dense than aluminum to more dense than iron. One way to tell the difference between glasses is to get the mass and volume, and use the following equation to compute the density: density = mass/volume.

Station 6: "Blood" Splatter

In this lab, students try to match the blood-splatter pattern on the paper found near the glass pieces at the crime scene. The dried (fake) blood can be displayed at Station 6. At this station, a beaker of blood and a dropper are used by students to create their own blood-splatter patterns. Instructions on the lab sheet direct students to drip the blood from the dropper from different heights measured up from the ground (e.g., at 1 m or 1.5 m), by holding the dropper next to two meter sticks taped together and secured to a chair. After looking at the blood splatters they create and measuring the dimensions (diameter and shape) of the drop, students compare the ones they have created to the sample found at the crime scene and estimate the height from which the drops fell, and potentially the height of the suspect. Optional: Students enjoy making fake blood for this lab using a chocolate recipe (see Resources), although a single batch made from one package of cocoa mix, corn syrup, red food coloring, and water makes a cup of fake blood, which will be enough to supply all class periods (each group needs less than a dropper full) and the cost is nominal. (Safety note: Students should not ingest anything made in a science lab. Gloves and aprons can be worn in addition to goggles to ensure the food coloring does not stain clothing or skin.)

Teacher's notes: Mixtures

Bloodstain pattern analysis is the examination of the shapes, locations, and distribution patterns of bloodstains. Human blood is 55% plasma and 45% red blood cells, white blood cells, and platelets. Plasma is 90% water, 8% proteins, and 2% inorganic and organic substances, such as minerals.

Station 7: Hairy Situation

At this station, students use microscopy to look at the suspect hair and compare it to their own. If students are suspects, to clear themselves they are asked to remove one of their own hairs (using scissors), place it on a slide, and compare it to the known suspect sample on a slide at the station (Note: if you have designated a school employee as the "suspect," obtain some hairs from the suspect and have one on a slide for students to view as the suspect hair.) As an extension, students may find it interesting to compare their hairs and that of the suspect to other samples online to see the variation of hairs and fibers under a microscope (see *http://sciencespot.net/Pages/classforsci.html* or preprinted examples from this site).

Teacher's notes: Elements in hair

The primary component of hair fiber is keratin, a protein. Proteins are compounds made up of long chains of amino acids. As raw elements, hair is composed of 51% carbon, 21% oxygen, 17% nitrogen, 6% hydrogen, and 5% sulfur, with trace amounts of magnesium, arsenic, iron, and chromium and other metals. The different chemical components of hair act together to maintain normal function. By looking at hair under the microscope, it is possible to determine if hair is damaged, its color, whether it has been chemically treated, if it has been pulled out by the roots, and if it is healthy.

Solving the crime

If students are suspects, they compare their data on individual data sheets against the "suspect" data sheet and eliminate themselves as suspects. Once they see that their data do not match that of the suspect sheet (posted on the board in a manila envelope—students are not allowed to look until their data sheet is complete), students can mark their name off the list (on the board or on the paper under the document camera).

The same process is used with provided suspects. Suspect names get crossed off the list, until one person is left (e.g., the media specialist), who then could be brought in for questioning or who you could have a story from, thus indicating involvement, but clearing the person of an actual crime.

Extensions

Students can interview likely suspects (such as the school principal, custodian, science teacher next door, or coach) with flip cameras, and play out roles as reporters, newscasters, or attorneys. This is a great way to coordinate with team teachers in language arts, social studies, and technology. For instance, flip cameras could also be used to document parts of the lab for a class video of the investigation and could be edited in a technology class. For connections to real-world crime investigations, invite your school's resource officer or a member of the local police or sheriff's department to come in to talk about crime scene investigations or demonstrate fingerprinting and dusting. ■

References

Jones, D.J. 2007. The station approach: How to teach with limited resources. *Science Scope* 30 (6): 16–21.

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

Volz, D., and S. Sapatka. 2000. *Middle school science with calculators.* Beaverton, OR: Vernier.

Resources

Crime Scene Labs by grade and standards (complete set of labs with rubrics)—*http://21ctl.fi.ncsu.edu/msms/crimescenelabs.html*

Fake blood recipes—*www.halloween-website.com/fake_blood.htm*

Forensic science lesson plans— *http://sciencespot.net/Pages/classforsci.html*

Marshall, J., B. Horton, and J. Austin-Wade. 2007. Giving meaning to the numbers. *The Science Teacher* 74 (2): 36–41.

SMART for teachers—*www.fi.ncsu.edu/project/smart-for-teachers*

United State Department of Agriculture soil flow chart— *http://soils.usda.gov/education/resources/lessons/texture*

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