Case File 10

Dropped at the Scene: Blood spatter analysis

Analyze blood spatter evidence and help identify Jessica Barnes' killer.

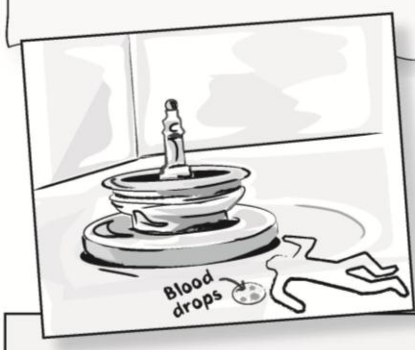
Re: Police Detective Status: Barnes Murder

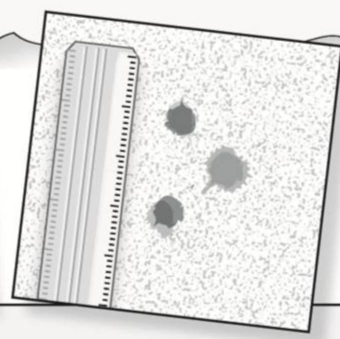
Museum curator Jessica Barnes was found dead on 10/05/05, the day before the grand opening of the world famous traveling exhibit Shadows of Egypt. Her body was found at the base of the large marble fountain in the center of the museum lobby.

It was clear that the victim was strangled. A few drops of blood were found on the tile floor, but blood tests show that the blood is not the victim's. Investigators have found traces of the same blood on the knuckles of the victim's hand. Investigators are suggesting that she fought her attacker, giving him or her a bloody nose or lip, and that the blood dripped onto the floor as the attacker fled the scene.

The small volume of blood suggests that the wound was minor and, thus, would have nearly healed by the time the suspects were apprehended. Indeed, none of the prime suspects showed evidence of a facial injury of any kind.

We may be able to narrow down the height of the killer from the blood spatter evidence. (We need this to order blood tests.)



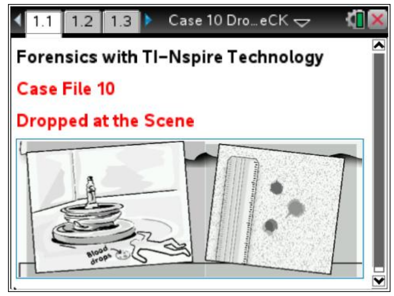


Barnes Murder
Suspect List
Three other museum employees were working after hours the night Ms. Barnes was killed:
Abraham Stein, photo archivist: 6'2"/ brown eyes/ brown hair
- knew Barnes was trying to cut funding for his vintage photo department

Ellie Walsh, museum curator: 5'3"/ green eyes/ brown hair
- was a candidate for the head curator position six months ago, along with Barnes—Barnes given position

Keith Hartman, administrative assistant: 5'8"/ blue eyes/ bleached blond hair
- was recently fired by Barnes and finishing his remaining two weeks in the position

About the Lesson



- This lab introduces students to the science behind blood spatter analysis. It also provides an opportunity for students to explore curve fitting and can extended to use r^2 values (optional) to determine the most appropriate curve fit for the data set.
- Teaching time: one 45 minute class period

Science Objectives

- Determine the height of a source of blood spatters or drops
- Graph data to find quantitative relationships
- Create a standard reference curve for comparison with unknown data

Activity Materials

- TI-Nspire™ technology
- *Case 10 Dropped at the Scene.tns* file
- *Case_10_Dropped_at_the_scene_Student.doc* student activity sheet
- metric tape measure or meter stick
- newspaper
- 13 pieces of white paper
- disposable pipettes or droppers
- simulated blood
- calipers, or compass and metric ruler

TI-Nspire™ Navigator™

- Send out *Case 10 Dropped at the Scene.tns* file.
- Monitor student progress using Class Capture.
- Use Live Presenter to spotlight student answers.

Teacher Notes and Teaching Tips

- The student activity sheet and .tns file contain the complete instructions for data collection. All assessment questions are also included in both places giving you the flexibility to either collect the .tns files with student data/answers (using TI-Nspire Navigator) or the student activity sheet.
- It should be noted that $r^2$is not the only measure of the quality of a curve fit. The function must also make sense for the situation. In this example, a quadratic function might have a better r^2, but because a quadratic function would reach a maximum and then decrease, this function would not make sense.
- You may want to have students review the Blood Stain Pattern Analysis Tutorial prior to the lab, which includes examples of origin determination and impact velocity calculation. http://www.bloodspatter.com/bloodstain-tutorial

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Allow students to read the forensics scenario on the first page of their student activity sheet.

Procedure

Teacher Preparation (Prior to the Lab)

1. Synthetic blood can be purchased from scientific supply houses, or you can use milk or Pepto-Bismol™ with a little red food coloring.
2. Before class, you will need to create the crime scene evidence by dropping 3 drops of simulated blood from a known height between 10 and 200 cm. Use the “blood” and dropper type that your students will use. Select the height so that one or more of the suspects are implicated (depending on how clear-cut you want your students’ results to be). Keep in mind that someone who is 5 feet tall could not create a blood drop that falls from 6 feet if the drop were produced by a nosebleed, but someone who is 6 feet tall could produce a drop from 5 feet if he or she bent over after being hit. The spatters you create should be given to the students as part of the evidence.
3. This activity is best done in groups of at least two so that the students are able to measure heights and create spatters at the same time.
4. Using dropper bottles instead of pipettes may be less messy.
5. You may want to let spatters dry before measuring.

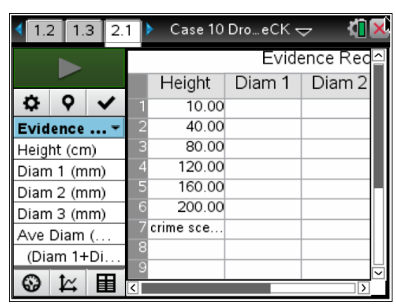
Part 1 – Collecting Data

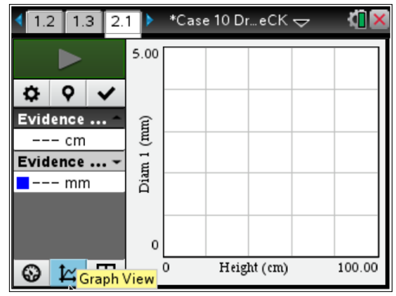
Move to pages 1.2–1.3.
Students follow the directions on pages 1.2-1.3 or on the student activity sheet to create blood spatters from known heights and then compare them with unknown samples.

Students will repeat the procedure twice more, moving the pipette to slightly different locations but maintaining a height of 10 cm Students calculate the average diameter of the spatters that fell from 10 cm, and record it in the Evidence Record. Students replace the white paper with a clean sheet, and then repeat steps 1 - 3 for each remaining height in the Evidence Record.

Part 2 – Analyzing the Data
Move to pages 2.1–2.3.

Students will transfer the data from their Evidence Record to page 2.1 in the .tns file, in order to view a graph of the average spatter diameter *vs*. drop height.





Students will then view the data in "graph view" on page 2.1. In order to determine the kind of relationship between height and blood spatter diameter, students will test several different types of curve fits to see which gives the best fit to the data. The first curve they will attempt to fit to the data will be linear (a straight line).

Students change the Fit Equation to Logarithmic and record the equation and the **r^2 value (optional). Students will need to scroll to the bottom of the dialog box or the details panel to the left side of the screen).Students will then repeat Step 6 using a quadratic fit, and then a power fit. Students should include a simple sketch of each graph on their evidence record, as they will need to refer to this to determine which best fits their data.

Students will change the Fit Equation to the equation with the best fit based on their sketches and/or comparison of the r^2 values**. Students then estimate the height from which the blood at the crime scene fell by comparing it to their known data.

Modifications

- ** r^2 values: For more advanced students, have them use r^2 values to determine best fit. Students should understand that one way to evaluate how well a curve fits a data set is to compare the r^2 value for each of the different possible fits. The r^2 is a measure of how far away, on average, the data points are from the fitted curve. Using the recorded r^2 values in the Evidence Record, students should determine which type of curve best fits the data. The r^2 value is a relative measure between 0 to 1. Values closer to 0 indicate a poor fit. Typically, values closer to 1 indicate a closer fit and result in better predictability. Based on this, they will then record the equation for the best curve fit in the Evidence Record.
- If time is short, collect fewer data on known-height blood drops.
- For more-advanced students, create crime scene evidence by dropping blood from a height outside the range of the heights the students will measure. In this case, it will be necessary for the students to use the equation for the best-fit curve to calculate the approximate height of the crime scene drops. You may also allow the students to try other types of curves, such as exponential or logistic.
- If extra time is available, have students perform the experiment on different types of surfaces (e.g., carpet, cardboard, towels, wood, tile) to determine how the relationship between height and spatter size can change from one surface to another. Alternatively, give each group a different surface to experiment with and then compare the results.
- As an extension activity to introduce more mathematics, have the students determine a relationship between angle of impact and the shape of the resulting spatter. The resources given above contain additional information on how to do it.

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Evidence Record

SAMPLE DATA

Using Pepto-Bismol

Height (cm)	Diameter of Drop 1 (mm)	Diameter of Drop 2 (mm)	Diameter of Drop 3 (mm)	Average Diameter of Drops (mm)	Shape and General Observations of Blood Spatters
10	7	7	7	7.0	
40	14	12	13	13.0	
80	15	16	15	15.3	
120	18	18	18	18.0	
140	18	18	18	18.0	
160	18	18	18	18.0	
200	20	20	20	20.0	
Crime Scene	11	12	11	11.3	

**Optional r^2 Method:

Equation for linear fit: **0.058x +9.687** — r^2 value: **0.891**

Equation for logarithmic fit: **–2.81 + 4.24 ln (x)** — r^2 value: **0.979**

Equation for quadratic fit: $\mathbf{-0.00032x^2 + 0.125x + 7.54}$ — r^2 value: **0.959**

Equation for power fit: $\mathbf{3.74x^{0.322}}$ — r^2 value: **0.969**

Type of curve that gives best fit to data: **logarithmic**

Equation for best fit: $\mathbf{y = -2.81 + 4.24 \ln (x)}$

Height of spatters from crime scene: **30 cm**

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Case Analysis

Have students answer the following questions in the .tns file, on their activity sheet, or both.

1. Which type of curve gave the best fit to your data?

   Answer: Answers may vary. In this case, the natural logarithm gave the best fit to the data. However, the relationship between height and diameter can vary, depending on the nature of the surface and the "blood" used.

2. Did the shape of the blood spatters change as the height increased? Explain.

   Answer: Answers may vary. Drops that fall greater distances may have more ragged edges because they are moving more quickly when they hit. Drops that fall farther may also form secondary drops as liquid bounces off of the paper.

3. Which of the three suspects could have created the blood spatters at the scene? Explain.

   Answer: In this case, any of the three suspects could have produced the spatters, since the approximate height is only about 30 cm. Students should indicate the understanding that blood drops of a certain height can be produced by someone taller than that height but are not likely to be produced by someone shorter than that height.

4. How accurate do you think your height estimate is? What factors can contribute to inaccuracy in your estimate? How can you reduce the errors from these factors?

   Answer: Answers may vary. Inaccuracies in drop height estimates can arise from a variety of sources, including inaccurate or imprecise measurement of test drops and heights, relatively poor fit of the best-fit curve, too few data points collected, and differences between the experimental and actual conditions (e.g., surfaces, air temperature and humidity, wind conditions).

5. Forensic scientists often do tests to determine the relationship between height and spatter diameter for the different cases they are involved in. What factors can cause the relationship between height and spatter diameter to differ from crime scene to crime scene?

   Answer: Factors that can influence the shape and/or size of a blood splatter include the following: consistency of the blood (although it is generally stable, it can change within a certain range); speed at which the drops are traveling; angle at which the drops hit the surface; type of surface the drops are hitting; amount of time between when the spatters were made and when they were measured; and environmental conditions at the scene (e.g., temperature, wind, humidity).

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