Activity: Experimental Design using Science and Engineering Practices

FOR THE TEACHER

Summary
In this activity, students will read a short story about an experiment that was conducted about an everyday question. Then the student will decide if and how the experimenter followed the scientific method. Then they will consider their own everyday questions and propose a way to answer them experimentally.

Grade Level
High School

Objectives
By the end of this activity, students should be able to
- recognize which of the key science and engineering practices (as listed in the Science and Engineering Practices handout) have been applied in a specific example investigation.
- describe how these science and engineering practices might be applied to an everyday question of interest to the student.
- successfully plan a valid scientific experiment to test a question.

Chemistry Topics
- Experimental Design
- The Scientific Method

Time
Teacher Preparation: 15 minutes
Lesson: One class session

Materials
- Student handout (three different story options are provided to choose from)

Safety
- No specific safety precautions need to be observed for this activity.

Teacher Notes
- The stories selected for this activity represent very ordinary questions that were explored by an extraordinary scientific thinker, Nobel laureate Richard Feynman. As such, they illustrate the essence of scientific thinking and practice and open students’ eyes to the idea that a problem need not be complex nor esoteric to be subject to scientific investigation.
- The teacher is encouraged to substitute her own experiences as a prelude to the actual reading assignment. If this assignment is used for lower-level classes, the story could be read aloud by students in turn or by the teacher.
No particular technical background is necessary for this assignment; indeed, it is suitable as an introductory assignment for any science class.

Please see the separate Student Handouts for details on the student lesson. Note that there are three different, but interchangeable, stories in the handouts. Ordinarily, only one story is selected for the lesson, though more could be used to generalize the scientific practices.

Cross-Disciplinary Extensions

Connect to Math
Students might be encouraged to propose ways to make the experiments described in the reading more quantitative and suggest ways to analyze the results. Quantitative data could be listed among the requirements of the investigation that the students propose in the Extension activity.

Connect to Reading
This assignment connects very readily to Reading and to Writing. The following are a few suggested reading comprehension questions for each of the three stories.

*It's as Simple as One, Two, Three...*
- In the phrase “that governed the ‘time sense’”, what is the meaning of the word *govern*?
- What does the author mean by “to count at a standard rate”?
- What was the difference in the way the author and his friend John Tukey did their mental counting?

*The Amateur Scientist*
- Based on the description of the dorm room, make a sketch of the bay window and surrounding area. Indicate where the string was placed and the different locations where ants were picked up and dropped off.
- What problem did Feynman notice that interfered with his ability to study the ants?
- Was Feynman able to propose an explanation for why the ants’ paths seem so nice and straight? If so, what was his explanation?

*Testing Bloodhounds*
- Why did Feynman have time to read in the hospital library when he went to visit his wife?
- Did Feynman conclude that human sense of smell is as good as a dog’s, or not as good? Use evidence from the story to support your answer.
- How did Feynman’s friends think he was able to determine what objects had been touched?

Connect to Writing
This assignment already has a significant writing component. The teacher might add greater stringency to the organization and detail of the writing as appropriate.
FOR THE STUDENT
Lesson

The Scientific Method – Option 3

Background
Every science class seems to begin with a description of THE SCIENTIFIC METHOD, as if you need to follow a specific process or procedure to work scientifically. In reality, the scientific method (no capitals this time) just describes the typical practices that a scientist may employ to find the answer to a question. How does your conception of the scientific method compare to an example of a scientific inquiry?

Instructions
Write your answers for 1, 2 and 3 below on a separate sheet of paper and attach it to this handout when finished.

1. Activating Prior Knowledge
Write a description of the scientific method as you recall it from past reading or classes. You can list steps or write in paragraph form.

2. Exploring Science Practices
Read the handout on Science and Engineering Practices. Consider how these practices compare to the scientific method as you wrote it. Are all of the steps of the scientific method represented in the science and engineering practices? Are there any practices that don’t have corresponding steps in the scientific method?

3. Reading an Example of a Scientific Experiment
Read the following passage describing an experiment performed by Richard P. Feynman, a Nobel prizewinning physicist. Answer the questions following the passage.

Testing Bloodhounds

WHEN I WAS at Los Alamos and would get a little time off, I would often go visit my wife, who was in a hospital in Albuquerque, a few hours away. One time I went to visit her and couldn’t go in right away, so I went to the hospital library to read.

I read an article in Science about bloodhounds, and how they could smell so very well. The authors described the various experiments that they did—the bloodhounds could identify which items had been touched by people, and so on—and I began to think: It is very remarkable how good bloodhounds are at smelling, being able to follow trails of people, and so forth, but how good are we, actually?

When the time came that I could visit my wife, I went to see her, and I said, “We’re gonna do an experiment. Those Coke bottles over there (she had a six-pack of empty Coke bottles that she was saving to send out)—now you haven’t touched them in a couple of days, right?”

“That’s right.”

I took the six-pack over to her without touching the bottles, and said, “OK. Now I’ll go out, and you take out one of the bottles, handle it for about two
minutes, and then put it back. Then I’ll come in, and try to tell which bottle it was.”

So I went out, and she took out one of the bottles and handled it for quite a while—lots of time, because I’m no bloodhound! According to the article, they could tell if you just touched it.

Then I came back, and it was absolutely obvious! I didn’t even have to smell the damn thing, because, of course, the temperature was different. And it was also obvious from the smell. As soon as you put it up near your face, you could smell it was dampish and warmer. So that experiment didn’t work because it was too obvious.

Then I looked at the bookshelf and said, “Those books you haven’t looked at for a while, right? This time, when I go out, take one book off the shelf, and just open it—that’s all—and close it again; then put it back.”

So I went out again, she took a book, opened it and closed it, and put it back. I came in—and nothing to it! It was easy. You just smell the books. It’s hard to explain, because we’re not used to saying things about it. You put each book up to your nose and sniff a few times, and you can tell. It’s very different. A book that’s been standing there a while has a dry, uninteresting kind of smell. But when a hand has touched it, there’s a dampness and a smell that’s very distinct.

We did a few more experiments, and I discovered that while bloodhounds are indeed quite capable, humans are not as incapable as they think they are: it’s just that they carry their nose so high off the ground!

(I’ve noticed that my dog can correctly tell which way I’ve gone in the house, especially if I’m barefoot, by smelling my footprints. So I tried to do that: I crawled around the rug on my hands and knees, sniffing, to see if I could tell the difference between where I walked and where I didn’t, and I found it impossible. So the dog is much better than I am.)

Many years later, when I was first at Caltech, there was a party at Professor Bacher’s house, and there were a lot of people from Caltech. I don’t know how it came up, but I was telling them this story about smelling the bottles and the books. They didn’t believe a word, naturally, because they always thought I was a faker. I had to demonstrate it.

We carefully took eight or nine books off the shelf without touching them directly with our hands, and then I went out. Three different people touched three different books: they picked one up, opened it, closed it, and put it back.

Then I came back, and smelled everybody’s hands, and smelled all the books—I don’t remember which I did first—and found all three books correctly; I got one person wrong.

They still didn’t believe me; they thought it was some sort of magic trick. They kept trying to figure out how I did it. There’s a famous trick of this kind, where you have a confederate in the group who gives you signals as to what it is, and they were trying to figure out who the confederate was. Since then I’ve often thought that it would be a good card trick to take a deck of cards and tell someone to pick a card and put it back, while you’re in the other room. You say, “Now I’m going to tell you which card it is, because I’m a bloodhound: I’m going to smell all these cards and tell you which card you picked.” Of course, with that kind of patter, people wouldn’t believe for a minute that that’s what you were actually doing!
People’s hands smell very different—that’s why dogs can identify people; you have to try it! All hands have a sort of moist smell, and a person who smokes has a very different smell on his hands from a person who doesn’t; ladies often have different kinds of perfumes, and so on. If somebody happened to have some coins in his pocket and happened to be handling them, you can smell that.


Questions
1. List the scientific practices that Feynman employed with supporting examples from the reading.
2. Write a paragraph explaining how Feynman’s practice of science compares with what you learned about the scientific method using evidence from the passage above.
3. Identify and list the hypotheses that Feynman was testing in his experiments. Where did these hypotheses come from?
4. Write a few sentences explaining how this reading helps you understand how scientists work to answer questions.

Extension
Think about the things you do every day. Were you ever curious about how something worked, or why something is the way it is? Choose a question about which you are curious. Write your guess for the answer to the question (your hypothesis) and give the reason for your guess. Describe an experiment that would test whether your guess was right or wrong. Assume you have a way to measure whatever you need to measure and that you can do any experiment safely and without cost.

Example 1
Question: I wonder if my car gets better traction if the tires are underinflated.
Hypothesis: I guess it might because more of the tire is in contact with the road when it is underinflated, and I think that would give better traction.
Experiment: I will see how fast I can drive around a sharp curve without skidding with my tires fully inflated and then with them underinflated.
Interpretation: If I can go faster without skidding when my tires are underinflated, then my hypothesis will be supported. If I can go faster when the tires are fully inflated, then my hypothesis will be disproven.

Example 2
Question: I wonder if rubbing alcohol removes crayon from glass better than water does.
Hypothesis: I guess it might because alcohol dissolves things that water won’t.
Experiment: I will draw some lines on a piece of glass with a wax crayon. Then, I will moisten a paper towel with water and another one with rubbing alcohol. I will wipe some crayon lines with the water towel and some with the alcohol towel, being careful to use the same number of wipes and the same pressure.
Interpretation: If the lines are removed better with alcohol than water, then my hypothesis will be supported. If water removes crayon better than alcohol, then my hypothesis will be disproven.