Scanning Probe Microscopy (SPM)

Purpose Students simulate the function of a scanning probe microscope.

Time required 60 minutes

Level: Grades 4–8 and 9–12: The procedure includes variations for students at higher levels.

Teacher Background This activity works best in groups of 3 students. Scanning Probe Microscopes (SPMs) of various types trace surface features by movement of a very fine pointed tip mounted on a flexible arm across a surface. SPM enables resolution of features down to ~1 nm in height, allowing imaging of single atoms under ideal conditions. In this activity, students will use their index finger as a probe to scan unseen objects.

Materials

- 6 boxes
- foam sheets, ¼ inch thick
- utility knife or scissors
- glue
- Legos
- Ziploc bag
- sand or clay
- cellophane tape
- craft paper
- tissue paper
- marker
- index card
- cotton swab or bamboo skewer
- table tennis balls
- Student worksheets
- pens

Numbered SPM boxes

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Advance Preparation Prepare 6 SPM boxes by following these steps:

1. Gather 6 cardboard boxes with lids. Boxes with dimensions of 10 in ×10 in ×10 in are suitable.
2. On a piece of foam, draw six different geometrical shapes (square, triangle, diamond, circle, ellipse) or any other shape that you like. Use a utility knife or scissors to cut out the shapes. LEGOs® and cookie cutters with geometric shapes can also be used. If LEGOs® are used, place them closely so that the bottom of the box is entirely covered. You may also use a Ziploc storage bag containing clay or sand with an impression of a handprint. This item can serve as a springboard for a discussion about the sensitivity of probing surfaces, i.e., we can deform and change the surface if we do not touch it lightly.
3. Glue a different object or pattern onto the bottom of each box. Record on an identification key the object or pattern that was inserted into each box. Allow the glue to dry before conducting the activity with students.
4. Close each box.
5. In one side of each box, cut an opening through which students will later insert their hand to access the contents of the box. Square or circular openings are acceptable. A five-inch square is a good size.
6. Wrap the boxes with craft paper or tissue paper.
7. Block students' view of each box's contents by inserting a sheet of craft paper or tissue through the opening. Tape the paper over the opening so it hangs like a curtain would hang.
8. Use index cards and markers to number the boxes 1 through 6.

Safety Information Do not place sharp objects in the boxes. Avoid wet, sticky materials.

Assessment Assess students' work by awarding points for accurate completion of the chart, answering analysis questions, and trying a new kind of probe.

Resources:
To learn more about nanotechnologyand scanning probe microscopy, here are some web sites with educational resources:
http://www.mobot.org/jwcross/spm/
http://www.nnin.org/nnin_seeing.html
http://www.weizmann.ac.il/Chemical_Research_Support/surflab/peter/afmworks/index.html

National Science Education Standards
For grades 5–8:

Standard A

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

Standard B

- Properties and changes of properties in matter

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Standard E

- Understandings about science and technology

Standard G

- Science as a human endeavor
- Nature of science

For grades 9–12:

Standard A

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

Standard B

- Structure and properties of matter
- Motions and forces

Standard E

- Understandings about science and technology

Standard G

- Science as a human endeavor

Directions for the Activity Before the activity, discuss the need for non-conventional ways to detect surface topography on the nanoscale (beyond optical microscopes). Ask students:

- What is the smallest size or object that you can see with the unaided eye? *Examples include a grain of sand or a human hair, which are about 100 micrometers ("microns") or 100,000 nanometers (nm) in size.*
- How can you look at smaller things? *Use an optical microscope.*
- What is the smallest size or object that you can see with an optical microscope? *About 0.2–0.5 micrometers or 200-500 nanometers; Viruses are an example of an object at this scale.*
- What can you do to see smaller things? *Use an electron microscope, or a scanning probe microscope.*

Please note that this activity will work just fine without the student worksheet. The student worksheet is provided as a means for assessment.

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Procedure

1. Students insert their hand into each box and use the tip of one finger to scan the surface of the bottom of the box's interior. Students can scan from left to right, right to left or in a random pattern.
2. Students then draw a picture representing what they felt on the bottom surface of the box. They should try to identify what the bottom surface of the box looks like.
3. Have students compare their findings in small groups.

Variation You may vary the activity for students in grades 8–12 by the following means:

- Create stairsteps in the topography by stacking (but not gluing) layers of foam onto one another. If legos are used, you can add a second layer.
- Cover (but do not glue) the bottom of the box with closely packed table tennis balls or other soft or hard balls. Drawing their topography requires more skill. You can further increase the challenge by introducing a few larger balls to the arrangement.
- Have students scan the bottom of the boxes using a cotton swab or a bamboo skewer instead of a finger. This method more closely simulates the function of a scanning probe microscope.

After students scan the object, ask them a few extra questions:

- Did they notice anything special about this box? *Yes*
- What was different? *The surface is not even in the case of the presence of steps. In the case of table tennis balls, the surface is formed by repetition of spherical objects, either hard or soft.*
- What did students have to do to be able to identify the object and the pattern? *Avoid pressing too hard on the surface or the pattern would be modified.*

Explain to students that this is true with a real Scanning Probe Microscope: a force that is too high could damage the sample that is being analyzed.

Cleanup Store boxes for reuse or break them down and recycle the materials.

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Student Worksheet

Scanning Probe Microscopy (SPM)

Materials

- 6 SPM boxes
- pencil

Make a Prediction

1. We cannot see items on the nano scale with an optical microscope. How would we figure out the shape of something that we cannot see.

I think we feel for it…sense it. Maybe like sonar.

Procedure

1. Take a piece of paper and pen.
2. Stand in front of each box, place your hand, cotton swab, or bamboo skewer into the box and scan its bottom surface.
3. On the table on page 2, draw a picture of what you think the bottom surface of each box looks like.
4. What do you think each object is? Record your answer in the table.
5. What do your group members think each object is? Record your answer in the table.

Record Your Observations

Draw a picture of the object in each box. Write what you think it is. Write what other students think it is.

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SPM Box Observations

	Your Drawing	What You Think It Is	What Others Think It Is
Box 1			
Box 2			
Box 3			
Box 4			
Box 5			
Box 6			

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Analyze the Results

1. Were you able to identify the objects in the SPM boxes?

   Yes.

2. Was it as easy or difficult as you expected? Explain.

   Some of the boxes were easier than others. I had to count the corners of the object and imagine what it looked like.

3. Can you think of possible problems that might arise when trying to use a real SPM to "observe" something at the nanoscale?

   If the tip is too big, we cannot get a good idea of the image. If we press down too hard on a soft substance, the shape of the substance can change.

4. What will be the smallest feature that you can identify with the tools you have been using?

   I could feel things as small as the tip of my finger, but I could not identify them. I could identify things as small as a centimeter.

Note to Teachers: At this point, explain how an SPM works.

5. Which part of an SPM system does the box, your finger (or swab or skewer) represent in this model?

   My fingertip (or swab or skewer) represents the tip of the SPM probe.

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6. Can we use this method to identify nanoscale objects?

Having a smaller "probe" than my finger will allow me to touch and feel smaller objects, even on the nanoscale.

Draw Conclusions

7. Think of three other kinds of tips you could use to probe objects in the SPM boxes. Choose the one that you think would do the job best. Try it out. Did it improve your results? Why or why not?

Examples include: a pencil, a toothpick, and a pencil eraser: I tried the pencil eraser but it did not work as well as my finger did. I can feel with my finger but not with a pencil eraser.

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