

Touching the Nanoworld: A Scanning Probe Microscopy Module for High School Students

Emma Tevaarwerk

Northwestern University

July 29th, 2005



NORTHWESTERN
UNIVERSITY



National Science Foundation

A Center to develop nanoscale science and engineering educators with leadership capabilities

Learning and teaching through
inquiry and design of nanoscale
materials and applications

A Center to develop nanoscale science and engineering educators with leadership capabilities

Learning and teaching through
inquiry and design of nanoscale
materials and applications

Center Goals

- Develop well-rounded NSEE leaders
- Create and implement in-service and pre-service professional development
- Design innovative instructional materials for grades 7-16, enhanced by new learning technology tools
- Work with school districts, colleges and universities to integrate NSE into STEM curricula
- Research impact of complex, interdisciplinary learning on STEM
- Build a globally competitive NSE workforce

Fundamental Questions

Three questions about nano-structured materials:

What makes them unique?



Area 1: Manipulation of Light in the Nanoworld

Area 3: Mechanical Properties of Nanomaterials

How can they be used?



Area 2: Information Storage and Processing

Area 6: Nanomaterials for Energy, Environment, and Pharmaceuticals

How can they be made and characterized?



Area 4: Tools for Probing the Nanoworld

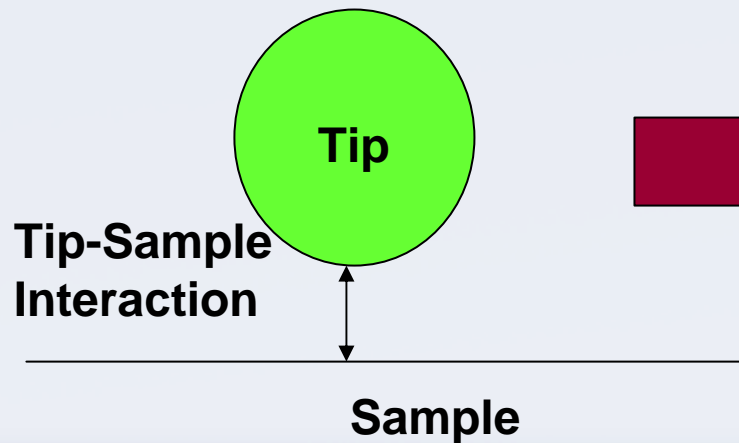
Area 5: Design and Fabrication of Nanomaterials

Scanning Probe Microscopy (SPM)

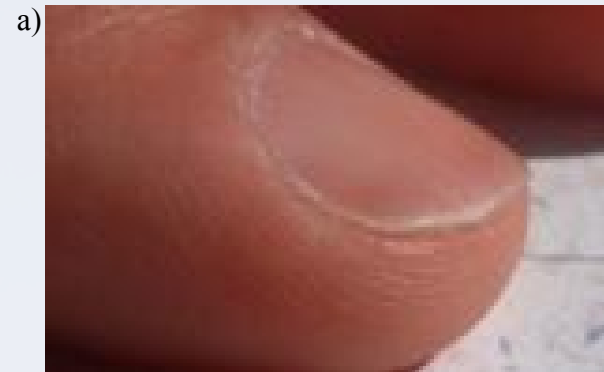
SPM is an important **measurement** technique of nanoscience.

Scanning Probe Microscopy is a touch-based way of characterizing (measuring) variations in the properties of materials at the nanoscale.

Basic Idea of SPM

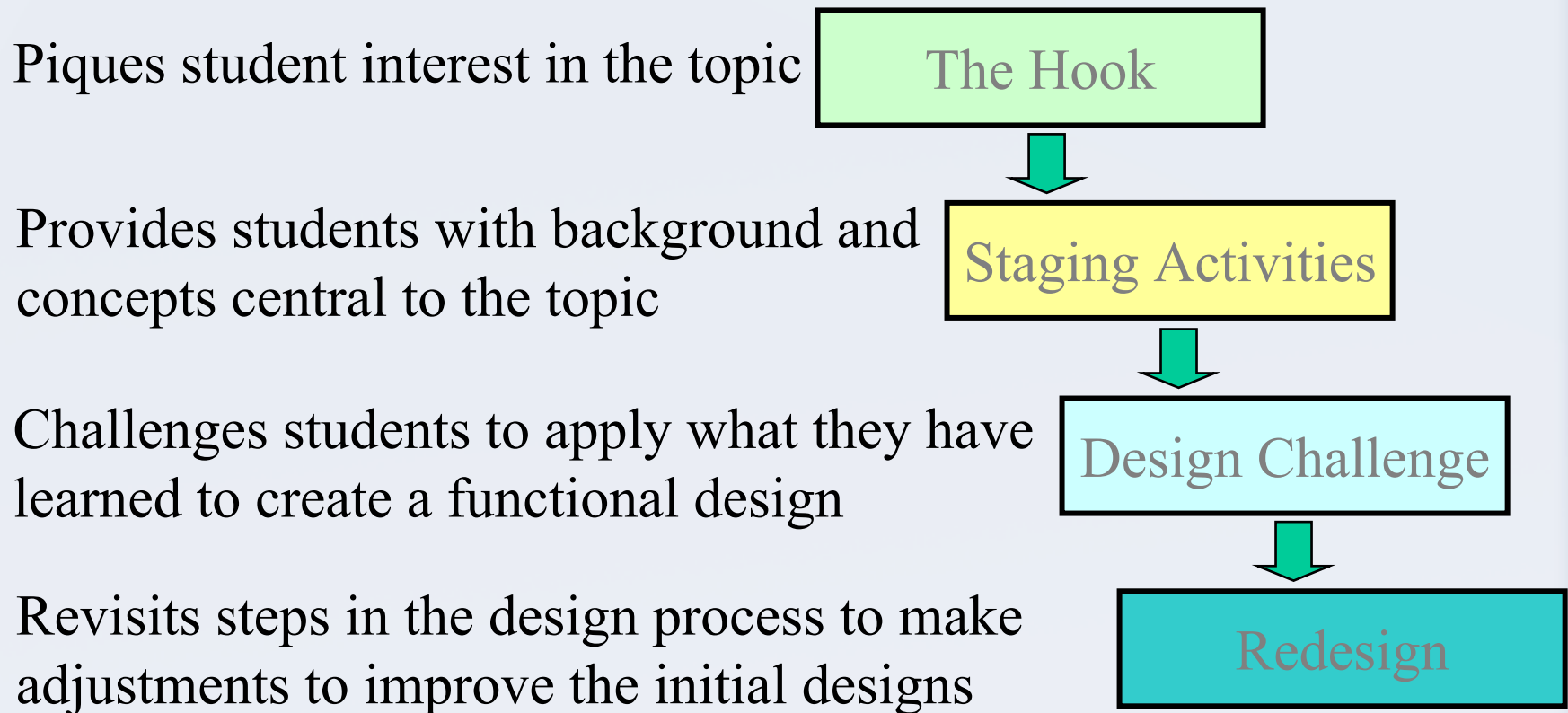


Macroscopic Analog

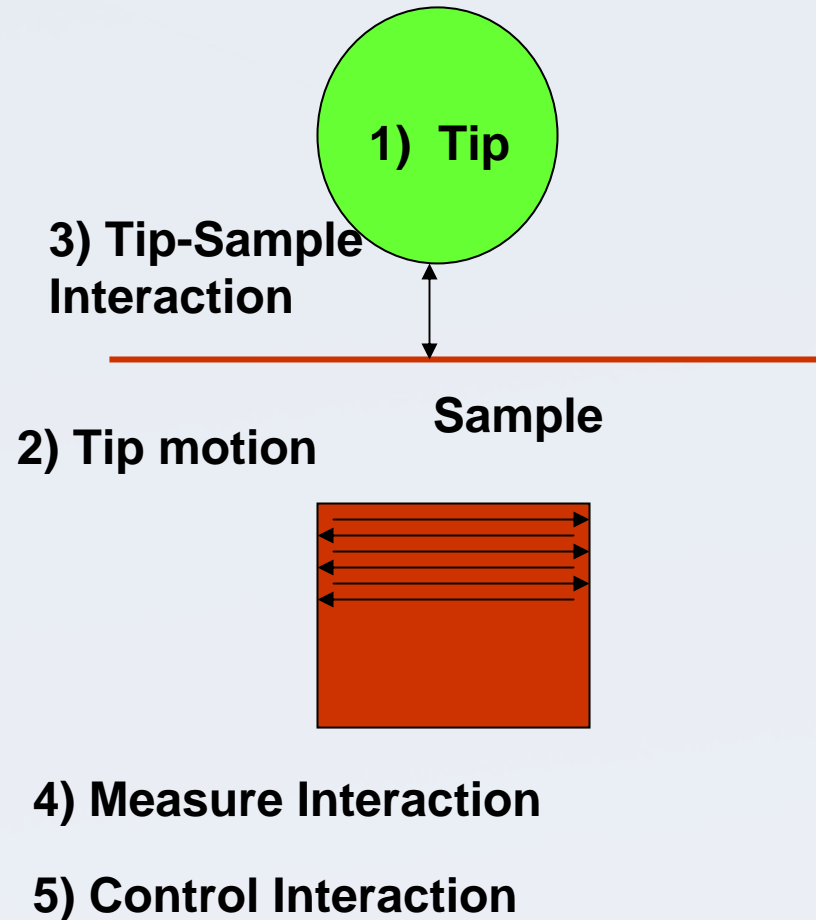


a) <http://www.bigfoto.com/sites/galery/hands/finger-nail-f5.jpg>

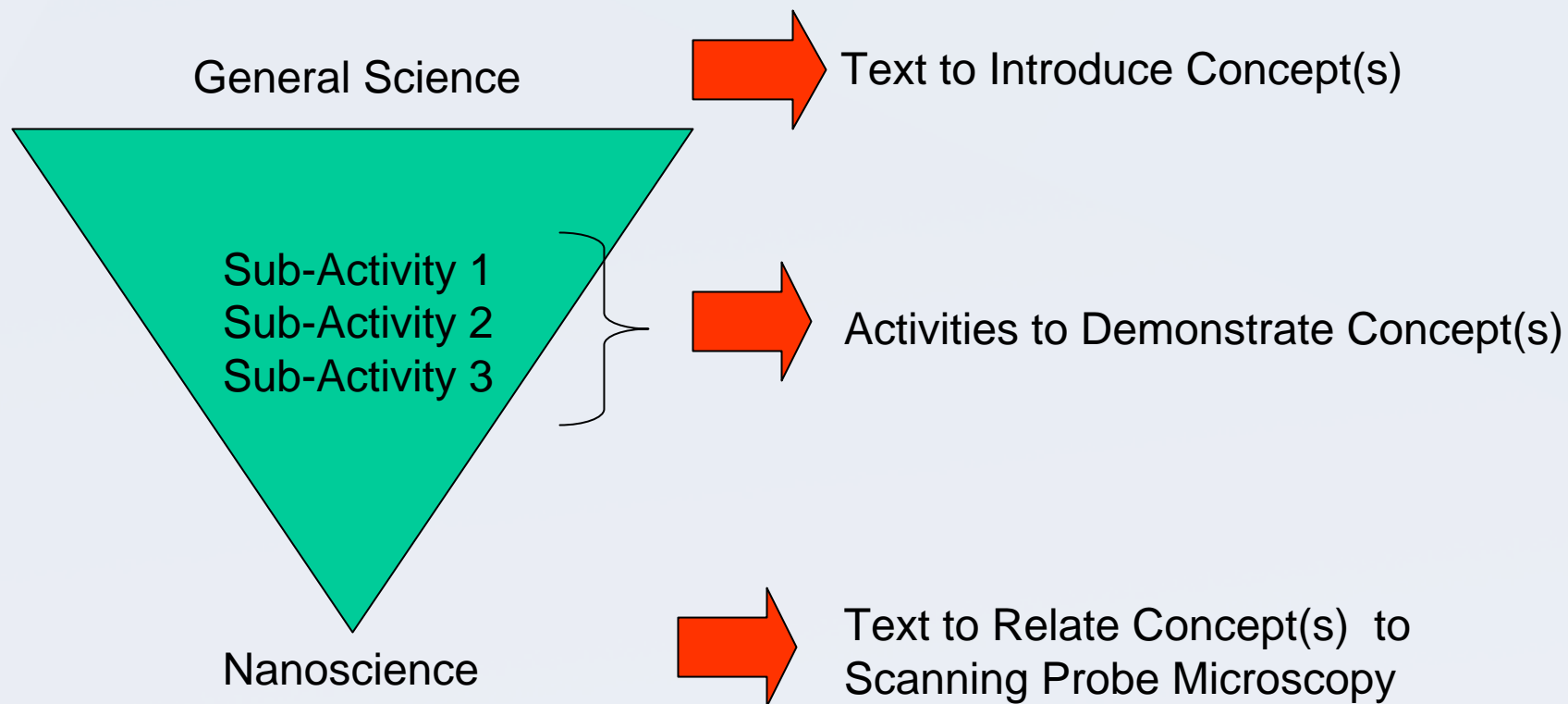
Materials World Modules Format



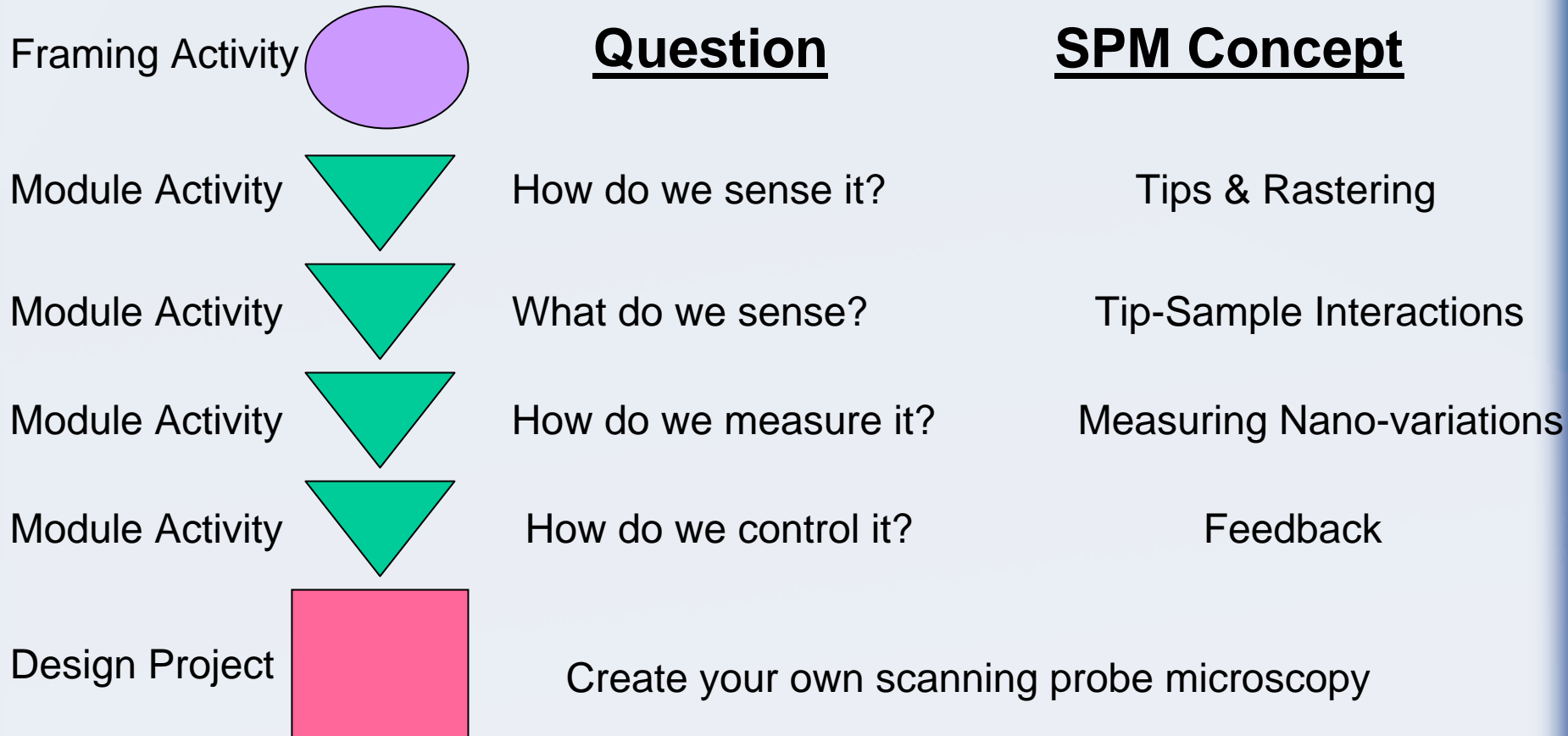
What do we want to communicate?



General Structure of An Activity



Overall Concepts and Layout of Module



Framing Activity: A Sense of Distance

Introduction: Measure without a Ruler?

Activity A: Measuring Distance with Our Eyes Open



(a)



(b)



(c)

Activity B: Measuring Distance with Our Eyes Closed



(d)



(e)



(f)

**Magnitude and Distance:
Need One to
Determine the Other**

Principles of the Five Senses

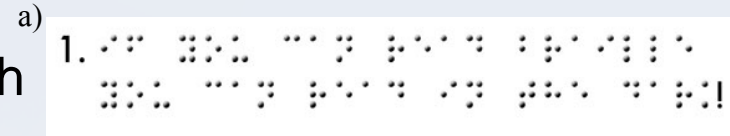
- a) <http://www.kepplah.com/stuff/eye.jpg>
- b) http://www.alexandersperl.de/courses/ps/pics/magnifying_glass.jpg
- c) http://www.kwiatyozdobne.pl/obrazy/bonsai_wypas.jpg
- d) <http://www.eslkidstuff.com/images/nose.gif>
- e) <http://www.undergrad.ahs.uwaterloo.ca/~rdcheung/649.jpg>
- f) <http://www.cs.helsinki.fi/u/mkoljone/handandpencil/hand.jpg>

Activity 1: Sensing with Touch

Introduction: Why Not Light?

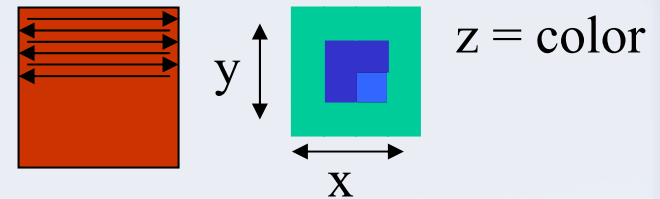
$\lambda_{\text{visible}} \sim 400 \text{ nm} - 700 \text{ nm}$

Sub-Activity 1A: Sensing with Touch



Sub-Activity 1B: A Nano-Finger: Tips

Sub-Activity 1C: Nano-Imaging: Scanning



Nano-Connection: Resolution & Nano-Motion

a) http://www.rnzfb.org.nz/IrisWorld/Images/braille_question_1.jpg

Activity 2: It's All About Interactions

Introduction: Atomic Resolution and STM

Sub-Activity 2A: What can you sense with touch?

Sub-Activity 2B: Functionalize It:
What might a Probe Sense?

Nano-Connection:
The Atomic Force Microscope

Map it



(a)



(b)

- a) <http://www.pelletlab.com/images/Bar%20Magnets.jpg>
- b) http://www.bethyoung.org/photos/caroline/static_electricity_july_04.jpg

Activity 3: Measuring Nano-variations

Introduction: Civilizations & Measurement

Sub-Activity 3A: Units, Precision,
Accuracy & Uncertainty

Sub-Activity 3B:
Amplification of Floor Vibrations

Mini Design 3C:
Designing a Vibration Isolation Stage

Nano-Connection:
The Atomic Force Microscope (AFM)

Measure in an Earthquake?

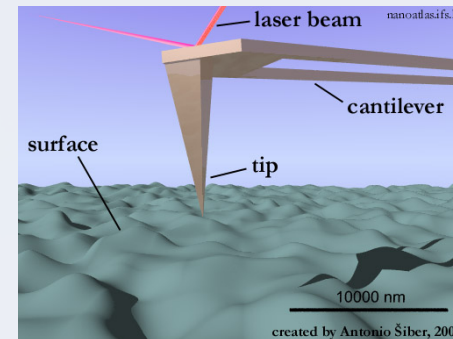
Signal



$1 \text{ nm} \pm 1 \mu\text{m}$

$10^{-9} \text{ m} \pm 10^{-6} \text{ m}$

Noise



http://www.nanotech-now.com/images/Art_Gallery/AS-AFM.jpg

Activity 4: Controlling Nano-motions

Introduction: Feedback: It's Everywhere!

Sub-Activity 4A:
Feedback and Movement:
Proprioception

Sub-Activity 4B:
Example of Feedback loop

Nano-Connection:
Feedback in Atomic Force Microscopy

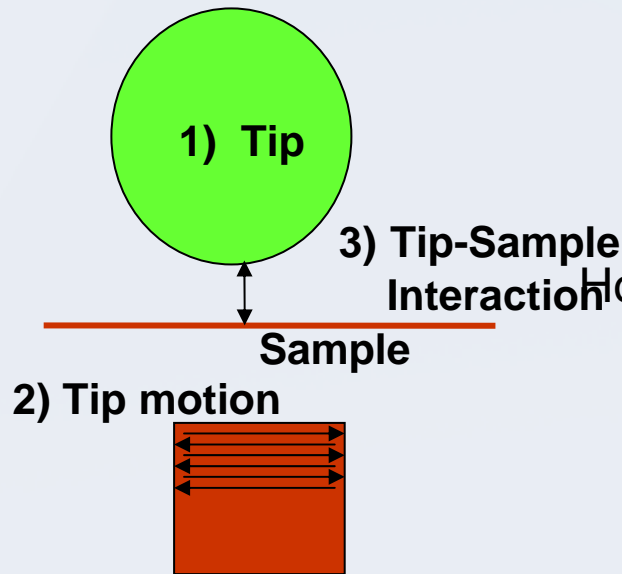


Warrior III

Mechanical?
Computer Simulation?

touching =
following surface
of constant force

Design Project: Your Own Scanning Probe Microscopy



What sort of **tip-sample interaction** will you use?

How would you design your **tip**?

What **motion** do you want your tip to have?

How will you **measure** the variations in your sample?

How will you **control** the tip motion?

[Build a model](#)

[Imagine an Image.](#)

4) Measure Interaction

5) Control Interaction

Provide kids with: magnets, silver paint, tin foil, velcro, sticks, boards, springs, rubber bands, laser pointers, batteries, wires, sticky tape, carpet(s), fiber optical cable...