

Design a Touch Microscope: Map a Surface You Cannot See

Investigation question: What criteria and constraints must a probe-based mapping method meet to produce a trustworthy map of a hidden surface, and how does your method compare with a scanning tunneling microscope?

Engineering design challenge

Groups of 4

2 sessions

Setup 10 · Activity 80 · Cleanup 10 min

MS-ETS1-1 · assesses

MS-PS1-1 · supports

Name _____

Group _____

Date _____

Your role today

- ☐ **Design lead:** Runs the criteria and constraints discussion, makes sure every criterion has a number or a clear test, and keeps the group to the agreed probing plan.
- ☐ **Prober:** Lowers the probe straight down through each grid point, reads the depth mark at the lid, and calls the value out. Never angles or sweeps the probe.
- ☐ **Recorder:** Writes each depth reading in the correct grid cell, converts depths to heights, and keeps the map sheet clean.
- ☐ **Mapper and checker:** Shades the height map from the recorded numbers, then at the reveal compares the map with the real surface and scores it against the group's criteria.

Safety

- Skewers are pointed sticks: use only blunted or glue-capped tips, probe straight down into the box, and never hold a skewer above desk height or point it toward anyone's face. Eye injury is the real risk here.
- Only the teacher uses a hot glue gun, if one is used to cap tips or fix landscape pieces; white glue or tape is the student option.
- Pushpins stay in the lid of their container when not making holes; count them out and back in.
- Keep boxes on the desk, not on laps, while probing.

Procedure

1. Session 1, define first. Before touching any material, write the problem in your own words: produce a map of a surface you cannot see, using a probe through a grid. Then write at least three criteria, each with a number or a clear test (for example: 'the map shows the location of every object taller than 1 cm to within one grid square'; 'the map's height values are within 1 cm of the real heights'; 'the map is finished in 20 minutes or less').
2. List at least three constraints you must work within: materials you have, time, the rule that the lid grid may not be lifted until the reveal, the probe may only go straight down, and anything about the box itself.

Record both lists in the criteria and constraints table.

3. Build a landscape for another group: fix three to five objects of different heights to the floor of your box with glue or tape. Sketch it on a hidden sheet, measure each object's height, and give the sheet to your teacher in a sealed envelope. Tape the grid sheet over the open top of the box and swap boxes with another group.
4. Design your probing method. Decide the grid spacing (every square, every other square, or coarser), how you will read depth (which mark on the skewer lines up with the grid sheet), how you will turn depth into height (height = box depth minus probe depth), and how you will shade the map. Write the plan and predict how many probe points you will take and how long it will take.
5. Session 2, map. Set the timer. The prober pushes the skewer straight down through the grid at each planned point until it stops, reads the depth mark at the grid sheet, and calls it out. The recorder writes the number in the matching cell of the map grid.
6. When the planned points are done, stop the timer and record the time. Convert each depth to a height and shade the map: one color for floor level, a second for 1 to 3 cm, a third for above 3 cm (or your own scheme). Mark where you think each object is and how tall it is.
7. Reveal. Open the envelope from the group that built your box and compare your map with their sketch and heights. Score your map against each of your own criteria: met or not met, with the evidence.
8. Revise. Choose one change to your method that would improve the result on the criterion you missed most (for example, probing every square in one region, or reading the skewer at eye level), and if time allows, re-probe one 6 by 6 region with the revised method.
9. Compare your method with the scanning tunneling microscope: list two ways they are alike and two ways they differ. Complete the analysis questions individually.

Record your observations

Lab 3 recording sheet: Design a touch microscope

Session 1: fill in the problem statement, the criteria and constraints table and the design plan before you probe anything. Session 2: fill in the map grid, the scoring table and the questions.

Criteria and constraints (write at least three of each; every criterion needs a number or a clear test)

Criteria: what a successful map must do	How we will test it	Constraints: limits we must work within	Why it limits us

Design plan

Grid spacing (cm)	Predicted number of probe points	Predicted time (min)	How we read depth	How we turn depth into height	Shading scheme

Map grid: write the probe depth (cm) in each cell you probe; leave skipped cells blank

Row	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1															
2															
3															
4															
5															
6															
7															
8															
9															

 Shade your height map here (or shade the grid above). Mark each object you think is present, label its estimated height, and add a key for your colors.

Scoring against our own criteria (after the reveal)

Criterion	Met? (yes/no)	Evidence from the comparison	What change would help

1. Time taken for the first full map: ____ minutes. Number of probe points: _____. Number of objects in the box: _____. Number your map found: ____.

2. Which of your criteria was hardest to write with a number? Rewrite it here in its final, testable form.

Analysis questions

3. Explain the trade-off between grid spacing and time using your own numbers. If you doubled the number of probe points, what would improve and what would get worse?

4. Your map was built from a table of numbers, not from a picture. Describe how the numbers became an image, and name one way the image could be wrong even if every reading was correct.

5. A classmate writes the criterion 'the map should be good.' Explain why that criterion cannot be used to judge a design, and rewrite it so it can.

6. Which of your constraints came from the physical world (the box, the probe, the objects) and which came from people (time, rules, materials budget)? Give one of each and explain how it limited your design.

7. The scanning tunneling microscope sweeps a probe over a surface and records a current that grows when the probe is closer to the surface. List two ways your method is like the STM and two ways it is different, including what the STM probe never does.

8. An object in the box was 2 cm wide and your grid spacing was 4 cm. Could your map have missed it entirely? Explain, and connect this to why the STM inventors set a criterion of about 100 picometers of resolution.
