

# Multiple Tools for Visualizing Equipotential Surfaces: Optimizing for Instructional Goals



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## Research Questions:

- How do the instructional tools - whiteboard, Mathematica notebook, and surface model - affect how students engage with the activity?
- How do the tools support the instructional goals of the activity?

## Theoretical Perspective:

Distributed Cognition - tools have conceptual and material features that mediate how people use them to accomplish tasks<sup>1</sup>.

## Data:

Classroom video of 3 of 13 groups doing *Visualizing Equipotential Surfaces* Activity.

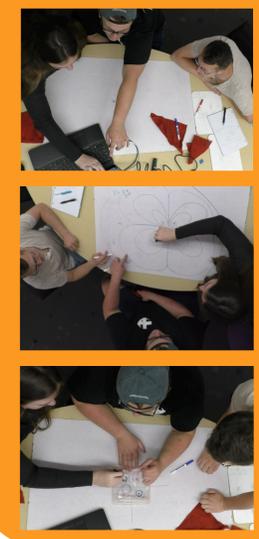
Post-class debriefing notes from instructors (EG and RW).

## Analysis:

- All authors viewed videos and took notes.
- Transcripts made of students were drawing contours for the quadrupole (Task 2).
- Researchers' attention focused on:
  - how students participated with each tool,
  - what information was represented with each tool<sup>2</sup>,
  - transformations/manipulations students did with the tools,
  - how the tool moved the students forward in their discussions.

## Aspects of Support & Engagement

### Individual Access to Tools



**Mathematica:** Works better in pairs. No groups placed laptop centrally.

**Whiteboard:** Each student can write, erase, point simultaneously.

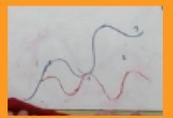
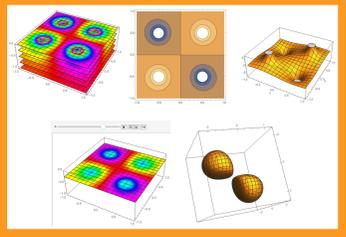
**Surface Model:** Lightweight, students placed it centrally. Students drew, pointed simultaneously.

Goal 5

### 3D Visualization of Potential Field

Mathematica offers several ways of visualizing the 3D electrostatic potential field. Some students had difficulty interpreting these representations

Some students were uncomfortable drawing contour plots. One group tried to draw a surface plot on the whiteboard.



Goal 2

Goal 4

Whiteboard



Mathematica

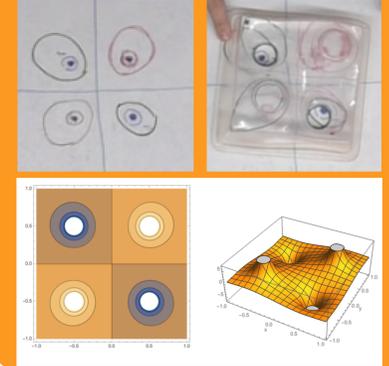


Surface Model



### Co-location of Representations to Make Connections

Surface model colocates surface plot and equipotential curves → connect steepness with density of curves



Student wrote the equation for a point charge on the whiteboard with their contour map.

Goal 1

Goal 3

Goal 4

### Making Decisions vs. Making Explanations

Mathematica and surface model perform superposition for students → "looking up answer" mode.

With whiteboard, students have to make decisions → questioning and productive struggle

**Anna:** Yeah, so is this distance supposed to be bigger, or is this distance supposed to be bigger? That's what I'm wondering. (pause) Can we try it over there? (points to the laptop)

**Charlie:** Yeah, why try to visualize when the computer can do the work for us?

**Anna:** [uses keyboard] Does that? That looks right.

**Charlie:** Oh, hey. That's exactly what it is.

**Bailey:** [chuckles] That's funny. All right. So let's just think of this picture then. [Anna evaluates a new Mathematica cell] What?

**Charlie:** Yeah, I was right! On the asymptotes it's zero because along those lines, there's equal push and pull.

**Anna:** Right. And then, yeah, so it is actually spaced farther out that way and closer this way [points to the computer screen]. So it's the opposite of what you drew. [starts altering whiteboard drawing]

**Bailey:** So let's think about why.

Goal 1

Goal 3

Goal 5

## Instructional Activity: Visualizing Equipotential Surfaces

- Task 1: in small groups, draw equipotential surfaces for 4 positive point charges on a whiteboard.
- Whole class discussion about how to determine curve shape.
- Students given Mathematica notebook with 5 representations pre-programmed.
- Instructor demos notebook for 4 positive charges.
- Task 2: draw equipotential surfaces for a quadrupole.
- Students given surface models<sup>5</sup>.
- Whole class discussion.



## Instructional Goals:

- Goal 1 Superposition** - add potential from discrete charges
- Goal 2 3D Function** - describe equipotential surfaces as existing in 3D space
- Goal 3 Contour Plot** - create plot, explain density of contours, explain shape of contours
- Goal 4 Graphical Representations** - interpret and compare various representations of the field
- Goal 5 Inquiry** - investigate physical phenomena

[1] E. Hutchins, *Cognition in the Wild*, A Bradford book (MIT Press, 1995).

[2] S. Ainsworth, *Learning and instruction* 16, 183 (2006).

[3] T. de Jong, M. C. Linn, and Z. C. Zacharia, *Science* 340, 305 (2013).

[4] A. V. Heuvelen, *American Journal of Physics* 59, 891 (1991).

[5] <http://www.raisingstem.org>.

