Student Use and Coordination of Computerized and Tangible Visualization Tools

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Investigation

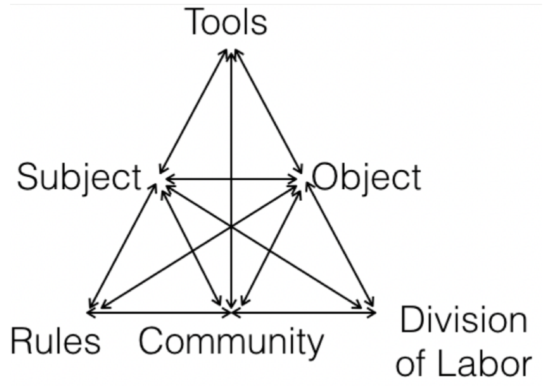
We have developed an instructional task to help students visualize the 3D scalar electric potential. Students are asked to draw equipotential curves on a whiteboard and are given a Mathematica notebook with several visualizations of the scalar field and a plastic surface model of the potential function. We examined classroom video of a group of students and identified ways the students used and coordinated the whiteboard, Mathematica notebook, and plastic surface.

Methods

- Reviewed video of four groups in a class of 36.
- Two groups progressed far enough in the instructional task to use surfaces.
- One group selected for a detailed coding and analysis due to the quality of the video and exceptional discussions present.
  - This group was identified as "special" by the instructor for the course. Their work should be considered exemplary, rather than typical.
- Transcribed relevant portions of the video.
- Performed open coding to determine ways the tools were used.

Framework

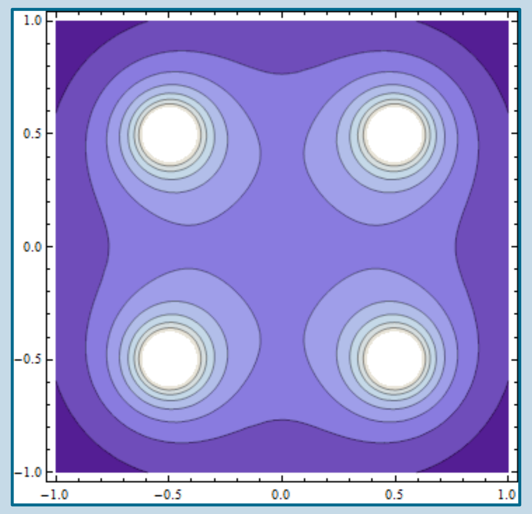
The results presented here are part of a study that uses the theoretical perspective of Activity Theory.[1,2]



Whiteboard Tool

- Students primarily used the whiteboard to generate representations of equipotentials, and occasionally drew things like graphs and equations. Words and sentences were not written on the whiteboard.
- The students would also mark on the whiteboard to emphasize or explain (drawing force vectors, circling charges, etc.).
- The whiteboard was generally an anchor for discussion, as students gestured above, around, and at the whiteboard while forming and presenting explanations.
  - ***"I kind of feel like she's [the instructor's] talking about, like, this [Points to a loop.] versus this [Points to next larger adjacent loop.]."***
- Students frequently used the whiteboard to ask questions about the physical system and its properties.
  - ***"Well I'm talking about if we dump charge right here, [Draws dot again far from center.] how much energy is it gonna pick up [Draws line from point toward center.] as it flies in towards [Gesturing inward,] that positive ch[arge]."***

Mathematica Tool



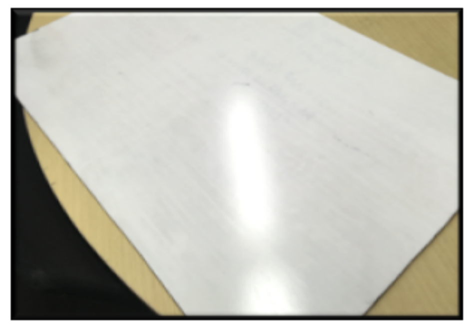
- Students followed a scaffolded Mathematica notebook that had:
  - Code for plots of the potential due to four positive point charges on the corners of a square
  - No code explicitly for a quadrupole.
- We found that the students primarily extracted information from Mathematica.
  - ***"Right. And then, yeah, so it is actually spaced farther out that way and closer this way [pointing to the computer screen]. So it's the opposite of what your drew. [Erases curve from whiteboard.]"***
  - The students view the Mathematica notebook with authority, but still consider the Mathematica image to be an insufficient response to the prompt.
  - One student summarized this "extraction" mindset by declaring, ***"I also appreciate that we can successfully use technology to not have to think about stuff."***

Surface Tool

- The students used the surface to "bridge" between their group-generated whiteboard representation and the extracted Mathematica information.
  - At one point shortly after the group has the surface on their whiteboard a student decides that the surface representation is insufficient, and transitions to the Mathematica notebook, ***"I like our picture. I want to know what these do farther out. [referring to equipotential curves] Is there a way. Let's do this. [Pulls up the laptop.]"***
- Since the surfaces are dry-erasable, the students drew on their surface several times.
  - They expressed great interest in drawing on the surface, with one student initially saying, ***"When we get the surfaces, let's draw some rings on them."***
- Despite the relative ease of generating an image in the Mathematica notebook, the students tenaciously sought coherence between representations throughout the activity. The surface increased the richness of the connections.

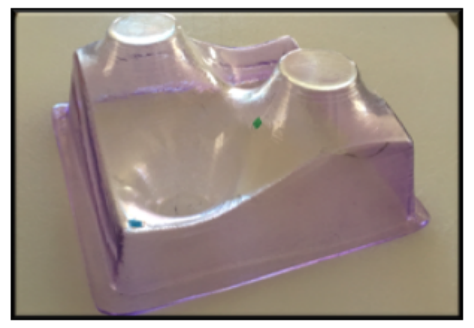
Instructional Timeline

- **Stage 1**: Draw equipotentials on a whiteboard for 4 positive point charges in a square.
- Whole class discussion about how to determine equipotential shape.
- Students given Mathematica notebook with 5 representations pre-programmed.
- Instructor demos notebook for 4 positive charges.
- **Stage 2**: Draw equipotentials for a quadrupole.
- Students given surface models.
- Whole class discussion about equipotentials.



Whiteboard

Mathematica Notebook



Surface Model

Conclusions

- The whiteboard was used for discussion and to interrogate the system.
- The Mathematica notebook was used to extract information.
- Students used the surface to explain and expand their understandings of each of the other two tools and as a bridge between the other tools.
- Students had little difficulty interpreting the surface.

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[1] Y. Engstrom, *Learning my Expanding: An Activity Theoretical Approach to Developmental Research* (Helsinki: Orienta-Konsultit, 1987), URL http://lchc.ucsd.edu/mca/Paper/Engestrom/Learning-by-Expanding.pdf
[2] D. H. Jonassen and L. Rohrer-Murphy, Educational Technol- ogy Research and Development 47, 61 (1999), URL http://link.springer.com/article/10.1007/BF02299477

This material is based upon work supported by the National Science Foundation. DUE 1612480