Middle School Student Ideas on the Relative Affordances of Physical and Virtual Models

Elizabeth McBride, Jonathan Vitale, and Marcia C. Linn
bethmcbride@berkeley.edu, jonvitale@berkeley.edu, mclinn@berkeley.edu
University of California, Berkeley

Abstract: This research investigates students' perceived differences between doing activities in hands-on versus virtual environments. Students explored an interactive virtual model of a solar oven and then built and tested a physical solar oven. We found that students often questioned the accuracy of virtual models, yet come to recognize the value of features in the virtual model, including visualizations of energy flow and ability to analyze trends in graphs.

Objectives

When designing inquiry curriculum, we often use interactive virtual models to allow students to investigate how variables in a system may be related. This study compares student perceptions of virtual and physical models. Models improve student learning by abstracting away unnecessary features and making invisible phenomena more visible (Snir, Smith, & Grosslight, 1993). Virtual models are now quite ubiquitous, however, their ubiquity is still relatively new, and while there is a wealth of research on supporting student learning of science concepts through the use of virtual models, not much work has been done to explore how students understand the practices involved in utilizing these virtual models.

Many studies have found students learn concepts, inquiry skills, and scientific practices at the same level or at a higher level through the use of virtual laboratories (versus physical laboratories) (e.g., De Jong, Linn, & Zacharia, 2013; Brinson, 2015). Virtual models allow students to develop their own knowledge by asking scientific questions, answering those questions using evidence, and connecting explanations to scientific knowledge. However, students may develop additional questions relating to the practice of using models (e.g., why do scientists use models? What can models tell us? What are the limitations of models?).

We use the knowledge integration framework to develop the curriculum about solar ovens, because the framework focuses on building coherent understanding (Linn & Eylon, 2011). The knowledge integration framework has proven useful for design of instruction featuring dynamic visualizations (Ryoo & Linn, 2012) and engineering design (McElhaney & Linn, 2011). The framework emphasizes linking of ideas by eliciting all the ideas students think are important and engaging them in testing and refining their ideas. Helping students to distinguish which sources of evidence are relevant and supportive (or not) of their ideas is a particular challenge for instruction. In order to develop relevant instruction, we need to know how they naturally think about the relative affordances of each type of model.

Methods

Five teachers from three different schools participated in this study, along with their students (N=640). All students were in the 6th grade, and all schools are in the suburbs of a large U.S. city serving mainly middle SES communities. Teachers A (N=137) and B (N=80) teach at school A, teachers C (N=190) and D (N=78) teach at school B, and teacher E (N=155) teachers at school C. Students completed pre- and posttests individually; during the curriculum, students worked in pairs or triads.

This study was implemented in a curriculum unit entitled *Solar Ovens*. The goal of the unit was to familiarize students with the way energy transforms from solar radiation to heat using a hands-on project and interactive models, covering the modeling aspect of the Science and Engineering Practices of the NGSS, as well as the standards associated with energy (NGSS Lead States, 2013). Students engaged with the curriculum in WISE (Web-based Inquiry Science Environment), utilizing a variety of instructional and assessment tools (Linn & Eylon, 2011). Students followed the design, build, test cycle with two iterations. During each design phase, students use the interactive model to test different features on a virtual solar oven.

We aim to find ideas students hold about the benefits and drawbacks of physical and virtual models by assessing student responses to a pre-/posttest question called *David's Claim*. This question asks students to help a fictional student, David, decide whether the box he will use for his solar oven should be tall and skinny or short and wide. Students are told that David thinks the tall and skinny box will heat up faster because the window on the top is smaller and will let less energy leave the box. Students are then asked whether David is correct or incorrect, and to explain their answer using evidence from the interactive model (where they can only manipulate box shape).

To understand student thoughts about affordances of physical and virtual models, we analyze a follow-up question, asking students whether they would rather use a physical or virtual model to help David (item: *Opinion*). While more students preferred to use the physical model at both the pretest and the posttest, there was a sight shift toward students preferring to use the virtual model or to use both models at the posttest. We found that students had ideas about benefits (or drawbacks) of physical and virtual models that fell in 10 categories, shown in Table 1.

Table 1: 10 categories for student ideas about the relative affordances of physical and virtual models, with description and name

Name	Description
Virtual Accurate	Virtual models are more accurate or valid than physical models
Physical Accurate	Physical models are more accurate or valid than virtual models
Virtual Visible	Virtual models have features that make them easier to use for explaining and learning how energy works (e.g., graphs, depiction of energy using symbols)
Physical Visible	Physical models are better because you can see them and see what's happening from any angle
Virtual Fun	Virtual models are more fun than physical models
Physical Fun	Physical models are more fun than virtual models
Virtual Fast/Easy	Virtual models are faster and easier to use than physical models, and do not require materials
Physical Fast/Easy	Physical models are faster and easier to use than virtual models
Physical Experience	Physical models give a better experience, and help students learn and focus better
Virtual Limitations	Virtual models have limitations and cannot show all the options that exist in real life

Results

By far the most common responses to the *Opinion* item were that students felt the physical model was more accurate than the virtual model and students found value in the features of the virtual model (e.g., the graph, the visualization of the phenomenon). From pre- to posttest, students' belief in the greater accuracy of the physical model compared to the virtual model increased, as did student appreciation for the visibility offered by the virtual model. Student reasoning about the limitations of the virtual model also increased drastically from pretest to posttest. In contrast, student statements about the benefits of the visibility of the physical model decreased, as did student statements that the experience of building a solar oven would help them to explain.

Conclusion

This work takes advantage of a curriculum featuring both physical and virtual models of solar overs to explore benefits and drawbacks. Moreover, the virtual model acts as a representation of the physical model students will build, providing students with an opportunity to explore the relative affordances of each type of model. This study reveals limitations in student understanding of virtual models that deserve attention to increase effectiveness of instruction featuring models. Focusing on increasing student consideration about *relative* benefits of physical and virtual models could help students appreciate virtual models and have lasting impact on their use of models.

References

Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. *Computers & Education*, *87*, 218-237.

De Jong, T., Linn, M. C., & Zacharia, Z. C. (2013). Physical and virtual laboratories in science and engineering education. *Science*, *340*(6130), 305-308.

Linn, M. C., & Eylon, B. S. (2011). *Science learning and instruction: Taking advantage of technology to promote knowledge integration*. Routledge.

McElhaney, K. W., & Linn, M. C. (2011). Investigations of a complex, realistic task: Intentional, unsystematic, and exhaustive experimenters. *Journal of Research in Science Teaching*, *48*(7), 745-770.

Ryoo, K., & Linn, M. C. (2012). Can dynamic visualizations improve middle school students' understanding of energy in photosynthesis?. *Journal of Research in Science Teaching*, *49*(2), 218-243.

Snir, J., Smith, C., & Grosslight, L. (1993). Conceptually enhanced simulations: A computer tool for science teaching. *Journal of Science Education and Technology*, *2*(2), 373-388.