Modeling hidden circuits: an authentic research experience in two hours

COASTAL CAROLINA UNIVERSITY
PHYSICS EDUCATION RESEARCH GROUP

J. Christopher Moore
Department of Chemistry and Physics
Coastal Carolina University

Abstract

Two wires exit a black box that has three exposed light bulbs connected together in an unknown configuration. The task is to determine the actual circuit configuration without opening the box. In this two-hour authentic research experience, we adopt the Investigative Science Learning Environment (ISLE) method of instruction to navigate students through the process of making models, developing and conducting testing experiments that can support or falsify models, and confronting ways of distinguishing between two different models that make similar predictions. We present examples from student-generated notebooks, where teams of students can be seen doing authentic science process to solve a research question. We also describe a twist that forces students to confront new phenomena, requiring revision of their model and incorporation of new ideas never previously explored in the coursework.

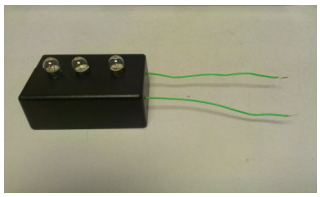
Hidden Circuits

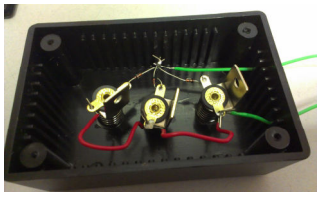
Three light bulbs connected in an unknown configuration with two exposed wires.

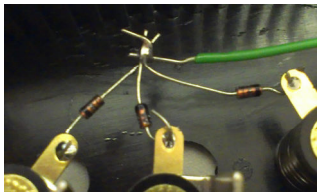
Student are told that we did not intentionally incorporate electrical shorts or open circuits within the box.

What students do not know is that we include diodes to add a direction dependence for certain bulbs. No discussion of diodes precedes the activity.

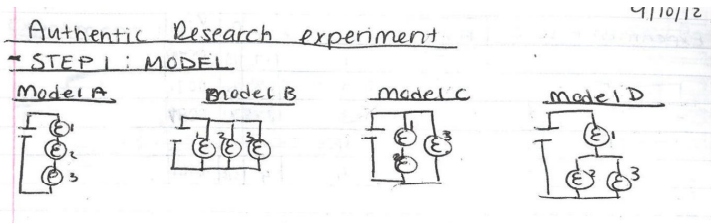
Students are initially given the boxes, but no other equipment until they have created models, made predictions, and devised testing experiments. They must request equipment and justify their requests.





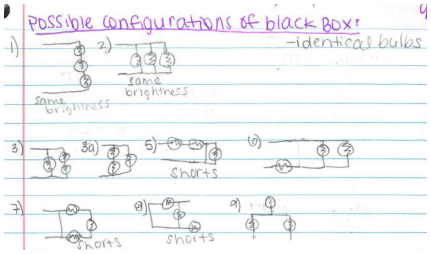


Models



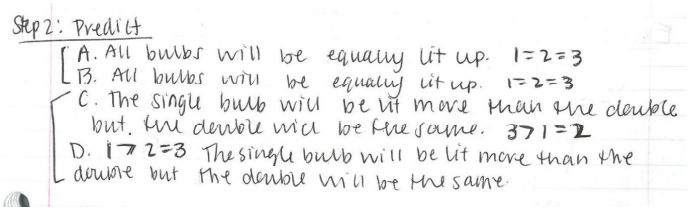
We spend 2-3 weeks on a circuits learning unit using *Physics by Inquiry*.

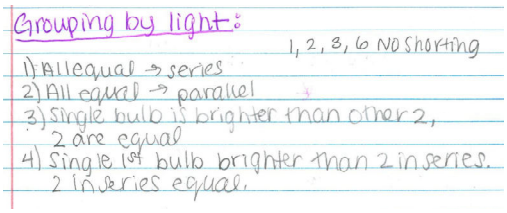
Students come up with between 4-8 circuits models and quickly narrow the models down to 4 different circuits after realizing some drawn models are equivalent.



Some don't trust me, and still incorporate shorts in their models!

Predictions



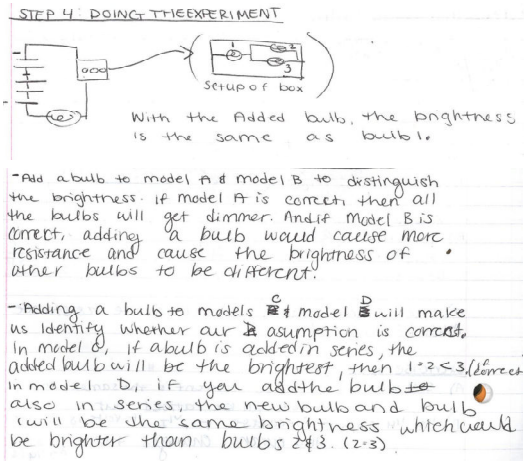


Students identify groups of circuit models that give the same predictions.

Initially, some groups believe they can distinguish from observation alone due to differences in brightness they can predict across two different circuits. They must be led to recognize that they have no means of comparing with only one box.

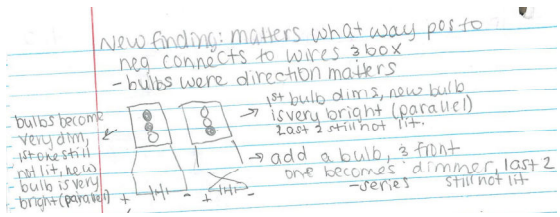
Testing Experiments

Groups must describe experiments and materials needed that would allow them to distinguish between models that give similar predictions.

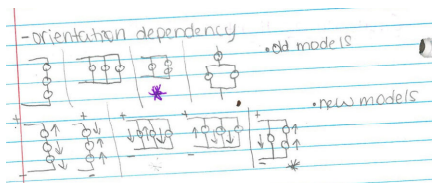


Students do not have access to any materials other than the boxes before they complete this step.

Extending the Model



Students quickly discover directional dependence.



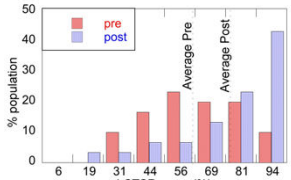
Extend their model for light bulb circuits with new "direction-dependent" bulbs with symbols similar to that of a diode.

Scientific Reasoning

4 authentic research activities during the semester as capstones to learning units.

Exam questions on science process and reasoning skills.

Significant gains on Lawson's Classroom Test of Scientific Reasoning (N = 33).



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E. Etkina & A. Van Heuvelen, "Investigative Science Learning Environment – A Science Process Approach to Learning Physics," in *Research Based Reform of University Physics*, E. F. Redish and P. Cooney, (Eds.) (2007)

E. Etkina, A. Warren, and M. Gentile, "The Role of Models in Physics Instruction," *Physics Teacher*, **44** 34-39 (2006).