Developing Scientific Reasoning in Pre-HS Education Majors by Eliminating Possibilities

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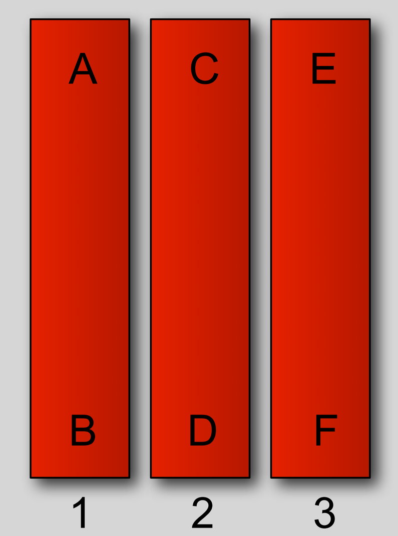
Future pre-HS teachers generally do not have much experience with scientific reasoning. For a *Physics for Teachers* course, I have enhanced existing activities by explicitly considering possibilities. That process, which is based on a psychological model for deductive reasoning[1], should be a productive way to communicate with students[2]. The goal is to reduce students' apprehension for scientific reasoning by helping them develop reliable skills.

Deductive Reasoning

Some of my students claim to "not be able to think like a scientist" but love games like sudoku. The reasoning process is similar; this activity points out that they **already know** how to think like a scientist!

This is a problem from PbI: given some observations, is each bar a magnet, non-magnet, or ferromagnetic?



		1						
		2		3				4
			5			6		7
5			1	4				
	7						2	
				7	8			9
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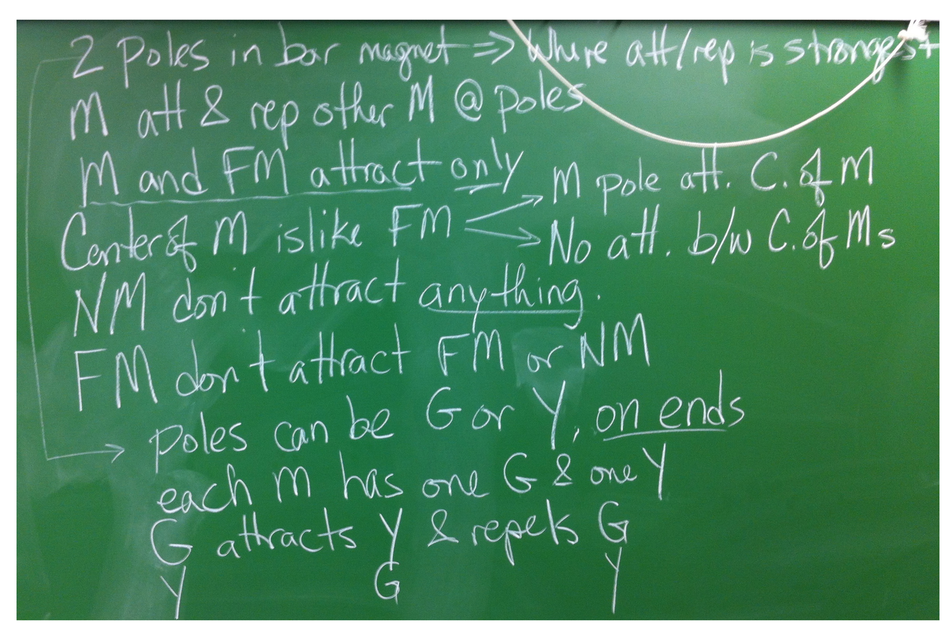
We compare with Sudoku and then list the "rules" for the deduction game, based on our observations of the materials.

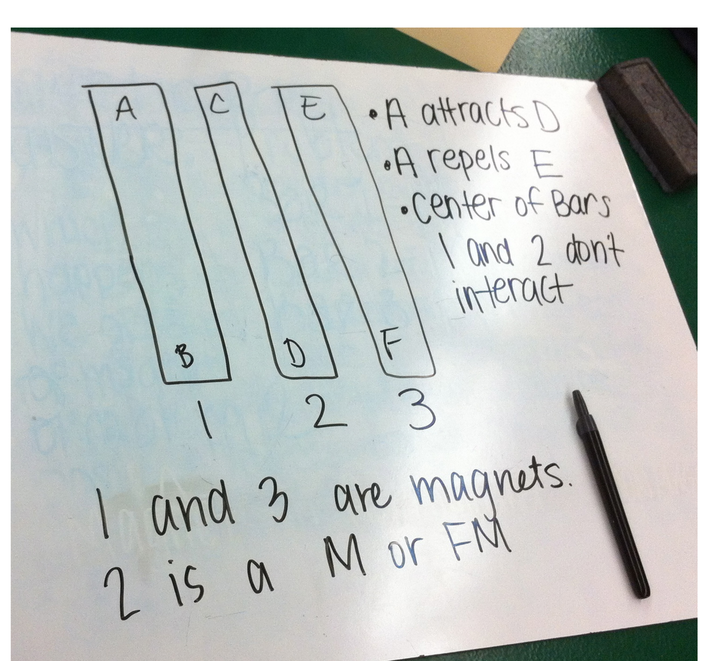
"Sometimes you need to write out every possibility based on the rules. Look for patterns!"

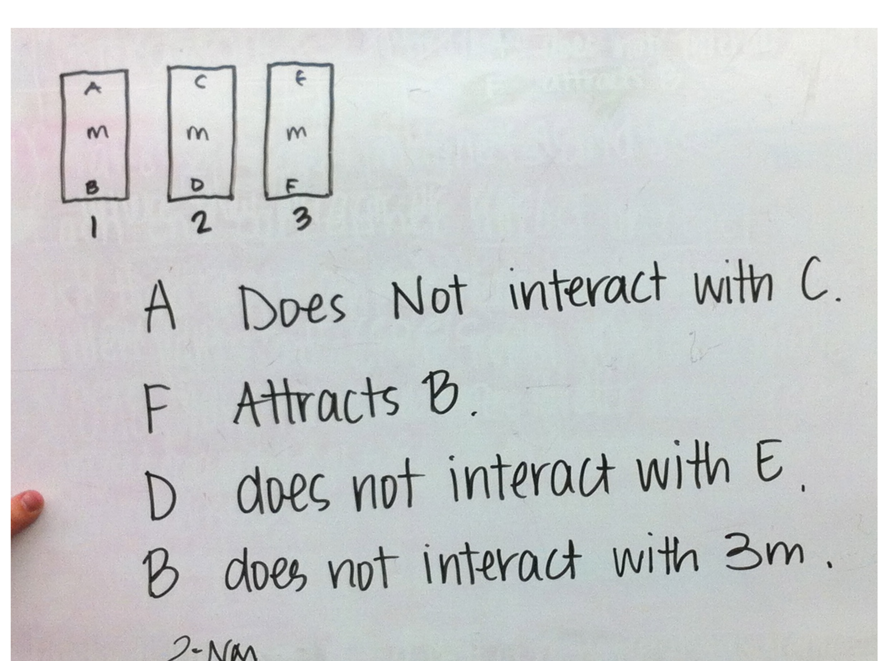


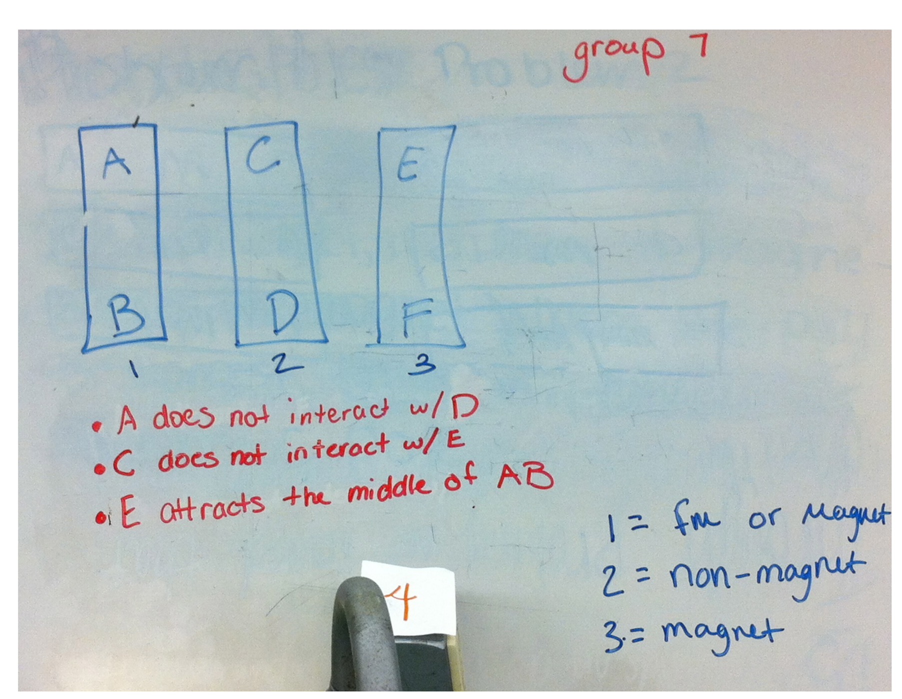
Students mark off impossibilities from a chart (provided) for each premise.

Possible Solution	Bar 1	Bar 2	Bar 3	Possible Solution	Bar 1	Bar 2	Bar 3	Possible Solution	Bar 1	Bar 2	Bar 3
1	M	M	M	10	FM	M	M	19	NM	M	M
2	M	M	FM	11	FM	M	FM	20	NM	M	FM
3	M	M	NM	12	FM	M	NM	21	NM	M	NM
4	M	FM	M	13	FM	FM	M	22	NM	FM	M
5	M	FM	FM	14	FM	FM	FM	23	NM	FM	FM
6	M	FM	NM	15	FM	FM	NM	24	NM	FM	NM
7	M	NM	M	16	FM	NM	M	25	NM	NM	M
8	M	NM	FM	17	FM	NM	FM	26	NM	NM	FM
9	M	NM	NM	18	FM	NM	NM	27	NM	NM	NM

We discuss the patterns that emerge (e.g., "bars that attract to the middle of another bar must be magnets") and cast those as "helpful tricks."

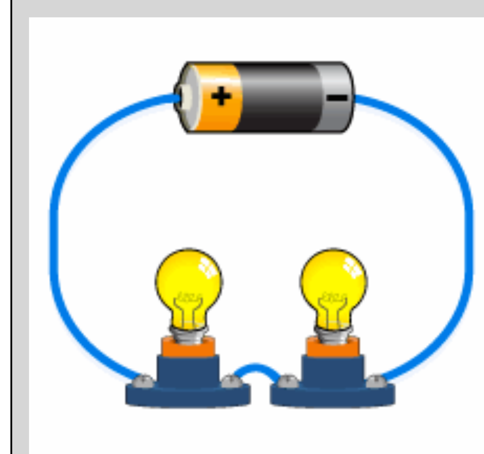






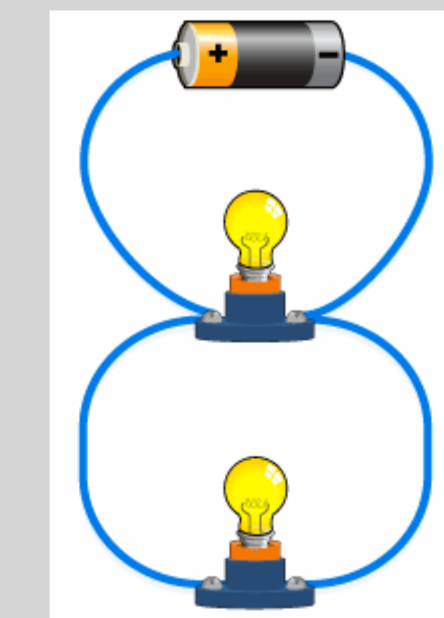
Students create their own examples and test each other!

Model Selection



Students struggle to understand why parallel bulbs light brighter than series bulbs, and they often have difficulty articulating a model that works. Is that because the true model is hard to imagine?

Instead of having students invent models, we explore five possible models and choose the ***best*** one.



Circuit Diagram (w/current)	Prediction	Explanation	Observation
One bulb, two batteries	The bulb should light, at standard brightness		
Two bulbs (in series), two batteries			
Two bulbs (in parallel), two batteries			

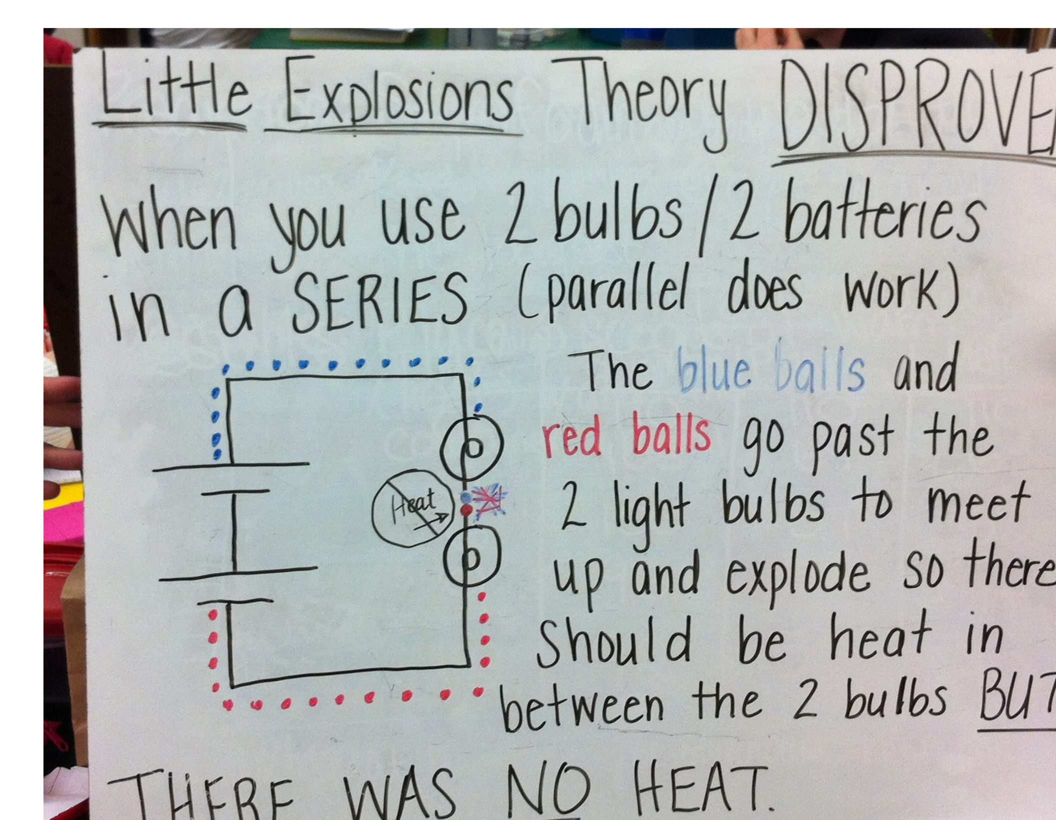
For each of the five models, students have to figure out *what the model predicts* for three situations, provide the *model's* explanation, and then record their observation of the circuit.

They are encouraged to 1) ask questions about the models and 2) go beyond the three circuits in the worksheet to test further predictions.

Each group gets one of the following models, which they have to disprove if possible:
1. Single-wire (done as a class)
2. Diminishing current (done as a class, following the expected procedure)
3. Flexible current (the battery adjusts the current depending on the load)
4. Shared current (each bulb "shares" the current)
5. Little explosions (charges meet in the bulb and explode, creating light and heat)

Students present their findings to each other in 3-minute mini-presentations. The instructor leads discussions about the arguments brought up by the students while they struggled with the models, and then lectures about the flexible current model while the students are engaged.

Instructor then challenges students by asking how to further test the "flexible current" model, and that brings about the use of ammeters and an extensive test of that model.



1. P. N. Johnson-Laird, Mental models: towards a cognitive science of language, inference, and consciousness (Harvard University Press, Cambridge, MA, USA, 1983).
2. J. D. H. Gaffney, Possibilities: A Framework for Modeling Students' Deductive Reasoning in Physics, Ph.D. thesis, North Carolina State University (2010).

Magnet picture from http://sweetclipart.com/big-red-magnet-913
Sketches of light bulb circuits from http://www.instructables.com/id/Operation-Game