Productive Engagement with PhET Simulations

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Research Questions

- How do students regulate their learning while working with PhET Simulations?
  - How do students learn with PhET Sims?
  - What dispositions and learning outcomes are associated with different patterns?
  - What is the effect of task on students' learning processes and outcomes?

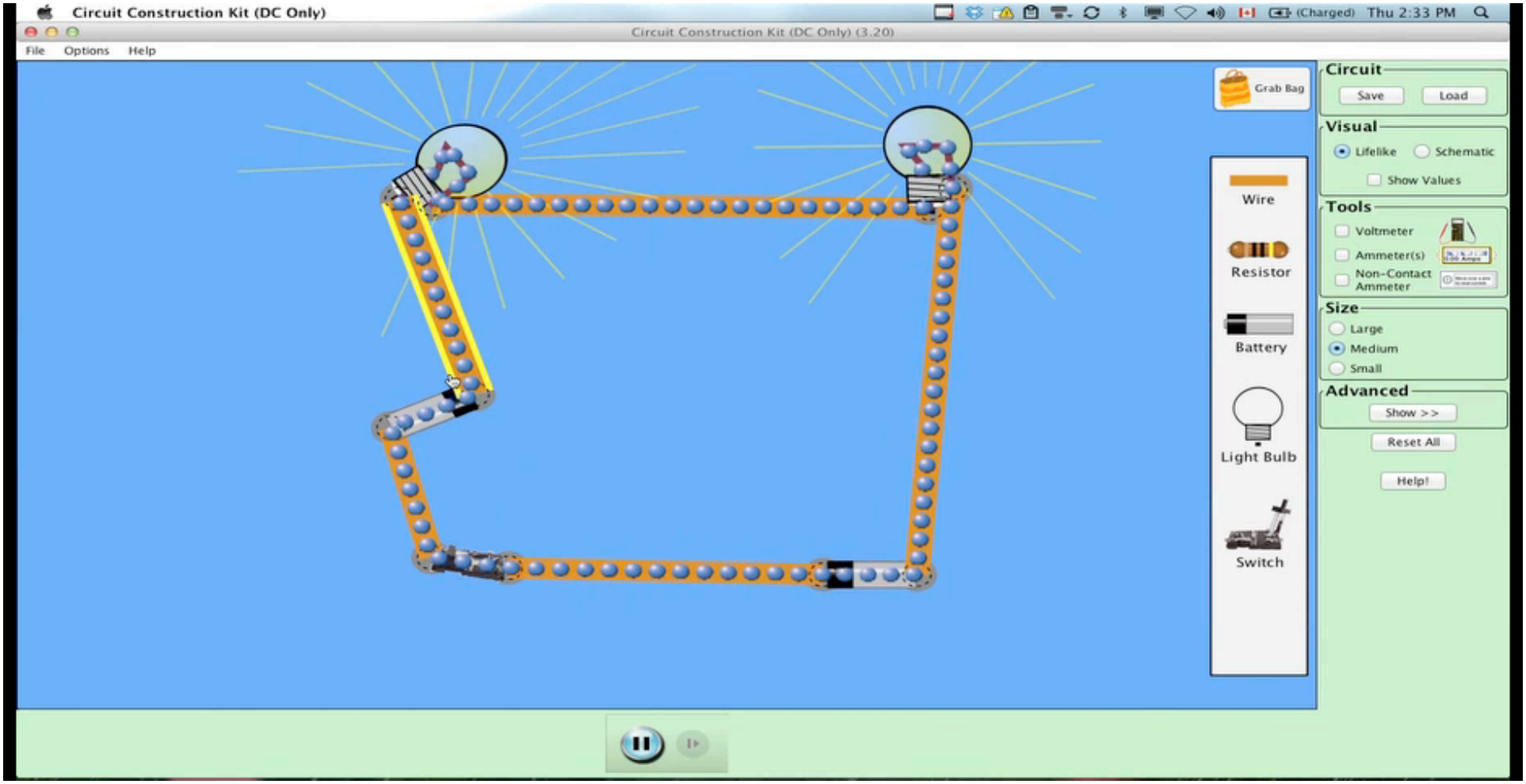
Motivation

- Better understand how students learn with PhET Sims
  - Inform task design
    - Design guidelines for tasks that support inquiry learning
  - Support productive strategies
- Later goals
  - Assessment of inquiry
  - Adaptive feedback

Context

- Out-of-class tutorials in Physics 101
  - So far we ran 55 participants
- Topic: light bulbs and resistors in D/C circuits

D/C Circuit Construction Kit



Procedure

15 min	Pre-survey Pre-test	
30 min: Activity 1	Inquiry activity (light bulbs)	Directed activity (light bulbs)
10 min	*Break*	
5 min	Mid-survey	
25 min: Activity 2	Inquiry activity (resistors) Puzzle (resistors)	
20 min	Post-survey Post-test (light bulbs & resistors)	

Pre-survey

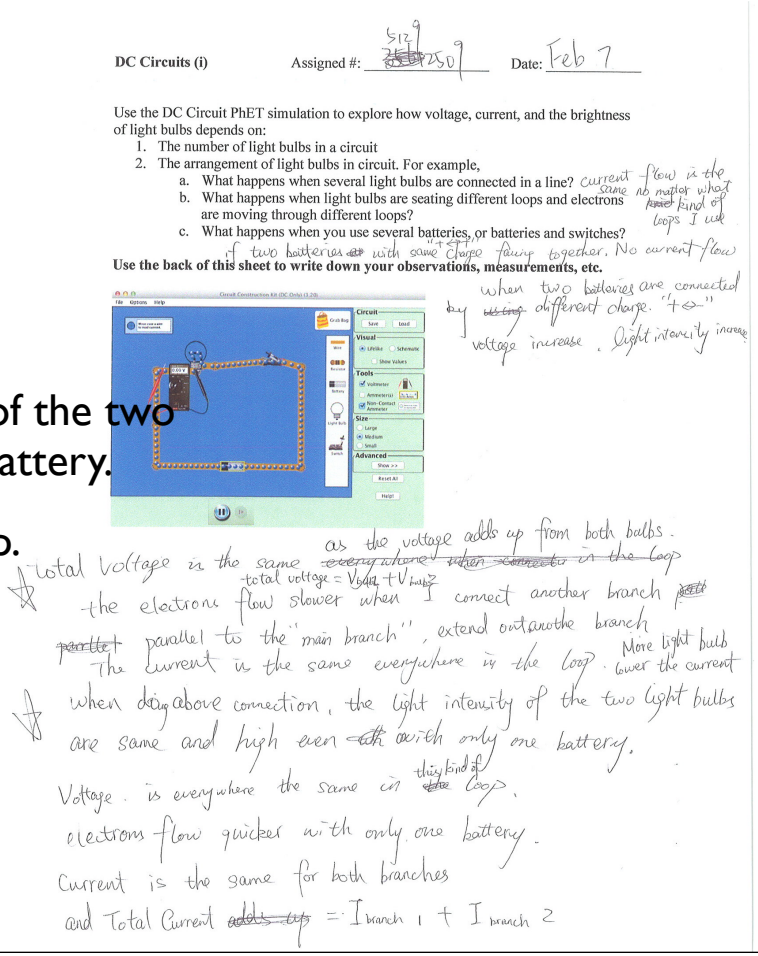
- Self efficacy
  - "I will succeed if the task is easy"
- Expected value
  - "This activity is interesting".
- Task interpretation
  - "I am being asked to find answers to all the questions".
- Goal orientation
  - "I am striving to do well compared to other students.

Activity 1: Light Bulbs

- Use the DC Circuit PhET simulation to explore how voltage, current, and the brightness of light bulbs depend on:
  - The number of light bulbs in a circuit
  - The arrangement of light bulbs in a circuit. For example,
    - What happens when several light bulbs are connected in a line?
    - What happens when light bulbs are sitting on different loops in the same circuit, and when electrons are moving through different loops?
    - What happens when you use several batteries and switches?

An example from an inquiry activity

- Connecting in a line:
  - Total voltage is the same as the voltage adds up from both bulbs.
  - The electrons flow slower when I connect another branch parallel to the "main branch", extend out another branch.
  - The current is the same everywhere in the loop.
  - More light bulbs lower the current
  - Total Voltage = $V_{light1} + VI_{light2}$
- Connecting in different loops:
  - When doing above connection, the light intensity of the two light bulbs are same and high even with only one battery.
  - Voltage is everywhere the same in this kind of loop.
  - Electrons flow quicker with only one battery.
  - Current is the same for both branches.
  - Total Current = $I_{branch1} + I_{branch2}$



DC Circuits (i) Assigned #: 512 Date: Feb 7

Use the DC Circuit PhET simulation to explore how voltage, current, and the brightness of light bulbs depends on:

1. The number of light bulbs in a circuit
2. The arrangement of light bulbs in circuit. For example,
   a. What happens when several light bulbs are connected in a line? current flow is the same no matter what kind of loops I use
   b. What happens when light bulbs are seating different loops and electrons are moving through different loops?
   c. What happens when you use several batteries, or batteries and switches?

of two batteries with same charge flowing together. No current flow

Use the back of this sheet to write down your observations, measurements, etc.

when two batteries are connected by different charge. "+ ⇔ −" voltage increase, light intensity increase

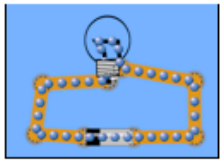
Total voltage is the same as the voltage adds up from both bulbs.
total voltage = $V_{bulb1} + V_{bulb2}$
the electrons flow slower when I connect another branch parallel to the "main branch", extend out another branch
The current is the same everywhere in the loop. More light bulb lower the current
when doing above connection, the light intensity of the two light bulbs are same and high even with only one battery.
Voltage is everywhere the same in this kind of loop.
electrons flow quicker with only one battery.
Current is the same for both branches
and Total Current = $I_{branch\ 1} + I_{branch\ 2}$

Directive Activity (I)

PART 1:

One Light Bulb

1. Drag and drop one light bulb and one battery in the work area. Drag and drop wires to connect the battery to the light bulb. Once the circuit is completed, the bulb should light and you should see the flow of charge from positive to negative end of the battery through the circuit. This is circuit 1.



Circuit 1: One bulb

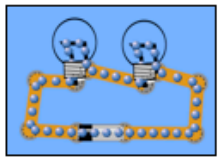
2. Use a voltmeter (check the box next to voltmeter on the right side of the display) to measure the voltage across the bulb and the battery. Use the **non-contact ammeter** to measure the current in the wires. Describe the brightness of the bulb.

	Bulb	Battery
Voltage		
Current		
Brightness of Bulb		----------

PART 2:

Light Bulbs in a Row

3. Set up another circuit with one battery and two light bulbs (everything is in one single loop). This is circuit 2.



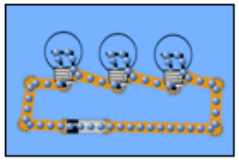
Circuit 2: Two bulbs in a row

4. Use the voltmeter and the non-contact ammeter to measure the values listed below. Describe the brightness of the bulbs.

	Bulb 1	Bulb 2	Battery
Voltage			
Current			
Brightness of Bulb			----------

1. Is the current almost the same in all the wires?

2. Set up another circuit with three bulbs in one single loop. This is circuit 3.



Circuit 3: Three bulbs in a row

3. Use the voltmeter and the non-contact ammeter to measure the values listed below. Describe the brightness of the bulbs.

	Bulb 1	Bulb 2	Bulb 3	Battery
Voltage				
Current				
Brightness of Bulb				----------

4. Is the current almost the same in all the wires?

5. What happens to the brightness of the bulbs as you add more bulbs in series?

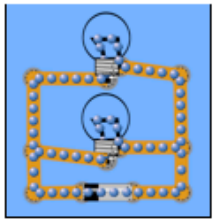
Directive Activity (II)

6. What happens to the current through the battery as you add more bulbs in series?

PART 3:

Light Bulbs in Different Loops

1. Set up a second circuit with one battery and two bulbs in different loops as shown below. This is circuit 2.



Circuit 2: Two light bulbs in different loops

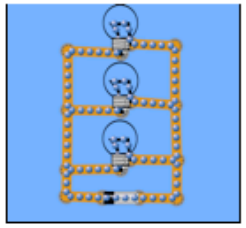
2. Use the voltmeter and the non-contact ammeter to measure the values listed below. Describe the brightness of the bulbs.

	Bulb 1	Bulb 2	Battery
Voltage			
Current			
Brightness of the Bulb			----------

3. Notice that the current coming from the battery splits. Some of it goes to bulb 1 and the rest goes to bulb 2. Show that $I_1 + I_2 = I_{battery}$

4. Is the voltage across bulb 1 almost the same as the voltage across bulb 2, and is this almost the same as the voltage across the battery?

5. Set up another circuit with three bulbs in different loops as shown below. This is circuit 3.



Circuit 3: Three light bulbs in different loops

6. Use the voltmeter and the non-contact ammeter to measure the values listed below. Describe the brightness of the bulbs.

	Bulb 1	Bulb 2	Bulb 3	Battery
Voltage				
Current				
Brightness of Bulb				----------

7. Once again current splits at each junction point. Show that the current going into a junction is equal to the current coming out of the junction. Do this for both junction points.

8. Is the voltage across bulb1, bulb2, bulb3, and the battery almost the same?

9. Does the brightness of the bulbs change as you add more bulbs in parallel?

10. What happens to the current through the battery as you add more bulbs in series?

Activity II: Resistors

- Next we will investigate how resistors affect the behaviours of circuits, using only resistors, batteries, and wires.
  - What happens to the current and voltage when you use resistors with different resistance? You can change resistance by right-clicking a resistor.
  - Investigate circuits that include multiple resistors with different resistance in a variety of arrangements.
  - Explore the properties of different combinations of resistors with the same resistance. For example, how can you combine resistors with resistance X to create a combination that is equivalent to a resistor with resistance Y?

Activity II: Puzzle

- Write your assigned-ID on a scrap paper and answer the following questions:

  1. Using only a single battery, wires, and resistors of **10 Ohms each**, create an arrangement that will have an overall resistance of **25 Ohms**. Draw your arrangement.

  2. Can you answer the question above with only four resistors?

  3. Can you think of additional arrangements with any number of resistors? Draw several alternatives.

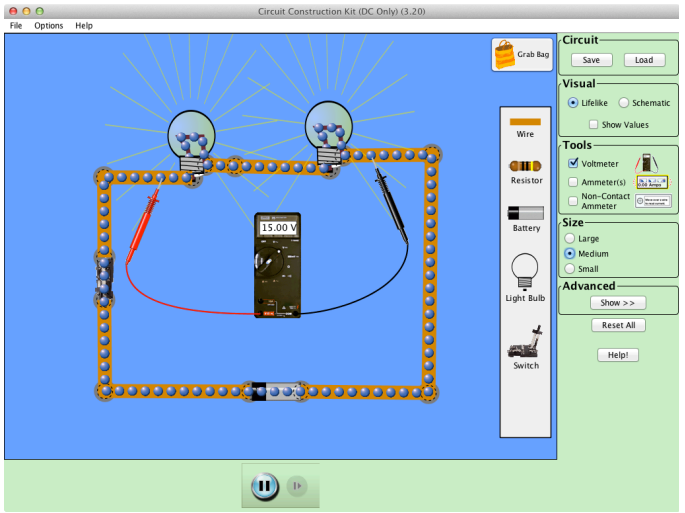
- You can use the PhET Sim if you like.

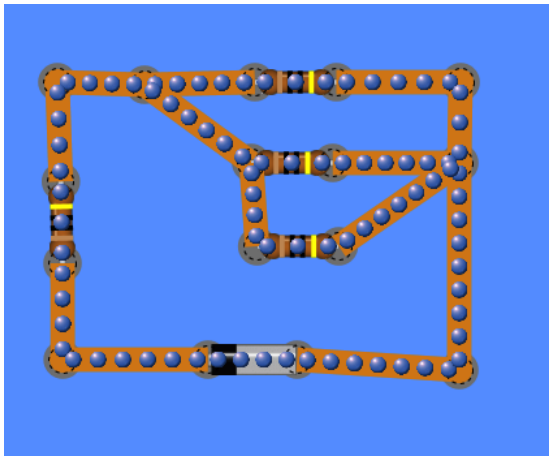
Post-survey

- Metacognitive strategies
  - Planning
    - "Before I begin working on a phet activity, I... just start using the Sim right away"
  - Monitoring:
    - "during my work on a PhET activity, I... identify what I do not understand".
  - Adjusting learning:
    - "when I encounter difficulties, I... stop working and give up"
  - *Self evaluation*:
    - "when I finish working on a PhET activity, I... re-read my work before handing it in".
- Cognitive strategies:
  - I look for the questions that I should answer.
  - try to explain the relationship between the different variables
  - Look for weird outcomes that I did not anticipate
  - When things don't work, I try something new instead of wasting time figuring out why.

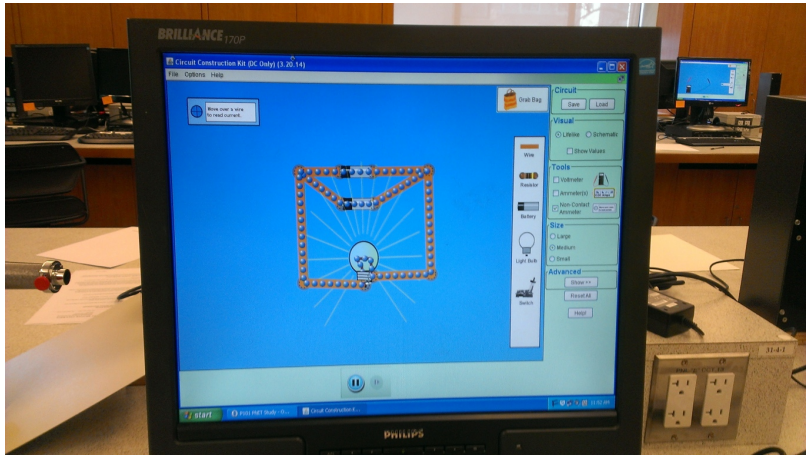
Post-test

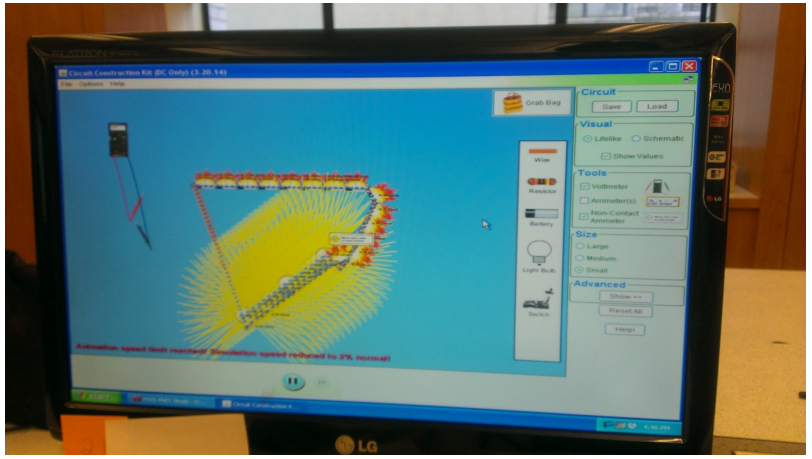
- Light bulbs
  - "What would be the voltage on the voltmeter if the switch (S) is replaced with another identical light bulb?"
- Resistors
  - "Rank the voltage across each of the resistors"

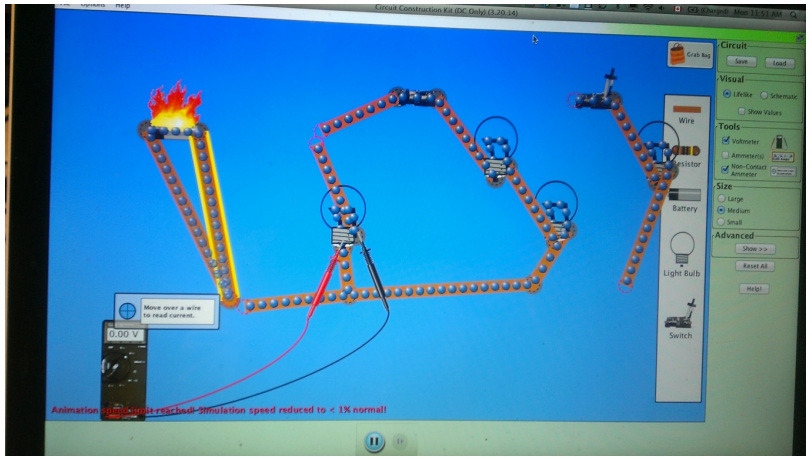


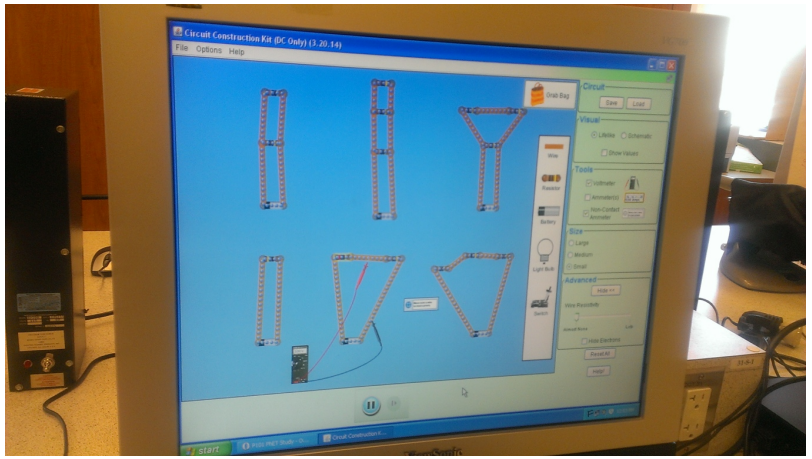


Examples


BRILLIANCE 170P
Circuit Construction Kit (DC Only) (3.20.14)
PHILIPS


Circuit Construction Kit (DC Only) (3.20.14)
LG


Circuit Construction Kit (DC Only) (3.20.14)
Move over a wire to read current.
0.00 V
Animation speed limit reached. Simulation speed reduced to < 1X normal!


Circuit Construction Kit (DC Only) (3.20.14)

Data Sources

- To evaluate knowledge and learning:
  - Pre- and post-tests
- To evaluate attitudes and motivation:
  - Pre-, med-, and post-surveys
- to evaluate the learning process:
  - Event-based logging of all interaction
  - Retrospective think-aloud protocols
  - Eye-tracker & robopen.

Event-Based Logging

- 1363630989709 wire.0 addedComponent
- 1363630992659 junction.33 movedJunction x = 7.100775193798454.046511627906977 y = wire.0.endJunction
- 1363630993681 lightBulb.0 addedComponent
- 1363630994360 junction.38 junction junctionFormed wire.0.endJunction lightBulb.0.startJunction
- 1363630997618 wire.0 movedComponent x = 3.25 y = 4.279069767441861 x2 = 8.666666666666668 y2 = 4.232558139534884
- 1363630999995 junction.32 movedJunction x = 5.751937984496124y = 4.387596899224806 wire.0.startJunction
- 136363100231 1 battery.0 addedComponent
- 1363631003899 junction.41 junction junctionFormed wire.0.startJunction battery.0.endJunction
- 1363631005254 wire.1 addedComponent
- 1363631008314 junction.44 junction junctionFormed battery.0.startJunction wire.1.endJunction
- 1363631010711 junction.42 movedJunction x = 4.511627906976744y = 7.162790697674419 wire.1.startJunction
- 1363631013414 wire.0 movedComponent x = 3.5193798449612403 y = 3.1317829457364343

Initial Results - Attitudes

- Strategies:
  - Directive students reported using the following strategies more:
    - reread the instructions to make sure I didn't miss something
    - try to recall information from class that may be useful
    - closely followed the steps in the instruction
    - try to make the sim explode or break the sim more often.
  - Inquiry students reported using the following strategies more:
    - recorded my observations
    - make a plan

- Task interpretation: Students who completed the directive activity perceived their task to...
  - memorize key information about resistors
  - complete a certain number of questions
- Success attribution:
  - Comparing mid-survey to pre-survey, directive students tended to...
    - believe that they can succeed because they are good in these activities
    - believed that they can succeed in memorizing key information

Data Analysis - examples

Research Question	Data
Domain knowledge	
- Do students learn from the PhET?	•Compare pre-test only group to both post-test only groups.
Inquiry learning	
- How do students regulate their learning with simulations?	•Top down analysis: pauses; multiple simultaneous circuits •Bottom up analysis: clustering data.
- How can we label the patterns?	•Survey •Retrospective think aloud •Common sense
- What patterns lead to productive inquiry?	•Solving the puzzle: %, time, # of actions •Resistor post-test

Research Question	Data
Attitudes	
Is one framing more engaging?	•Voluntary time on task
Which attitudes correspond to which patterns?	•Evaluate frequencies and success as a function of pre-survey
What is the effect of the faming activities?	•Compare success on puzzle and test as a function of framing activity.