A Balance

Effective Levels of Guidance for Students Engagement and Learning

PhET Interactive Simulations

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Hewlett Foundation

King Saud University

NSF

University of Colorado

Introduction

- **Levels of guidance**
  - Direct Instruction
  - Pure Discovery
- **Learning Theories**
  - Constructivism
  - Modes of engagement
- **Interactive Computer Simulations**
  - Effectiveness in lab
  - Levels of Guidance for constructing understanding
  - Levels of Guidance for engaging student exploration.

Direct Instruction

First tell how to do problems, then

- A train crosses a 100 m bridge at 5 m/s. After crossing the bridge it accelerates at 2 m/s^2 for 10 seconds to reach its normal cruising speed.

1. How long does it take the train to cross the bridge?

   100 m / 5 m/s = 20 seconds

1. Just after crossing the bridge, what is the train's velocity?

   5 m/s

2. What is the train's final velocity?

   $v_f = v_0 + at =$

4. What is the train's average velocity from the start of the bridge until it reaches cruising speed?

   $v_{avg} = (v_f - v_0)/t$

Research says….

- **Found that students do not engage in their homework or laboratories as a scientist would.**
  - Do not investigate, explore, ask questions, make connections, and deduce the rules.
  - Instead they just answer what has been asked
  - Transfer and retain little.

- **Why?**
  - Students don't know how to be a scientist?
  - Students don't care? In a hurry.
  - Underprepared?

Pure Discovery

- **Many suggested pure discovery as an alternative.**
  - Here is a compass, magnet, battery, light bulb and wire. Play with them and figure out how to make the light bulb light and if and how the magnet can affect the light bulb.





  - Give grade school students paper, paper clips and a sink full of water. Build a boat that can hold the most paper clips.

Research Says…

- **Pure discovery students may learn less than with cookbook labs!** (Mayer 2004)
  - Memory overload, confused without directions, frustrated, lots of false starts.
  - Students don't know what is important or what they have learned.

Learning Theories

- **Constructivism - Students need a framework of the main ideas to build knowledge on.** (Bransford et al 1999)

  An active process where students are active sense makers **– cognitive not behavioral.**

  – Direct Instruction - no framework

  – Pure Discovery - about 500 years

  – Cognitive load (Sweller)

  – Contrasting Cases or Guided Inquiry

- **Performance Mode vs. Learning Mode (Dweck) or Math frame versus sense making frame (Bing)**

  – Motivation. What is the game?

  – The way the problem is set up determines the mode students engage in.

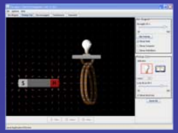
Simulation Interviews

- Think-aloud style
  - *Does not mean ask student what they think of the sim!*
- Minimal guidance - limited to 1 or 2 conceptual questions.
  - Prediction
  - Play
  - Revise prediction
- 30 to 60 minutes per simulation
- 4-6 interviews per version of sim
  - 20+ for specific projects
- 250+ with over 100 students

Unique Environment for Learning and Research

- Researcher
  - Common Visualization & probe into student brain
    - “See” student thinking
    - Watch student actions even if quiet
  - Common Vocabulary
    - Students use words from the sim
    - Student shows what the words mean to them
    - If students don’t know the word, they use the sim to show the interviewer what they mean.

Unique Environment for Learning



- **Student**
  - Fun and Engaging (not too fun!)
  - Interactive and animated (simulate real equipment)
  - The Invisible is Visible
  - Multiple Representations (macro & microscopic, graphs, math, counters etc…)
  - **Minimal Guidance** (text, external), but nonzero!
  - Balanced Challenges – little puzzles and clues
    - attainable, build up to understanding the underlying concept.

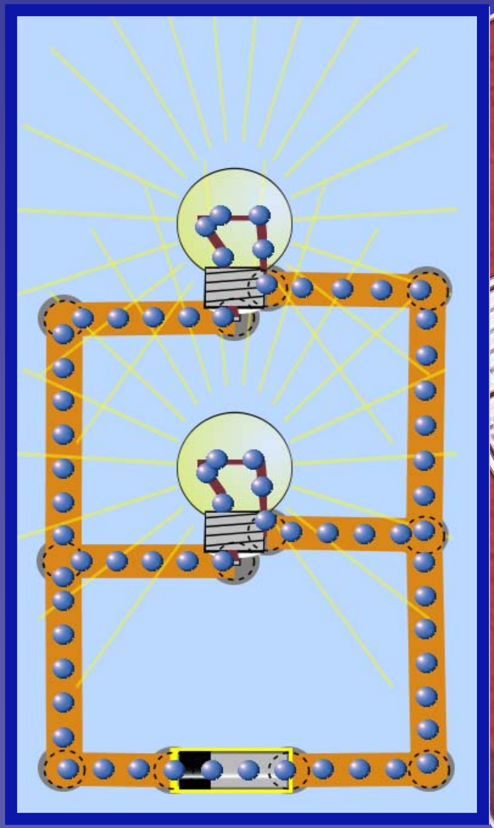
Unique Environment for Learning

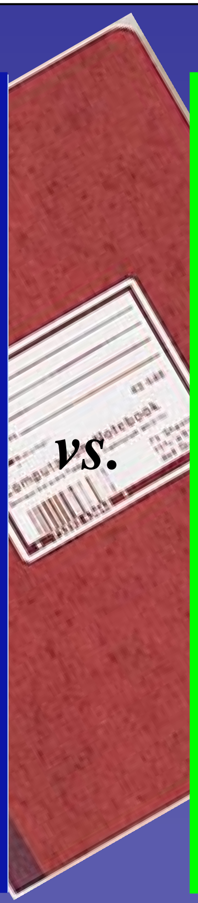
- **Student**
  - Exploration via their **own questioning**
  - Look for what is missing and investigate
  - Development of Expert-like Framework
  - Knowledge has more connections and common **visualization**

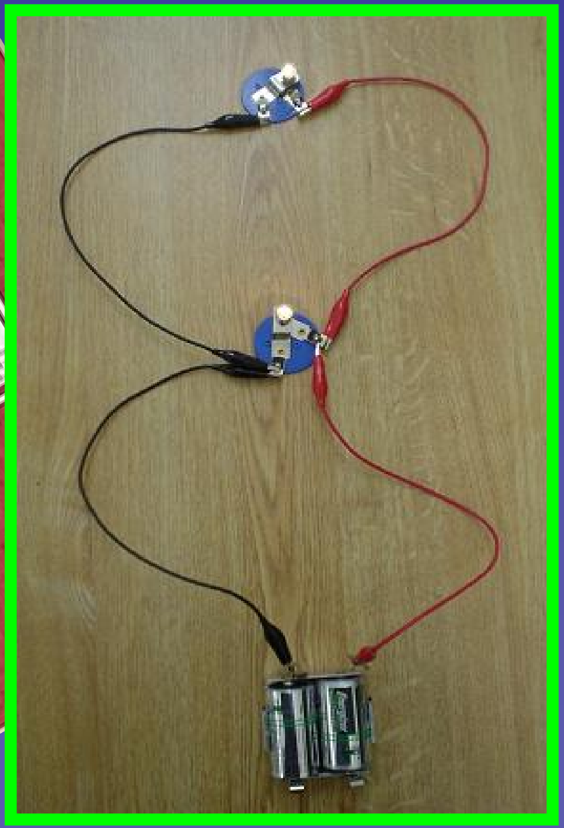
ideal for all learning

Lab (Algebra-based Physics)

Simulation vs. Real Equipment



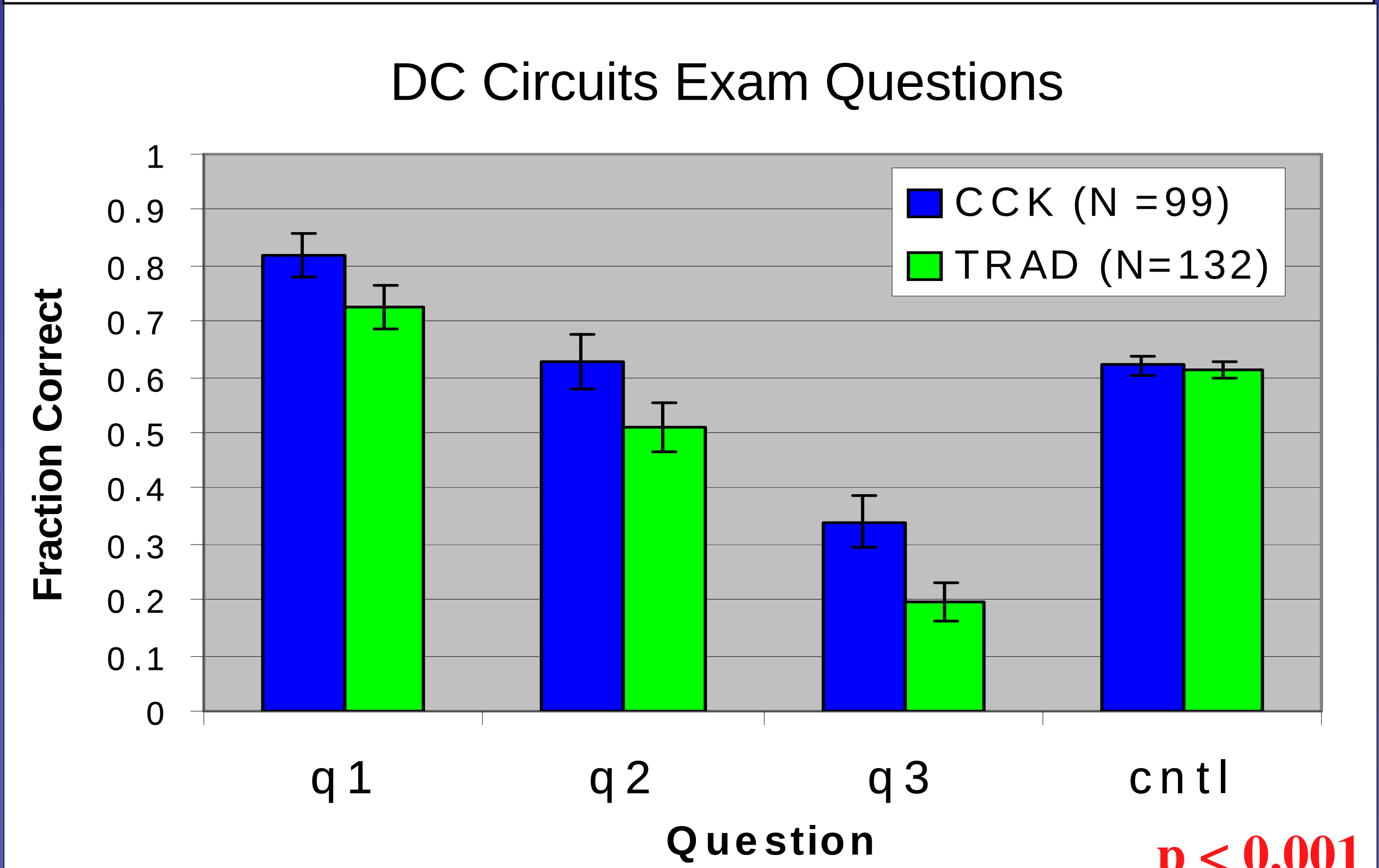




Finkelstein, Adams, Perkins, Keller

Lab (Algebra-based Physics)

Simulation vs. Real Equipment



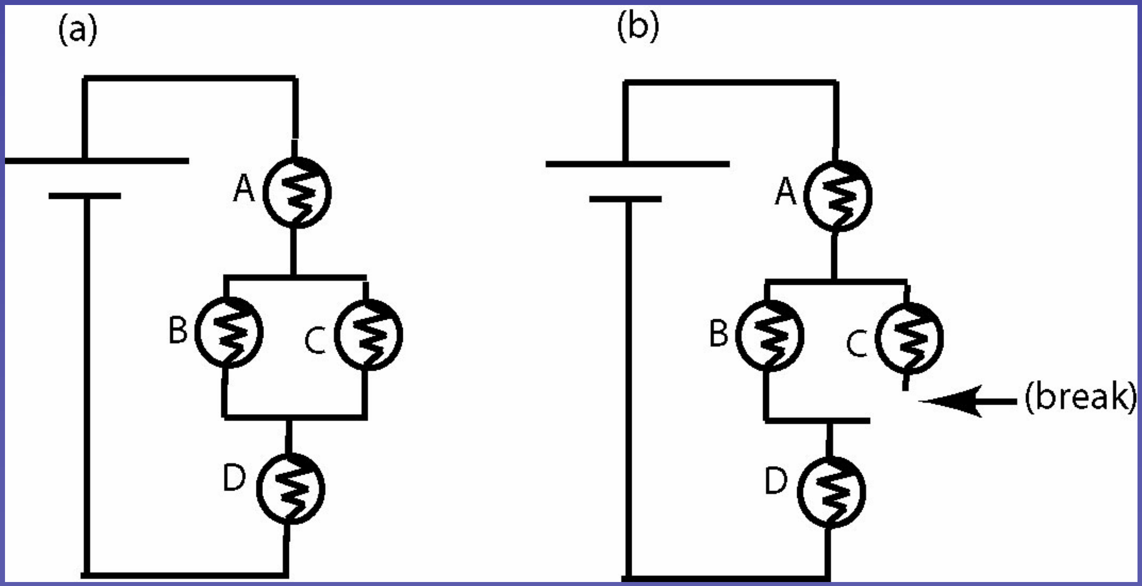
$p < 0.001$

Finkelstein, Adams, Perkins, Keller

Lab (Algebra-based Physics)

(a) Build a circuit with REAL equipment.

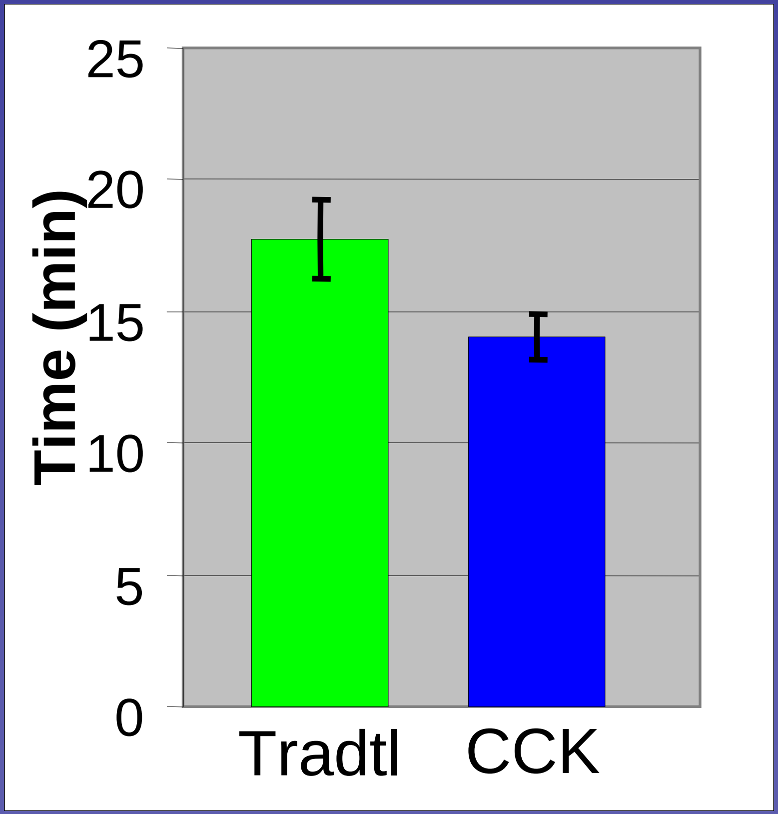
(b) Explain what happens when you create a break and why?



Lab (Algebra-based Physics)

Build a circuit with REAL Equipment

Timing



Lab (Algebra-based Physics)

How do they feel about it? ("Affective")

Traditional

- Many questions, TAs cannot keep up!
- Nervous about getting electrocuted or damaging the equipment.
- Looking for the correct answer ONE time.

CCK

- Minimal questions – TA spent most of their time watching.
- Trying all sorts of different configurations and discussing what might happen.
- Question their physics if sim shows something different than they expect.

Unique Environment for Learning

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Minimal Guidance

Goes against our instincts…

We know pure discovery doesn't work!

Why does minimal guidance work?

Appropriate Scaffolding

applies to all learning

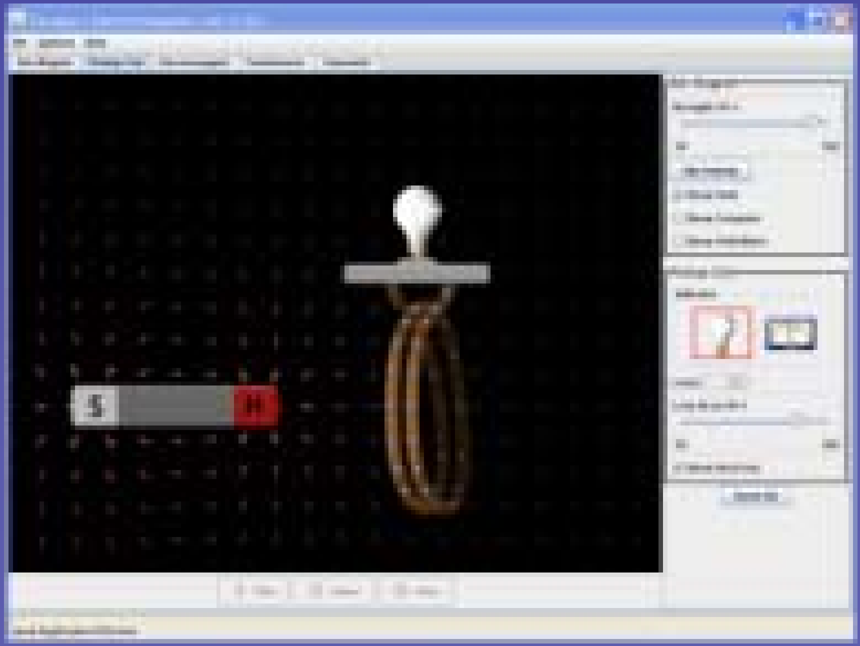
- **Simulations provide scaffolding of the material.**
  - Students see only the parts needed to understand and build a mental framework.
  - Controls are limited to features that affect the phenomena.
  - Contrasting cases (analogies) are provided.

Levels of Guidance in Interviews

- Guided
- Gently Guided (GG)
- Driving Questions (DQ)
- No instruction

Gently Guided (GG)

- Archie Paulson – crafted the activity through a series of a dozen interviews using the simulation.
- The goal was to help the students play with all objects necessary to learn about Faraday’s Law.



Gently Guided (GG)

Before opening the Sim:

"Can a magnet effect an electron?"

"What are some ways you can make a magnet?"

Open the sim:

1. In the "Bar Magnet" tab, identify the things on the screen and in the controls in the control panel (at the right.)
   a. What does the "Strength" slider do?
   b. What does the "Field Meter" do?" …
2. Go to the "Pickup Coil" tab. Identify the things on the screen and in the control panel.
   a. How does motion of the magnet affect the electrons in the coil of wire?

Driving Questions (DQ)

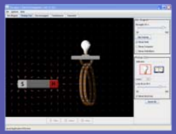
Before opening the sim

"Can a magnet effect an electron?"

"What are some ways you can make a magnet?"

Open the sim:

"Play with everything and talk aloud as you do this."



GG

8 students

Student Mode:

Students answer question and wait for the next.

"OK, continue?"

"Is that sufficient for 2"

Limited framework dev. Often don't tie pieces together.

If forget to mention crucial part of the sim, students miss it.

DQ

4 students

Engaged Exploration:

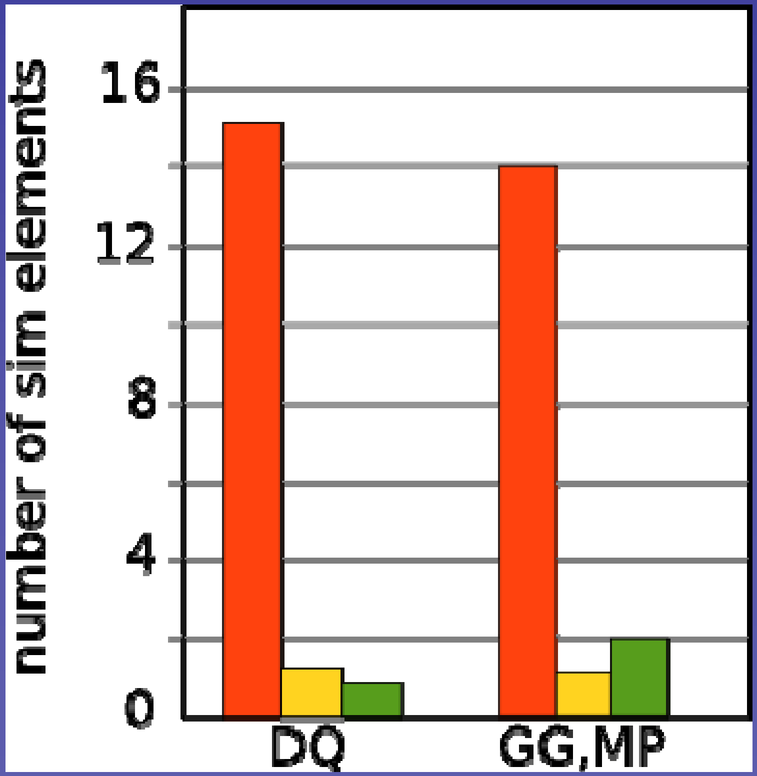
Explore via their own questioning

"Oh, I wasn't expecting that"

"I was looking around to see if it was an effect of having more wires."

Must be open conceptual type questions

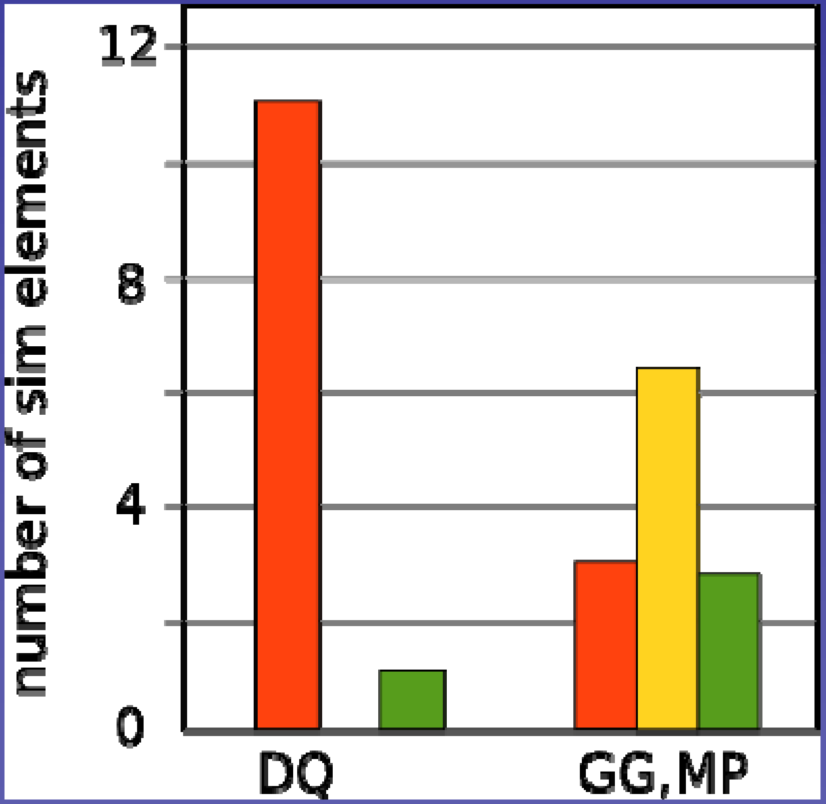
What did students notice?



Elements mentioned in the GG activity.

- Explored
- Just Noticed
- Unoticed

What did students notice?



Elements not mentioned in the GG activity.

- Explored
- Just Noticed
- Unnoticed

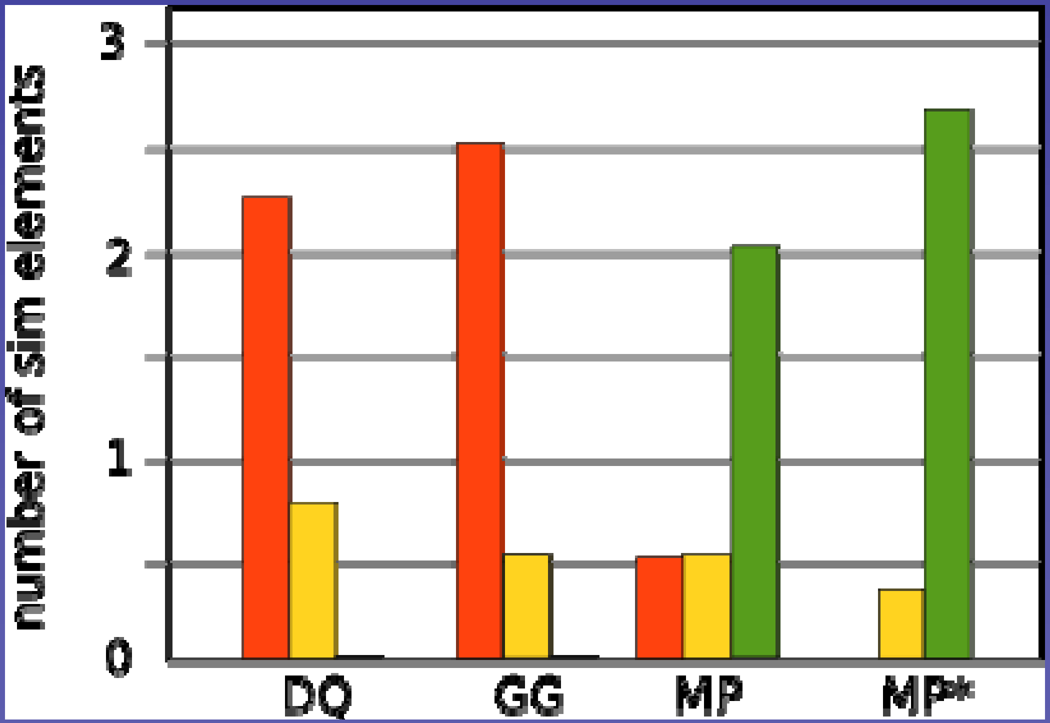
Missing Pieces (MP)

- **With GG activity students were in “student mode”. If something wasn’t mentioned, they didn’t explore it.**

- **To test this we created a Missing Pieces (MP) activity.**
  - Two questions were omitted from the GG activity
  - Three sim elements were mentioned in these two questions.

What did students notice?

Missing Pieces (MP)



Elements omitted from the GG activity.

Explored
Just Noticed
Unoticed

MP* - Anomalous student removed.

Research says….

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  - Do not investigate, explore, ask questions, make connections, and deduce the rules.
  - Instead they just answer what has been asked
  - Transfer and Retain little.

- **Why?**
  - Students don't know how to be a scientist?
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Minimal Guidance

- **Mental Framework**
  - Implicit scaffolding and contrasting cases in the simulation
  - Explore items they were ready to learn about
- **Engaged Exploration**
  - **Driving questions**
    - Explore via their own questioning
    - Behave as a scientist does
  - Gently Guided
    - Limited framework development
    - very sensitive to question choice

Conclusion

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- **Levels of Guidance**
  - Constructing a mental framework – active sense-making
  - Set up learning mode: “engaged exploration”
- **Minimal Guidance**
  - Driving Questions

    not Guiding Questions

Provide scaffolding

Quantum Mechanics Course

"I definitely not only enjoyed the simulations, but I'd go as far to say that the simulations taught me the most about the course because I could really visualize the inner workings of the physics processes that were going on."

"I thought the simulations were great. It helped me to gain intuition about the topic. This is especially useful in quantum mechanics where it is not normally possible to directly observe the described phenomena."