

# What Do Students Learn about Work in Physical & Virtual Experiments with Inclined Planes?



Jacquelyn J. Chini<sup>1</sup>, Adrian Madsen<sup>2</sup>, N. Sanjay Rebello<sup>2</sup> and Sadhana Puntambekar<sup>3</sup>  
<sup>1</sup>University of Central Florida, <sup>2</sup>Kansas State University, <sup>3</sup>University of Wisconsin, Madison

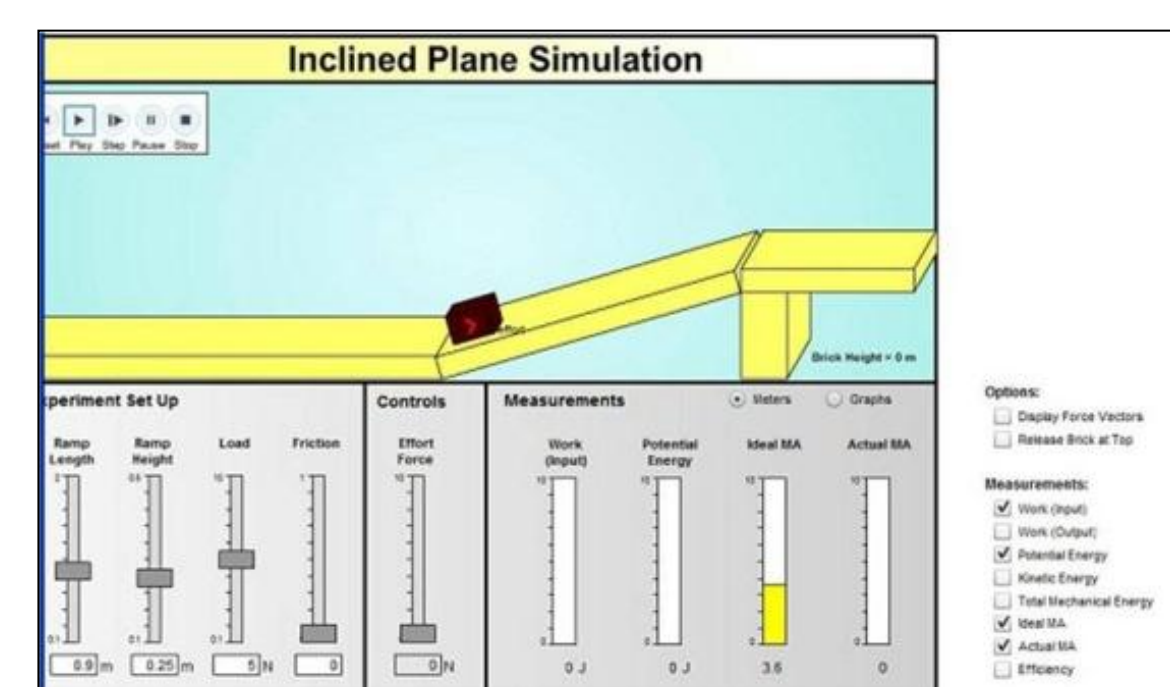
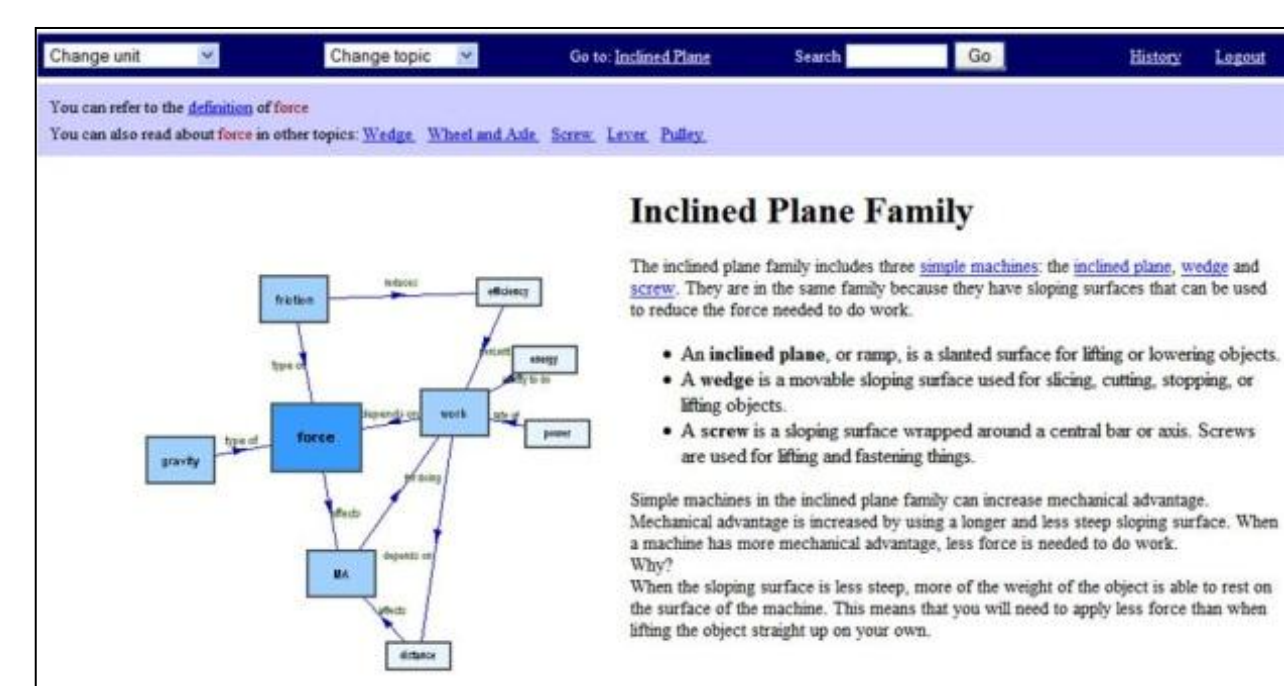
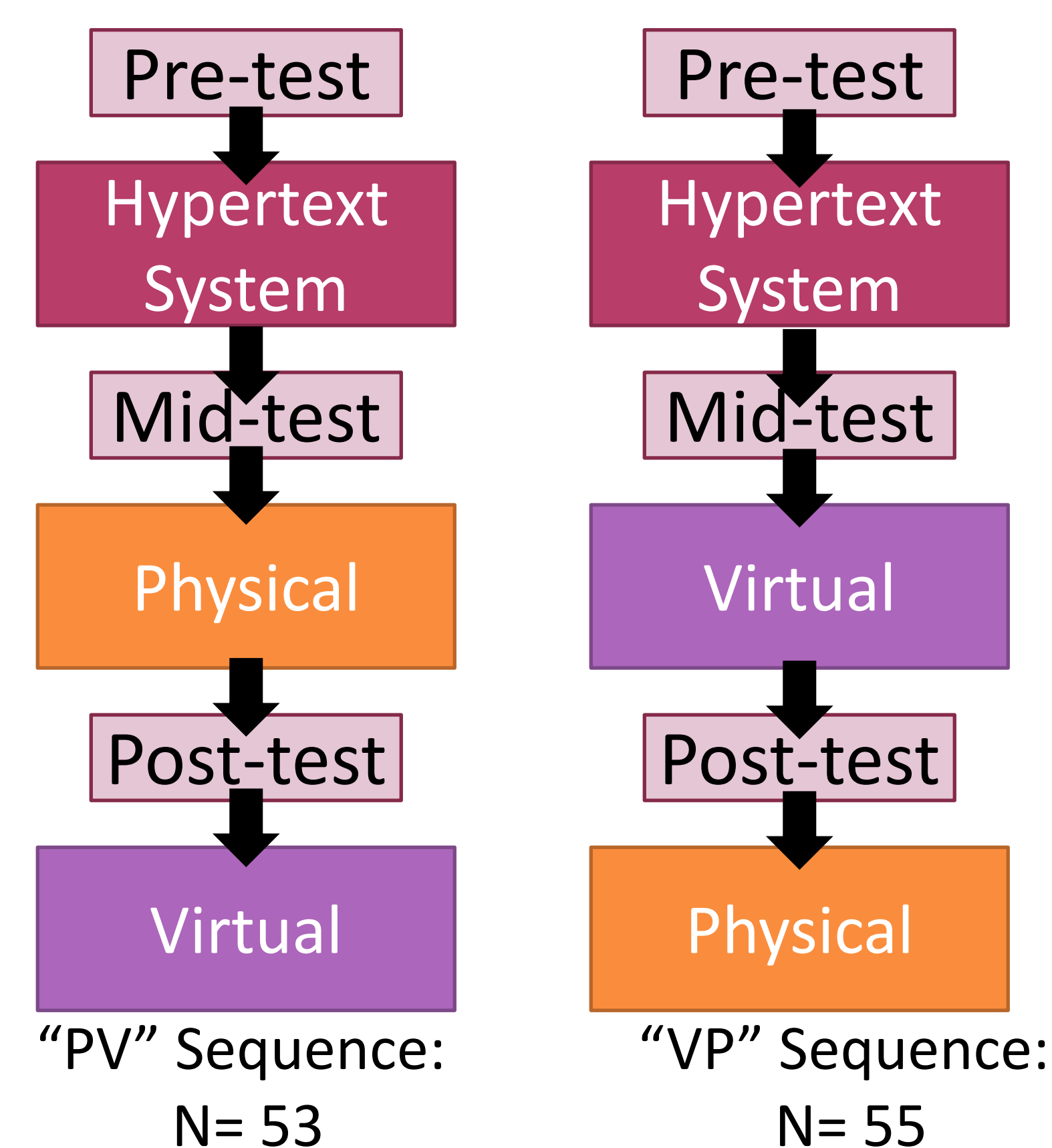


## Introduction

- Previously reported that experimentation with a simulation better supported students' understanding of work than similar experimentation with physical equipment<sup>1</sup>
- Noted that analysis may have been biased in favor of simulation, since students may have answered multiple-choice questions in accordance with frictional effects observed in physical experiment
- Research Question: *What patterns do we observe in the answers selected by students in the physical-virtual (PV) and virtual-physical (VP) sequences to a subset of questions about work in the context of inclined planes?*

## Study Design

- Students enrolled in conceptual-based intro physics laboratory performed physical & virtual activities with inclined planes
- Same types of trials and analysis questions in both activities
- Two sequences:



## Question Subset

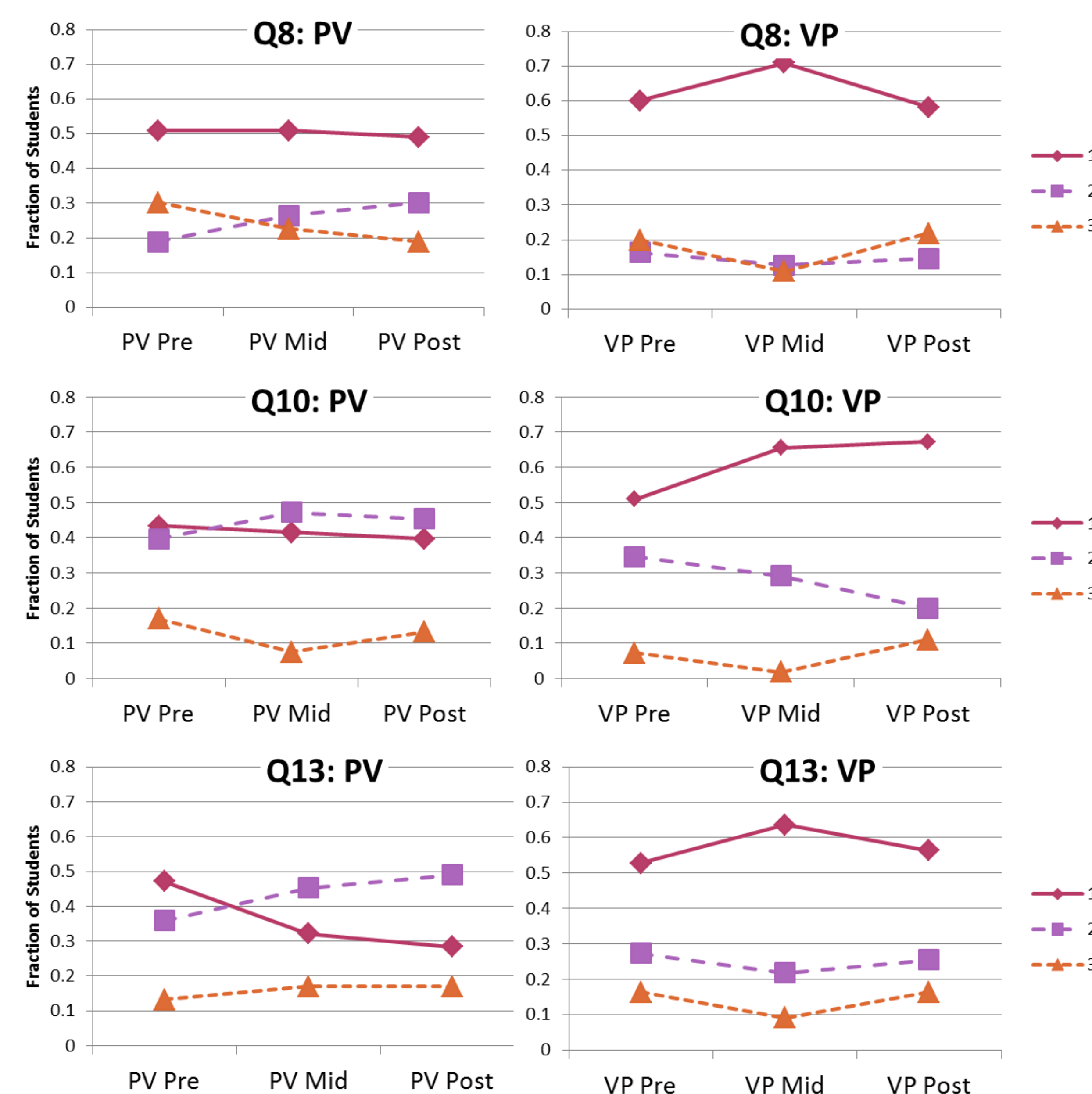
- Questions were chosen so that each multiple-choice option corresponded to one of the following models:
  - Model 1:** If frictional effects can be ignored, the work required to lift an object with a ramp depends only on the *height* to which the object is lifted (canonical physics model).
  - Model 2:** A longer ramp requires less work to lift an object to the same height as a shorter ramp (conflates force and work<sup>2</sup>).
  - Model 3:** A longer ramp requires more work to lift an object to the same height as a shorter ramp (includes frictional effects)

Q	Question	Model 1	Model 2	Model 3	Other
8	Moving an object with a longer ramp to the same height would cause work to:	Stay the same	Decrease	Increase	Not enough info
10	Does directly lifting a box or using a ramp to lift it to the same height require more work?	Both same work	Direct lift	Ramp	Not enough info
13	Of three different length, same height ramps, which would require the most work to lift a box?	All same	Shortest ramp	Longest ramp	Mid-length ramp

\*All questions specified that frictional effects should be ignored

## Results & Discussion

### Frequency of Models



#### VP sequence trends:

- Model 1 is most commonly used across all tests and questions
- Model 3 becomes more common after physical experiment

#### PV sequence trends

- Model 1 is replaced by Model 2 as most common on Q8 & Q13 on mid- and post-tests
- On all questions, Model 2 becomes more common after the physical experiment
- Surprisingly, Model 3 only becomes more popular after the physical experiment on Q13

**Overall, PV sequence leads to higher use of Model 2, which conflates force and work**

### Written Explanations

- Q8 & Q13 asked students to explain their answer. Responses were coded and tallied by model and sequence.
- Frequencies of themes given as (number of students using theme/number of students using model) summed across Q8 & Q10 mid-test and post-test, unless otherwise noted

	Reasoning Theme	PV	VP
Model 1	Both objects lifted to <i>same height</i>	28/96	49/144
	Tradeoff between force and distance	27/96	7/144
	No friction/ Friction did not change	6/96	19/144
	Work equal to change in potential energy	3/96	16/144
Model 2	Less force needed means less work needed	15/79	10/42
	Less steep ramp needs less work (Q8 only)	9/30	2/15
	Restated answer as explanation n (Q8 only)	10/20	1/15
	Using a ramp is just better (Q10 only)	11/49	14/27
	Ramp better because of mechanical advantage	14/49	1/27
Model 3	Object has to travel longer distance (no explicit reference to friction)	24/33	15/23

### Summary & Implications

- PV sequence not only leads to lower frequency of correct responses to questions about work, but actually decreases percentage of students choosing the correct answer on a subset of those questions
- Rather than choosing responses consistent with frictional effects observed in the physical experiment, students in the PV sequence chose answers that seem to indicate a failure to differentiate between force and work
- Future efforts should be directed towards refining the VP sequence to enhance its ability to:
  - Help students differentiate physics concepts
  - Understand the role of friction in the physical experiment

#### References

- J. J. Chini (2010). Doctoral dissertation. Retrieved from K-State Research Exchange: <http://hdl.handle.net/2097/6391>.
- M. J. Leonard and S. Rebello, "Changes in Students' Conceptual Models of Science Phenomena through CoMPASS instruction," in *American Educational Research Association Annual Meeting*, Chicago, IL, 2007.

This work is supported in part by U.S. Dept. of Education, IES Award R305A080507.



<http://physics.cos.ucf.edu>