Exploring the Benefits of Physical and Virtual Manipulatives in Simple Machines

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Motivation

- Previous studies comparing usefulness of physical and virtual manipulatives show mixed results
  - Some studies show added benefits of virtual manipulatives. Egs: Zacharia, 2005; Finkelstein *et al.*, 2005
  - Some studies show no difference between the two. Egs: Klahr, Triona, & Williams, 2007; Zacharia & Constantinou, 2008
- Previous studies have focused on limited contexts in physics, such as electric circuits & heat/temperature

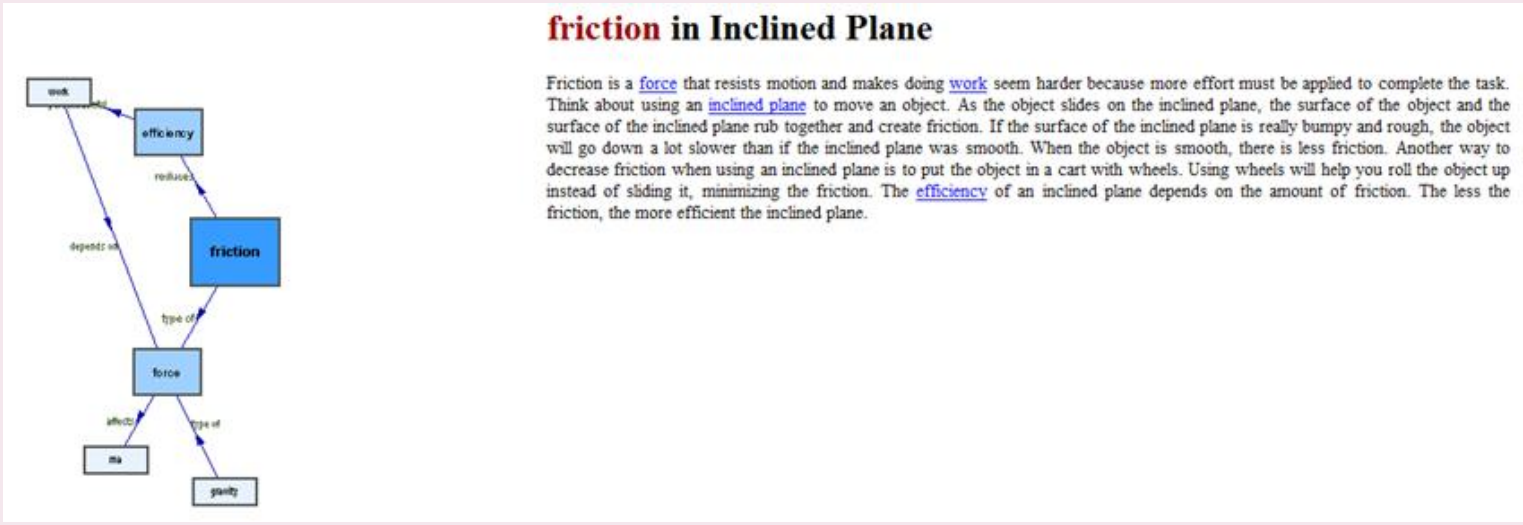
Research Questions

- Is there a difference in conceptual understanding, as measured by a multiple choice test, between students who perform experiments with physical and virtual experiments?

- Are there specific concepts that are supported more by the physical or virtual manipulatives?

Context of the Studies

- Simple machines: inclined planes & pulleys
- CoMPASS (Concept-Mapped Project-based Activity Scaffolding System) curriculum
  - Brings together dynamic concept map and text, design and inquiry based activities

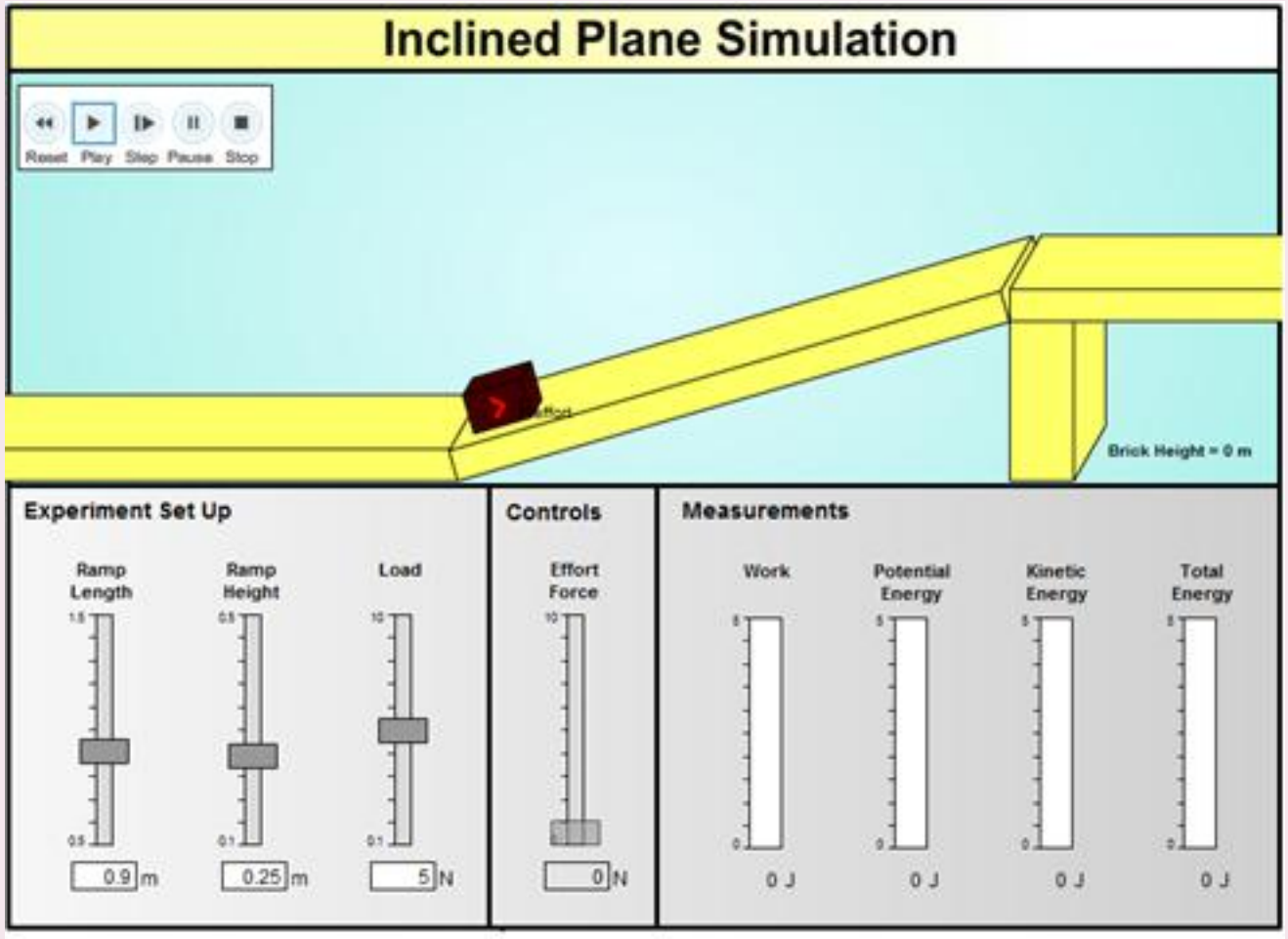


For more details on CoMPASS, see www.compassproject.net; Puntambekar

Inclined Plane Study

- Conceptual-based physics students in lab
- Used physical or virtual manipulatives to perform experiments
- Varied length & height or length & friction of inclined plane
- Answered worksheet questions and took pre- and post-tests

Inclined Plane Virtual Environment



IP Pre- and Post-test Performance

Section	N	Pre-Test	Post-Test
LH Physical	29	60%	66%
LH Virtual	37	60%	78%
LF Physical	25	59%	66%
LF Physical	30	60%	66%
LF Virtual	33	57%	67%

- LH Physical and LH Virtual are statistically the same on the pre-test (p=.9878)
- LH Virtual is statistically significantly higher than LH Physical on the post-test (p=.0008)
- No statistical difference between LF groups

Questions Leading to Difference

Four questions had 20% or more difference between LH Physical and LH Virtual

Quest. #	LH Physical	LH Virtual	Context
6.2	21%	78%	Work
7	21%	49%	Work
14	3%	86%	Work/PE
15	28%	49%	Mech. Adv.

*All deal with a frictionless environment.

IP Question 14

An object sits at the top of a frictionless ramp. How does the object's potential energy compare to the work required to move it to the top of the ramp?

Answers	Physical	Virtual
A. The object's potential energy is greater than the required work.	28%	8%
B. The objects potential energy is less than the required work.	69%	0%
C. The object's potential energy is the same as the required work	**3%**	**86%**
D. Not enough information to decide	0%	5%

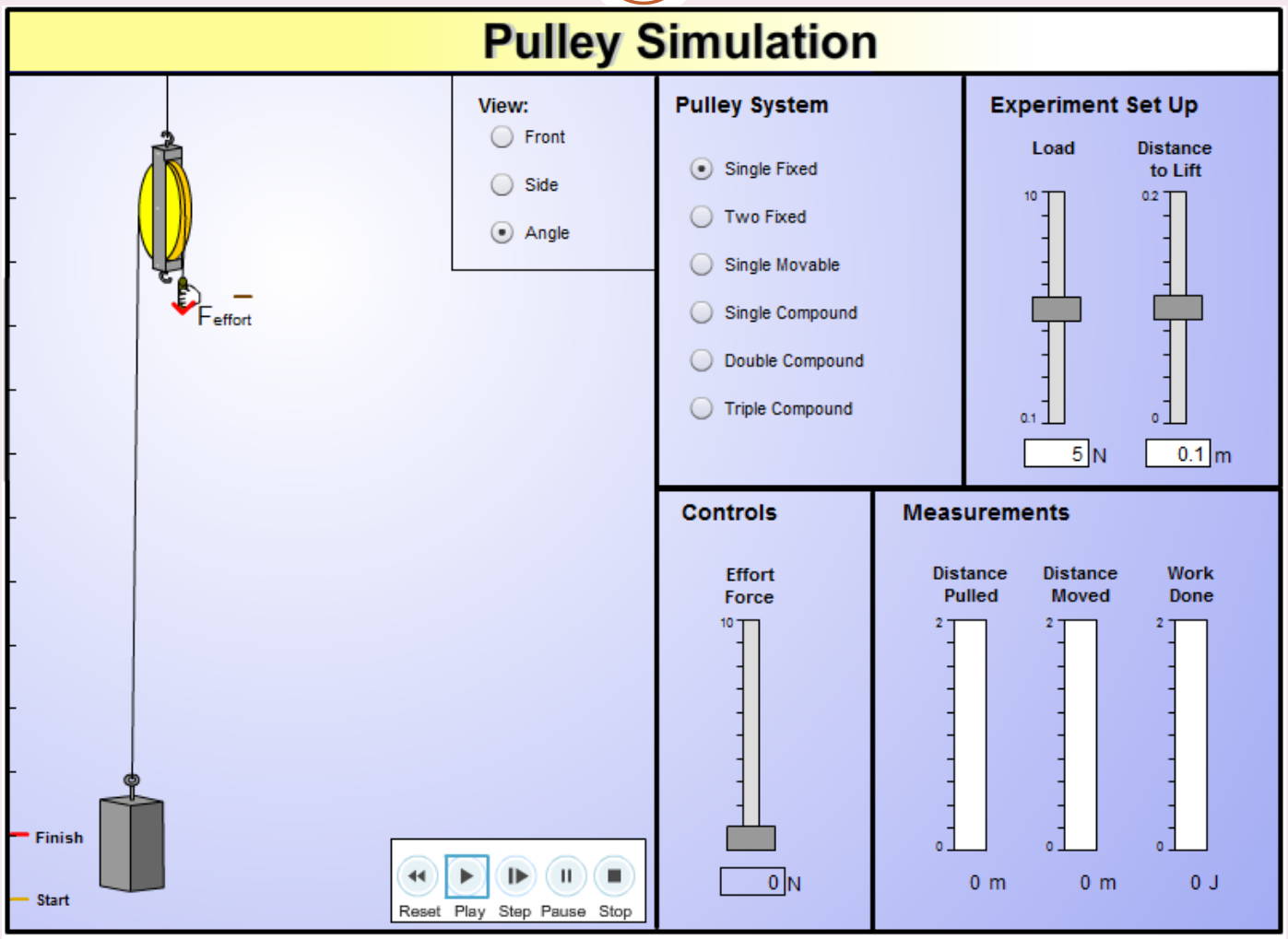
Inclined Plane Results Summary

- Performance difference for LH students largely the result of questions about a frictionless environment
- Appears students who used physical manipulatives had difficulty extrapolating to frictionless case
- Virtual environment can create contexts which are impossible in the real world
- Of course, frictionless experiments are not realistic

Pulley Study

- Conceptual-based physics students in lab
- Use physical and virtual manipulatives to perform experiments
- Varied pulley setup
- Answered worksheet questions and took pre-, mid-, and post-tests
  - Here, focus on mid-test which allows us to compare physical and virtual conditions

Pulley Virtual Environment



Pulley Pre- and Mid-test Performance

Section	N	Pre-Test	Mid-Test
Physical/Virtual	21	33.7%	42.7%
Physical/Virtual	24	37.8%	47.8%
Physical/Virtual	28	37.6%	51.0%
Virtual/Physical	31	34.0%	55.7%
Virtual/Physical	31	32.6%	41.5%

- No difference in average Mid-test scores: Physical- 58.1%; Virtual- 59.6%
- Large difference between sections within each condition

- Do we see any questions where there is a performance difference between students using physical or virtual manipulatives?

Pulley Questions with Performance Difference

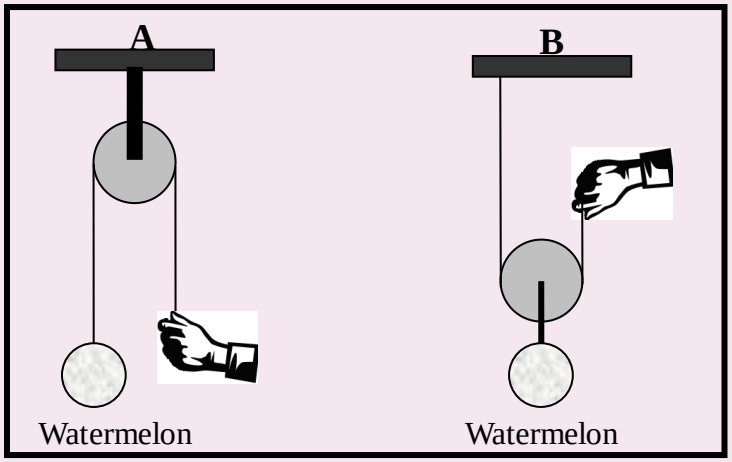
On 7 of 13 questions, more than 20% difference between physical and virtual

Question	Physical	Virtual	Topic
1	85%	63%	Force
6.1	90%	56%	Force
6.2	29%	81%	Work
7	75%	53%	Work (calc.)
9	17%	65%	Work
11	88%	55%	Mech. Adv.
13	32%	77%	Work

- Physical outperformed virtual on 4 questions and underperformed virtual on 3 questions

Question 6.1

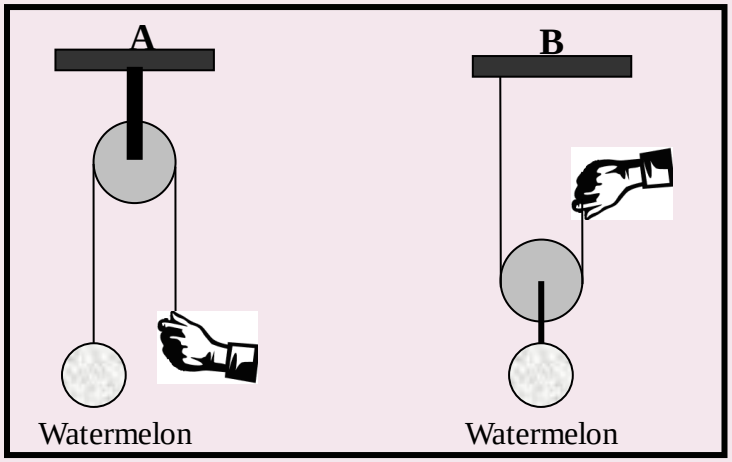
You use pulley A to lift a watermelon to your tree house. If you used pulley B instead to lift the same watermelon, the *effort force* needed would:



Answers	Physical	Virtual
Increase	12.6%	28%
Decrease	**87.5%**	**55.5%**
Stay the same	0.0%	16.5%
Not enough info	0.0%	0.0%

Question 6.2

You use pulley A to lift a watermelon to your tree house. If you used pulley B instead to lift the same watermelon, the *work* needed would:



Answers	Physical	Virtual
Increase	36.5%	15.1%
Decrease	36.2%	5.1%
Stay the same	**28.7%**	**81.5%**
Not enough info	1.4%	0.0%

Pulley Results Summary

- No overall difference between students who used physical or virtual manipulatives, but differences on many specific questions
- Students who used physical manipulatives performed better on effort force and mechanical advantage questions
- Students who used virtual manipulatives performed better on work questions

Conclusions & Future Work

- Conclusions:
  - Inclined Plane study indicates virtual manipulatives can help students reason about frictionless environment
  - Pulley study indicated physical and virtual manipulatives may better support different concepts

- Future Work:
  - Can students who only use virtual manipulatives reason about friction?
  - How do students perform if they use both types manipulatives?