The Effects of Physical and Virtual Manipulatives on Students' Conceptual Learning about Pulleys

Elizabeth Gire

Kansas State University
Physics Education Research

Supported in part by U.S. Department of Education, Institute of Education Sciences award R305A080507.

Co-Authors

Adrian Carmichael, Jacquelyn Chini, Amy Rouinfar & N. Sanjay Rebello

Kansas State University

Garrett Smith & Sadhana Puntambekar

University of Wisconsin

Research Questions

Is conceptual understanding of the physics of pulleys supported equally well by physical and virtual manipulatives?

Does the sequence in which these manipulatives are encountered affect students' conceptual development of the physics of pulleys?

Outline

- Some previous research
- Context
- Results
- Conclusions

Finkelstein et al., 2005

- Electric circuits
- Physical circuits vs. computer simulation
- Representation of invisible mechanism (electron flow)
- Transfer Task: Building a circuit

Properly designed simulations can be beneficial to student learning when applied appropriately.

Triona, Klahr & Williams, 2007

- Mechanics: Mouse trap car
- Elementary school students
- Number of cars vs. Amount of time
- All conditions equally effective: causual factors, design ability, confidence

Simulations may be preferred due to other pragmatic advantages.

Zacharia et al, 2008

- Heat & Temperature
- Physical vs. Physical & Virtual
- Variable: speed of manipulation
- Physical < Physical & Virtual

Difference due to faster manipulation than physical manipulatives.

Zacharia & Constantinou, 2008

- Heat & Temperature
- Control for curriculum, method of instruction, resource capabilities

Both modes of experimentation are equally effective in enhancing students' conceptual understanding.

Our Study

- Mechanics: Pulleys
- Control for curriculum, mode of instruction
- Speed of manipulation, friction, experimental uncertainty

Classroom Context

- Large, public university with very high research activity
- Spring 2009
- Conceptual physics lab (N=132)
  - 5 labs
  - 40 students max per lab
  - Groups of 4 students
- Non-science majors
- Associated lecture
- Grade largely based on participation

Experimental Design

6

PV Sequence (N=71) — **Physical-Virtual Sequence**

VP Sequence (N=61) — **Virtual-Physical Sequence**

Pre-Test

Predictions & CoMPASS

Physical Experiment | Virtual Experiment

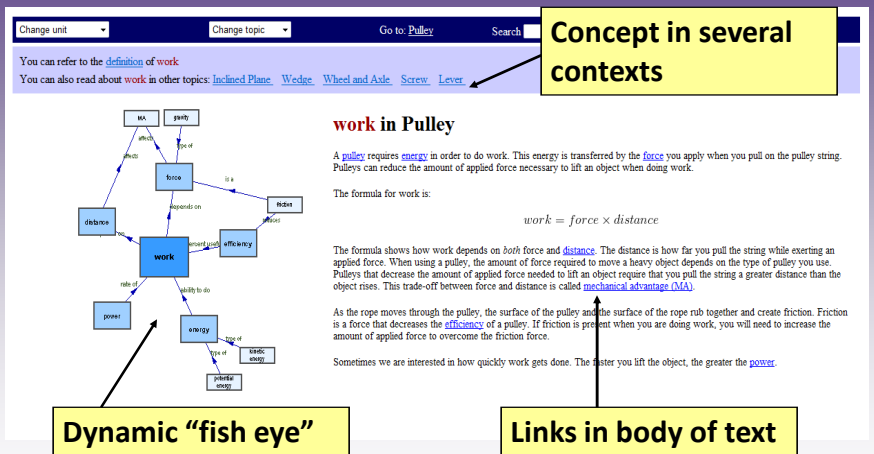
Mid-Test

Virtual Experiment | Physical Experiment

Post-Test

CoMPASS Interactive Concept Maps

7

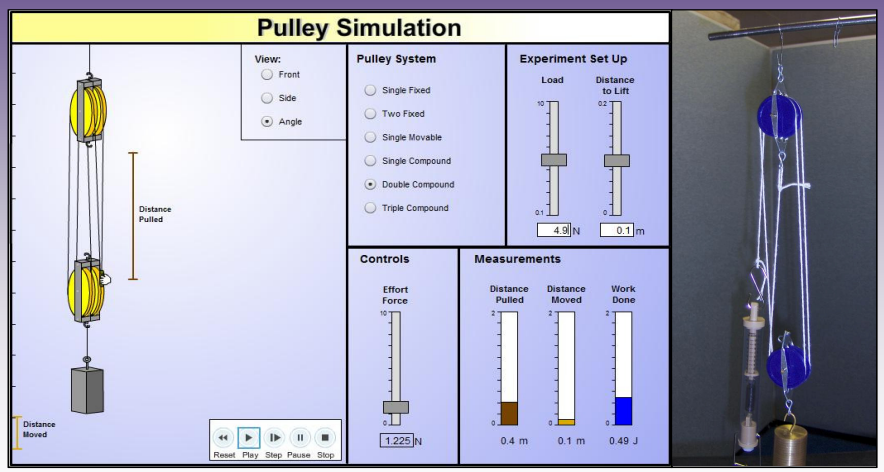


Concept in several contexts

Dynamic "fish eye" concept maps

Links in body of text

Physical and Virtual Manipulatives



Assessment

- 13 Multiple Choice Questions
- Effort Force, Work, Mechanical Advantage, Distance Pulled, Potential Energy
- Cronbach's α

  Effort Force = 0.70

  Work = 0.51

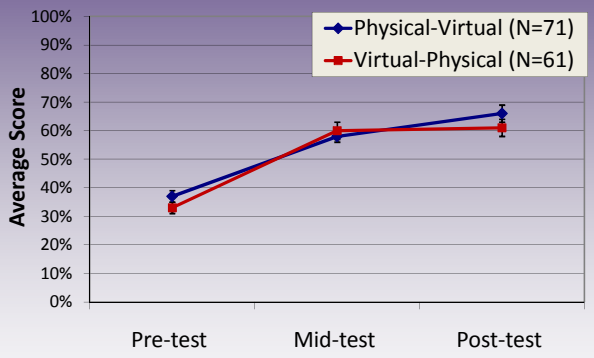
Overall Score

Mixed ANOVA
Main Effect: p < .001

Interaction: p = 0.12

Pre-Mid:
Main Effect: p < .001
Effect size: 0.75

Pre-Post:
Main Effect: p < .001
Effect size: 0.79



Overall Score supported equally well by both manipulatives and both sequences.

Force Questions

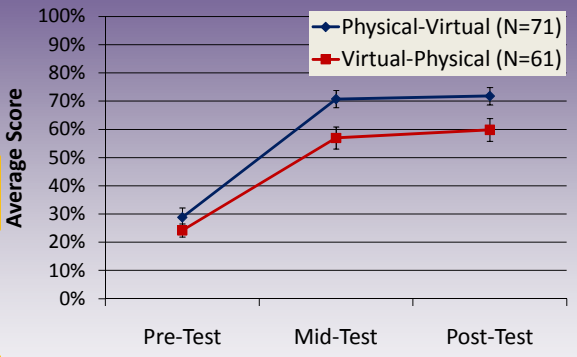
Mixed ANOVA
Main Effect: p < .001
Interaction: p = 0.02

Pre-Mid:
Main Effect: p < .001
Effect size: 0.76

Interaction: p = 0.02
Effect size: 0.20

Pre-Post
Main Effect: p < .001
Effect size: 0.78

Interaction: p = 0.02
Effect size: 0.20



Force Score supported a little better by physical manipulatives and by Physical-Virtual Sequence.

Work Questions

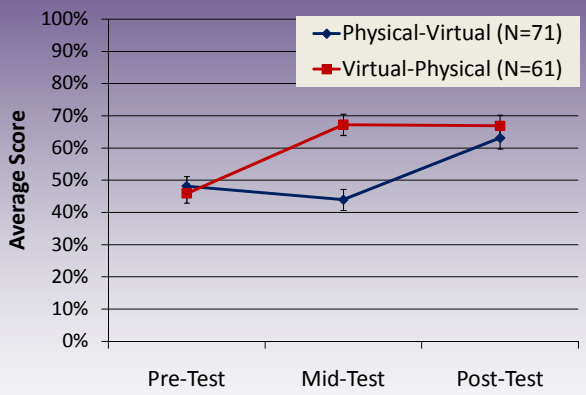
Mixed ANOVA
Main Effect: p < .001
Interaction: p <.001

Pre-Mid:
Main Effect: p < .001
Effect size: 0.28

Interaction: p = <.001
Effect size: 0.40

Pre-Post:
Main Effect: p < .001
Effect size: 0.50

Interaction: p = 0.27

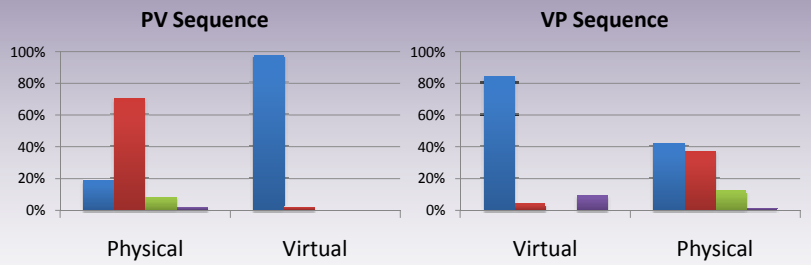


Work Score is better supported by virtual manipulatives and but supported equally well by each sequences.

Worksheet Question About Work

"Based on your data, when you changed the pulley setup, how did it affect the work required to lift the object?"

work stayed same **work changed slightly**
work changed **other**



Work Changed → Work Stayed the Same

Work Stayed the Same → Mixed Response

Conclusions

Is conceptual understanding of pulleys supported equally well by physical and virtual manipulatives?

- **"Total Score" supported equally well.**
- **"Force Score" supported better with physical.**
- **"Work Score" supported better by virtual.**

Conclusions

Does the sequence in which these manipulatives are encountered affect students' conceptual development?

- **No interaction effect for overall score.**
- **"Force" better with Physical-Virtual**
- **"Work" supported equally well by both sequences: Interpretation differences with virtual**

Future Changes

- Smaller student groups
- Longer time for students to work
- Pre-test after CoMPASS
- Assessments of other competencies/retention

Physical	→	Virtual	→	Physical
Force		*Force & Work*		*Work*

Thank You!

egire@phys.ksu.edu

Kansas State University
Physics Education Research