

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

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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: causal 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

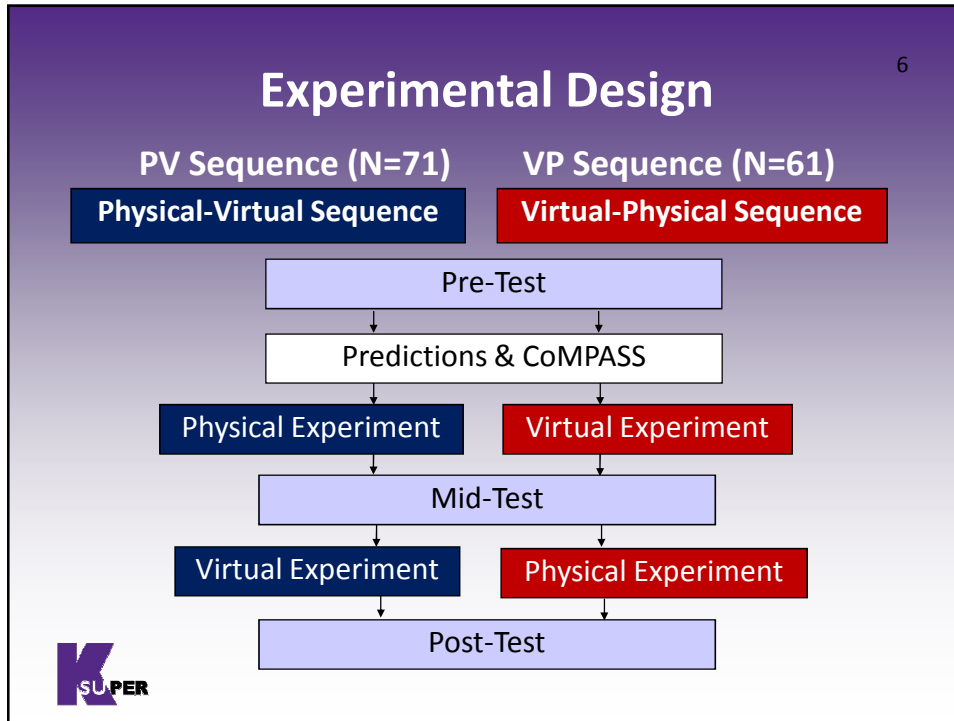
- Mechanics: Pulleys
- Control for curriculum, mode of instruction
- Speed of manipulation, friction, experimental uncertainty



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





CoMPASS Interactive Concept Maps

Change unit | Change topic | Go to: Pulley | Search

You can refer to the [definition of work](#)

You can also read about [work](#) in other topics: [Inclined Plane](#), [Wedge](#), [Wheel and Axle](#), [Screw](#), [Lever](#)

Dynamic "fish eye" concept maps

Concept in several contexts

work in Pulley

A pulley requires **energy** in order to do work. This energy is transferred by the **force** you apply when you pull on the pulley string. Pulleys can reduce the amount of applied force necessary to lift an object when doing work.

The formula for work is:

$$work = force \times distance$$

The formula shows how work depends on **both force and distance**. The distance is how far you pull the string while exerting an applied force. When using a pulley, the amount of force required to move a heavy object depends on the type of pulley you use. Pulleys that decrease the amount of applied force needed to lift an object require that you pull the string a greater distance than the object rises. This trade-off between force and distance is called **mechanical advantage (MA)**.

As the rope moves through the pulley, the surface of the pulley and the surface of the rope rub together and create friction. Friction is a force that decreases the **efficiency** of a pulley. If friction is present when you are doing work, you will need to increase the amount of applied force to overcome the friction force.

Sometimes we are interested in how quickly work gets done. The faster you lift the object, the greater the **power**.

Links in body of text

K SUPER

Physical and Virtual Manipulatives

Pulley Simulation

The simulation interface is divided into several sections:

- View:** Radio buttons for Front, Side, and Angle.
- Pulley System:** Radio buttons for Single Fixed, Two Fixed, Single Movable, Single Compound, Double Compound (selected), and Triple Compound.
- Experiment Set Up:** Two vertical sliders. The 'Load' slider is set to 4.9 N, and the 'Distance to Lift' slider is set to 0.1 m.
- Controls:** A vertical slider for 'Effort Force' is set to 1.225 N. Below it are buttons for Reset, Play, Step, Pause, and Stop.
- Measurements:** Three vertical sliders showing 'Distance Pulled' (0.4 m), 'Distance Moved' (0.1 m), and 'Work Done' (0.49 J).

On the right side of the simulation, a photograph shows a physical pulley system with a blue pulley and a weight, mirroring the virtual setup.

K SUPER

Assessment

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

Effort Force = 0.70

Work = 0.51

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Overall Score

Mixed ANOVA

Main Effect: $p < .001$

Interaction: $p = 0.12$

Pre-Mid:

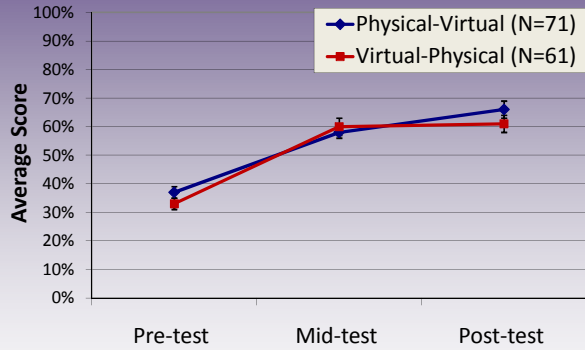
Main Effect: $p < .001$

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

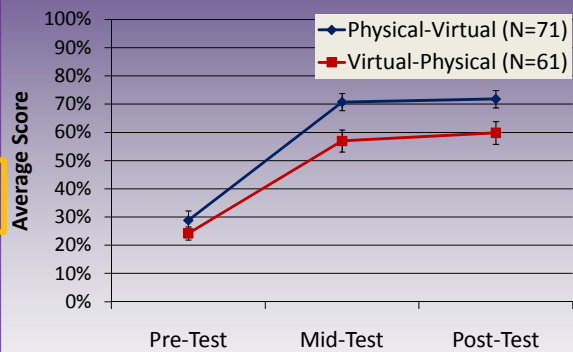
Pre-Post

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:

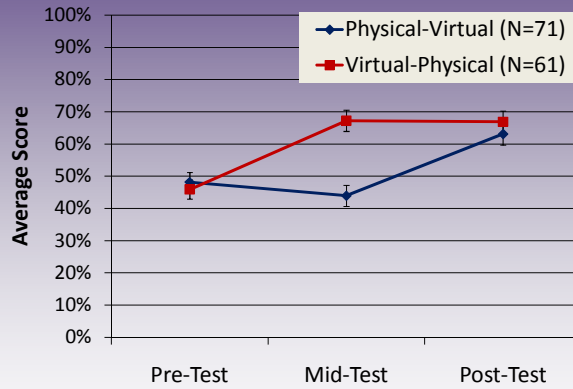
Main Effect: $p < .001$
 Effect size: 0.28

Interaction: $p = < .001$
 Effect size: 0.40

Pre-Post:

Main Effect: $p < .001$
 Effect size: 0.50

Interaction: $p = 0.27$



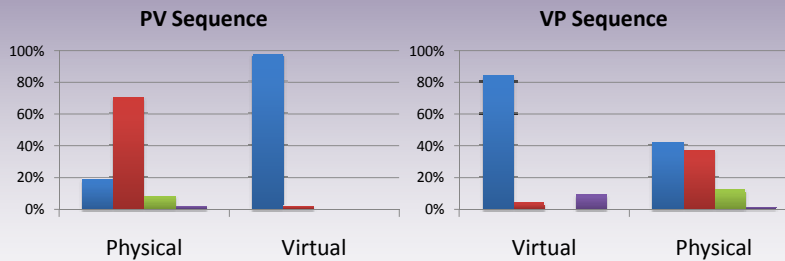
Work Score is better supported by virtual manipulatives and but supported equally well by each sequences.



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
- work changed slightly
- 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!

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