

Comparing Physical and Virtual Manipulatives for Retention and Preparation for Future Learning of Science Concepts

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Background

- Simulations may offer better support than physical equipment (Finkelstein *et al.*, 2005; Zacharia *et al.*, 2008)
- Simulations and physical equipment may offer equal support (Triona, Klahr & Williams, 2007; Zacharia & Constantinou, 2008)
- Our previous research : No overall learning difference using physical–virtual or virtual–physical sequences in the context of pulleys (Chini *et. al.*, 2012)

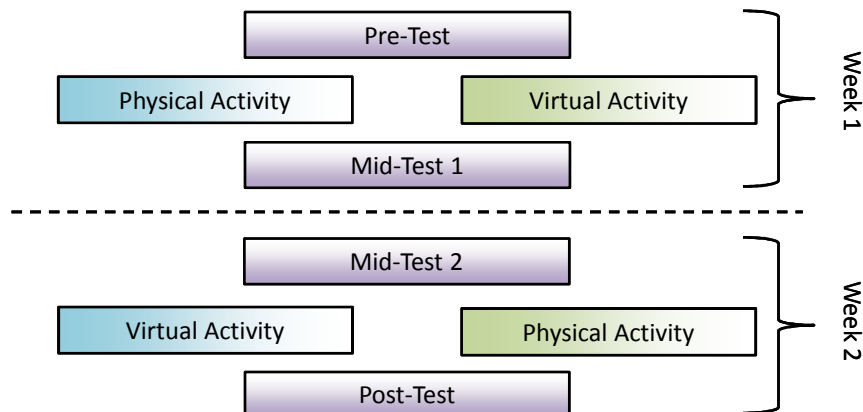
Context of Study

- Used CoPASS pulley curriculum (Puntambekar, *et al.*, 2003)
 - Integrates hypertext with hands-on activities and simulations.
- Conceptual physics lab for non-science majors (N=121)
 - Five lab sections
 - Work in groups of 4
 - In each section, half used physical and half used virtual
- Traditional laboratory setting meeting weekly for 2 hours
 - Physical and virtual activities took same amount of time

Research Design

Physical-Virtual (PV) Sequence (N=58)

Virtual-Physical (VP) Sequence (N=63)



Manipulatives

Pulley Simulation

The simulation interface includes the following sections:

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

A photograph on the right shows the physical experimental setup with a blue pulley system and weights.

Sources of Data

- Pre, mid, and post-tests had same questions
 - 16 Multiple Choice Questions
 - 13 Reasoning Questions (Short-answer)
 - Cronbach's Alpha = 0.743
- Concepts assessed:
 - Force
 - Work
 - Potential Energy
 - Mechanical Advantage

Data Analysis

- Multiple choice graded as correct/incorrect
- Reasoning questions graded using rubric
 - Scored on 0-2 scale
 - Inter-rater reliability >80%

Score	Standard
0	Incorrect Response
1	Uses basic, everyday language
2	Scientific explanation using appropriate terminology

Research Question – Retention

Which manipulative – physical or virtual – when used to learn about pulleys better facilitates retention of the concepts they have learned one week after their learning episode?

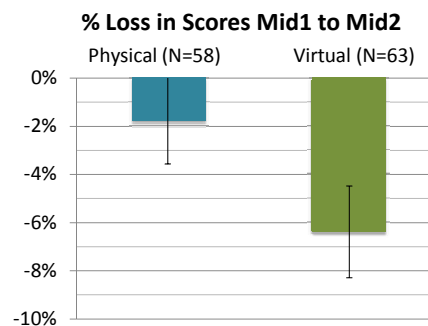
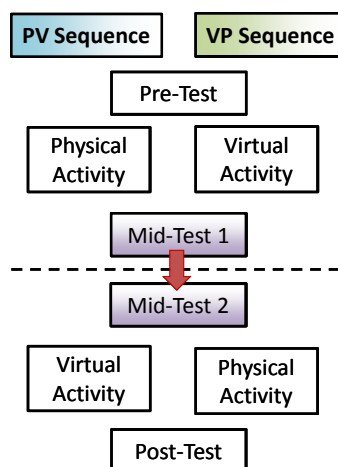
Compare test scores from end of 1st week to those at beginning at 2nd week

Retention

Ability to remember, recall on cue what one has learned previously in a new situation (Bennett & Rebello 2012)

- Physical and virtual manipulatives may offer different support when it comes to retention
 - Physical manipulatives have been shown to facilitate retention in younger learners (Reed, 2005)
- Organizing information into a schema or the use of “organizers” improves retention. (Lawton & Wasanka, 1977; Moore & Readance, 1984)
 - Virtual manipulatives might better facilitate organization of information into a schema and hence support retention

Results – Retention



Those who used physical better able to retain information one week later

Mid-Test 1 to Mid-Test 2
Interaction: $p = .014$
Effect Size: $r = .224$

Research Question – Transfer

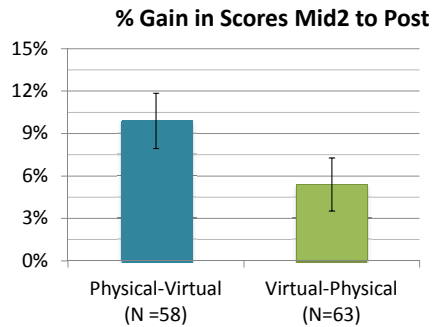
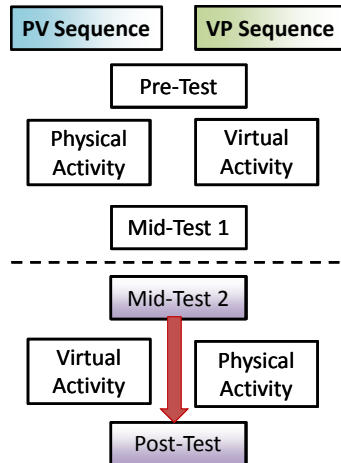
Which manipulative – physical or virtual – when used to learn about pulleys better facilitates preparation for future (re)learning using the second manipulative one week after their first learning episode?

Compare test scores from beginning of 2nd week to those at end of 2nd week

Theoretical Framework – Transfer

- **Preparation for Future Learning (PFL)** (Bransford & Schwartz, 1999)
- Asks ...
 - Not if students can *apply knowledge* to new situation
 - If students can *learn* in a new situation
- Does one manipulative better prepares students for future learning using the other manipulative

Results – Transfer



Those who used physical first were better prepared to use virtual manipulative
 Interaction: $p = .01$
 Effect Size: $r = .221$

Conclusions

- Physical manipulative seems to facilitate better retention
 - Smaller decline from end of 1st week to start of 2nd week
- Physical manipulative better prepared students to learn from virtual manipulative later
 - Larger increase in scores during the 2nd week

Future Work

- There may be long-term differences in retention
 - Need more post-testing
- Test scores alone do not tell us everything
 - Need to analyze worksheet questions
- Gains in test scores are low (<10%)
 - Re-examine curriculum and how students are using it

Thank you!

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Mixed ANOVA

Main Effect: $p < .001$
Interaction: $p < .001$

Pre-Test to Mid-Test 1

Interaction: $p < .001$
Effect Size: $r = .405$

Mid-Test 1 to Mid-Test 2

Interaction: $p = .014$
Effect Size: $r = .224$

Mid-Test 2 to Post-Test

Interaction: $p = .015$
Effect Size: $r = .221$

Pre-Test to Post-Test

Interaction: $p = .706$
Effect Size: $r = .091$

Results

Time Point	PV (N=58)	VP (N=63)
Pre-test	~8	~10
Mid-test1	~14	~20
Mid-test2	~13	~18
Post-test	~17	~20

No significant difference between PV and VP from Pre to Post-Test

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17