Comparing the Effect of Simulations and Hands-on Activities on Student Learning

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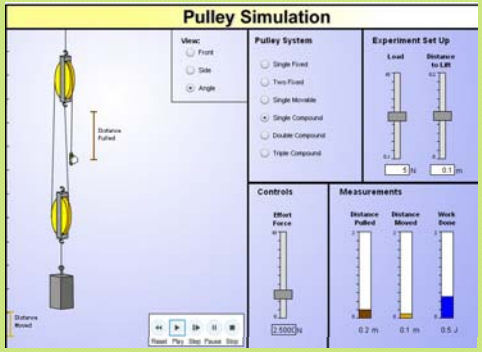
This work is funded in part by U.S. Department of Education, Institute of Education Sciences, Award # R305A080507

1. Introduction

- Studies comparing effectiveness of simulations to hands-on activities have shown varying results. [1, 2]
- We investigate the effectiveness of virtual versus physical activities in the context of pulleys.
- Research Questions:
  1. How does students' conceptual understanding change after doing physical vs. virtual activities?
  2. On which concepts did students show greatest differences in physical vs. virtual activities? How was student reasoning different?



2. Methodology

- **Participants**: conceptual physics laboratory
  - **Physical** Experiment (N=71)
  - **Virtual** Experiment (N=61)
- **CoMPASS challenge**: Design the best pulley setup to load a pool table into a van.
  - ✓ Pre-test
  - ✓ Brainstorm about challenge
  - ✓ Use CoMPASS hypertext system to investigate science ideas associated with challenge
  - ✓ Physical (or Virtual) Experiment
  - ✓ Open-ended summary questions
  - ✓ Mid-test
  - ✓ Virtual (or Physical) Experiment
  - ✓ Open-ended summary questions
  - ✓ Post-test
- **Analysis**:
  - **Quantitative**: Performance on multiple choice test.
  - **Qualitative**: Phenomenographic analysis of written responses. [3]

3. Pre- and Mid-Test Overall

- Compared multiple choice **pre-test** and **mid-test** scores between **physical** vs. **virtual** groups.
- No statistically significant difference between physical and virtual groups on either pre- or mid-test.

Pre- and Mid-Test Mean ± Std. Dev.		
Test	**Physical**	**Virtual**
Pre	36.5% ± 13.6%	33.3% ± 12.8%
Mid	47.5% ± 12.9%	48.7% ± 18.3%

4. Conceptions of *Work* and *P.E.* on Pre-Test and Mid-Test

- **Question 9**: Compare the *work* needed to lift a load using three frictionless pulley systems -- single fixed, single compound and double compound.
- **Question 13**: Compare *work* done to *potential energy* gained when lifting a watermelon to your tree house if friction is not a factor.

Pre- and Mid-Test % Correct Responses			
Treatment	**Test**	**Question 9**	**Question 13**
Physical	Pre	29.6%	52.9%
	Mid	16.9%	31.4%
Virtual	Pre	24.6%	52.5%
	Mid	63.9%	75.4%

- No statistically significant differences between physical and virtual groups on **pre-test**.
- Statistically significant differences between physical and virtual groups on **mid-test**.

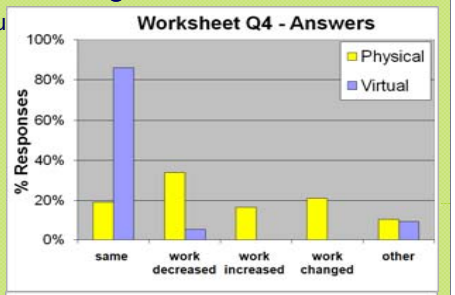
5. Reasoning Patterns

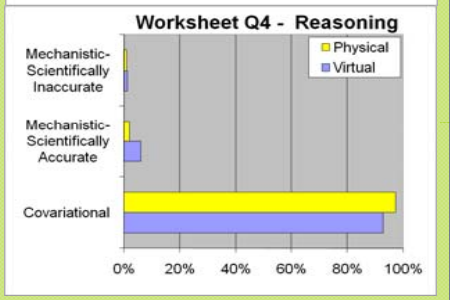
Responses to worksheet summary question showed three kinds of reasoning:

- **Covariational**: attributing an effect to one of its possible causes with which it covaries. [4]
- **Mechanistic**: an explanation of observed results by describing the mediating process by which the target factor could have produced the effect. [5]
  - Mechanistic reasoning is either scientifically accurate or scientifically inaccurate.
- **Data-based**: Referring to data collected in experiment to support answer.

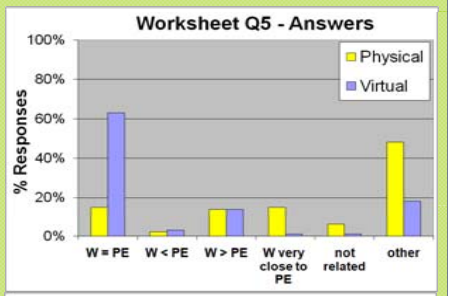
6. Reasoning about *Work & PE*

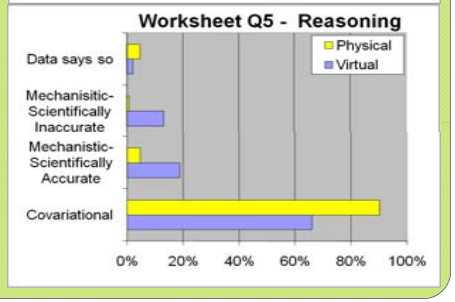
Q4: When you changed the pulley setup, how did it affect the work? Why?





Q5: How does work (W) compare to potential energy (PE) for a given pulley system? Why?





7. Conclusions

- No significant difference in student performance on pre- and mid-test between virtual and physical groups.
- Conceptual differences between virtual and physical:
  - Virtual group showed gains on work, PE questions from pre-to mid-test while physical group showed losses.
- Reasoning differences:
  - Both groups showed mostly covariational reasoning.
  - Virtual group had more correct answers to work and PE questions, but mostly did not show mechanistic reasoning.

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3. F. Marton, Journal of Thought **21,** 29-39 (1986).
4. Woei Hunga and David H. Jonassen, "Conceptual Understanding of Causal Reasoning in Physics," International Journal of Science Education, Vol. 28, No. 13, 27 October 2006 (1601–1621).
5. B. Koslowski, , L.Okagaki, C. Lorenz, & D. Umbach, "When covariation is not enough: The role of causal mechanism, sampling method, and sample size in causal reasoning," *Child Development, 60,* 1316–1327 (1989).