Comparing Students' Performance and Reasoning with Physical and Virtual Manipulatives to Learn about Pulleys

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Background

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- Previous studies have shown mixed results:
  - Simulations outperform analogous physical experiments
    - Zacharia, Olympiou, & Papaevripidou, 2008
    - Finkelstein, et al., 2005
  - No difference in learning using physical or virtual manipulatives
    - Klahr, Triona, & Williams, 2007
    - Zacharia & Constantinou, 2008
- Zacharia and Constantinou (2008):
  - More research is needed to describe how physical and virtual manipulatives should be integrated in a physics curriculum.

Context

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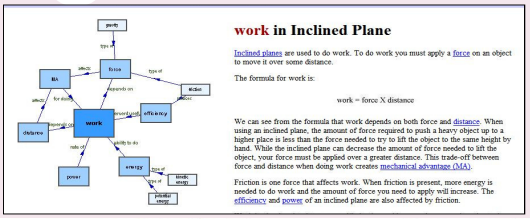
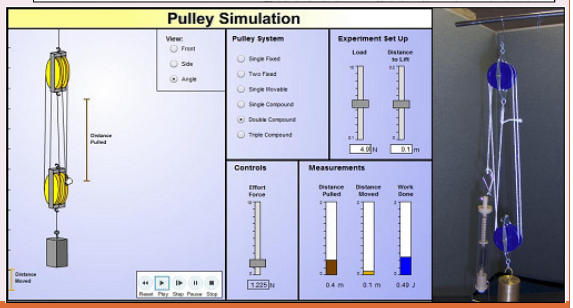
- CoMPASS[1] pulley Curriculum
  - Hypertext system
  - Physical experiment
  - Simulation

CoMPASS: Concept Mapped Project-based Activity Scaffolding System





[1]Puntambekar, Stylianou & Goldstein (2007)

Research Questions

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- Is there a difference in understanding as measured by students' **performance on a multiple choice test**?
- Is there a difference in understanding as measured by students' **verbal explanations and reasoning**?

Theoretical Background

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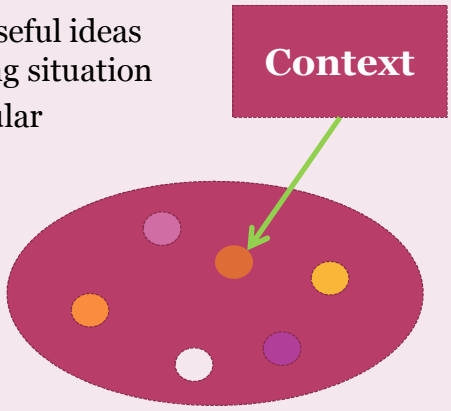
Context affects the ideas students use

- Hammer (2002) resources
  - Resources: potentially useful ideas students bring to learning situation
  - Context activates particular resources



Description of Studies

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In-Class Study (N=132)

Pre-test

Physical or Virtual Activity

Mid-test

Virtual or Physical Activity

Post-test

Interview Study (N=13)

Pre-test

Pre-test Interview (Half of Q's)

Physical or Virtual Activity

Post-test

Post-test Interview (Half of Q's)

Analysis

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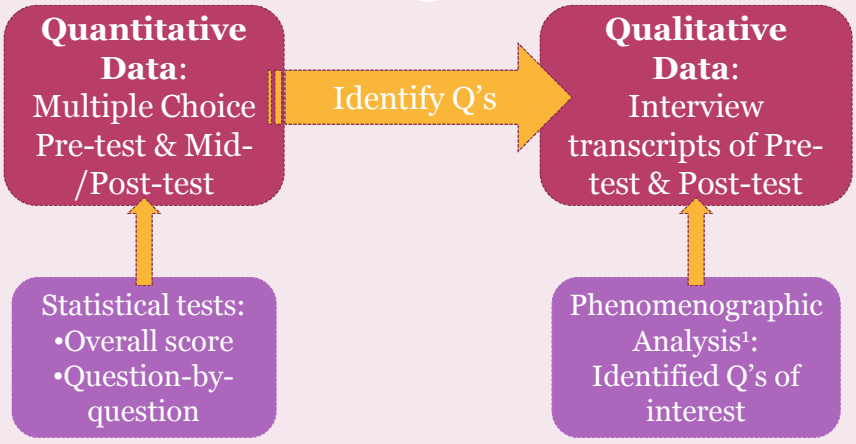

[1]Marton, 1986

Quantitative Results: Overall Score

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		Pre-test		Mid-test	
Treatment	**N**	**Mean**	**SD**	**Mean**	**SD**
Physical	71	37%	18%	58%	19%
Virtual	61	33%	13%	60%	24%

- ANCOVA results:
  - Covariate (pre-test score) significantly related to the mid-test score $F(1, 129)=26.5$, $p<.001$
  - Treatment (physical or virtual experiment) not significantly related to mid-test score $F(1, 129)=.946$, $p=.332$

Quantitative Results: By Concept

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- Students in physical condition performed better on questions related to force, distance of rope pulled, and mechanical advantage
- Students in virtual condition performed better on questions related to work
- To be reported in Gire *et al.*, 2010, *International Conference of the Learning Sciences*

Specific Questions with Performance Difference

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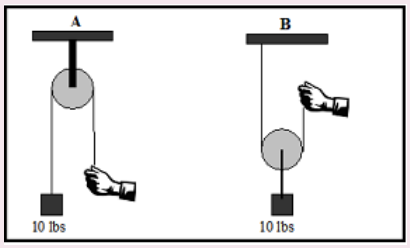
	Class Physical (N=71)	Class Virtual (N=61)	p-value	Interview Physical (N=7)	Interview Virtual (N=6)
Q1 Pre	11%	11%	.970	0%	0%
Q1 Mid or Post	83%	62%	.008	71%	17%
Q 6.2 Pre	32%	42%	.230	29%	33%
Q 6.2 Mid or Post	28%	80%	<.001	14%	67%



Which setup requires the least:
•Q1: force?
•Q6.2: work?

Physical Outperforms Virtual

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Less force?	Physical Pre	Virtual Pre	Physical Post	Virtual Post
Single fixed	4	3	0	2
Single movable	0	0	3	1

- Pre-instruction, mainly intuition-based resources
  - Easier to pull down than to pull up
  - Easier to pull with gravity than against gravity
- Post-instruction, no observed trend in reasoning
  - One student (virtual) used common sense reasoning
    - Working against gravity to pull up
  - One student (physical) provided scientifically correct reasoning
    - Distance increases, so force decreases

Virtual Outperforms Physical

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More work?	Physical Pre	Virtual Pre	Physical Post	Virtual Post
Single fixed	0	0	1	0
Single movable	3	3	2	0
Same	1	0	0	3

- Pre-instruction, difference in reasoning
  - More force means more work: Used by all virtual and one physical
- Post-instruction, difference in responses and reasoning
  - Virtual provided scientifically correct reasoning
    - Eg: Object weighs the same and moves the same distance
  - Physical correctly identify factors but do not apply them correctly
    - Eg: Pulley requires more force; Pulley requires more distance pulled

Definitions of Force (Q1)

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- Pre-instruction, no difference between physical and virtual
  - Effort or force physically exerted to lift object
  - Referred to work *or* included role for distance
- Post-instruction, observed difference
  - Physical: Effort or force physically exerted to lift object
  - Virtual: Referred to energy and/or included role for distance

Definitions of Work (Q 6.2)

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- Pre- instruction, wide variety & varying scientific correctness
  - Change in kinetic energy (Virtual)
  - Spending energy (Physical)
  - Amount of effort and duration (Virtual)
  - What it takes to get the thing from point A to point B (Physical)
- Post-instruction, no difference between physical and virtual: mostly scientifically correct
  - How much object weighs and distance you have to move it (Physical & Virtual)
  - Amount of effort you put in over the distance pulled (Physical)
  - Work is equal to force times distance (Virtual)
  - Distance pulled divided by effort force (Virtual)

Discussion: Force

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- "Common sense" reasoning
  - Observed more often before instruction than after instruction
  - Not observed after instruction for physical
  - Observed after instruction for virtual
- Possible explanation: Hammer's[1] model of conceptual resources
  - Context activates and deactivates resources students use to build understanding
  - Physical manipulatives may better support deactivation of resource related to "downward movement is easier"

[1]Hammer, 2002

Discussion: Work

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- Definitions of work
  - Students in physical and virtual provided equally useful definitions of work
  - Virtual more likely to use definition to arrive at correct answer
    - Physical having more difficulty applying definition in context
- Common sense resources: "more input means more output"
  - Used as "more force means more work" and "more distance pulled means more work"
  - Needs to be deactivated in favor of resource for proportional reasoning
    - "Force and distance change proportionally" (Virtual)

Conclusions

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- While overall performance on the test was similar, specific concepts[1] and questions exhibit a performance difference
- Interviews allow us to probe these differences more deeply
- Possible mechanism: physical and virtual activities may activate and deactivate different conceptual resources
  - Force: Physical indicated suppression of "downward movement is easier"
  - Work: Virtual indicated suppression of "more input means more output" possibly for a resource for proportional reasoning

Gire *et al.*, 2010

Thank you!

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