Comparing Benefits of Hypertext Exploration versus Virtual Experimentation on Students' Analysis of Physical Experiments

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Introduction

- Studies on how students' learning of introductory physics concepts is supported by physical and virtual manipulatives have found mixed results
  - Learning may be enhanced by virtual experimentation (Zacharia, Olympiou & Papaevripidou, 2008; Finkelstein *et al.*, 2005)
  - Learning may be similar for both manipulative types (Klahr, Triona & Willaims, 2007; Zacharia & Constantinou, 2008)
- Our previous research in the context of simple machines shows the difference may be concept-based (Gire *et al.*, 2010)
  - Physical manipulatives better for force
  - Virtual manipulatives better for work and energy

Purpose of Study

- Zacharia and Anderson (2003) have shown simulations improve students' predictions and explanations of physical experiments
  - Performing a virtual experiment may improve learning in a physical experiment
- Research Question: *Does a prior experience with a virtual experiment change the type of interpretations students make of the data from a physical experiment?*

Theoretical Underpinnings

- Possible stances towards anomalous data (Chinn & Brewer, 1983)
  - Ignore the data
  - Reject the data
  - Hold the data in abeyance
  - Reinterpret the data while maintaining the existing theory
  - Make peripheral theory changes
  - Change the theory

Theoretical Underpinnings

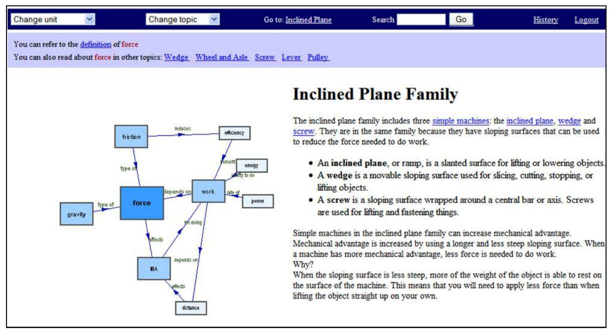
- Stance may be influenced by properties of data
  - Less credible data is easily *rejected*
    - Previous work (Chini *et al.*, 2010) shows students trust the simulation over the physical experiment
  - Ambiguous data is easily *reinterpreted*
    - Physical experiment generates "messy" data due to frictional effects and measurement errors

Theoretical Underpinnings

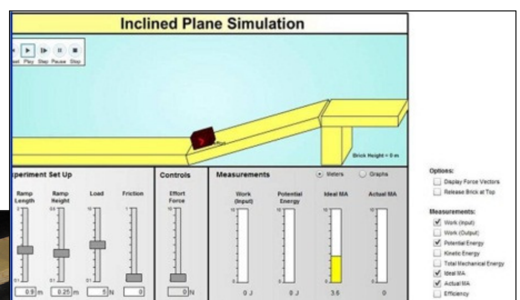
- Dynamic Transfer
  (Schwartz, Varma & Martin, 2008)
  - Learning environment plays a role in *dynamic transfer*
    - Allows for distributed memory
    - Affords alternative interpretations
    - Offers candidate structures by constraining & structuring actions
    - Provides a focal point for coordination
  - Physical and virtual manipulatives may offer *different support* for dynamic transfer

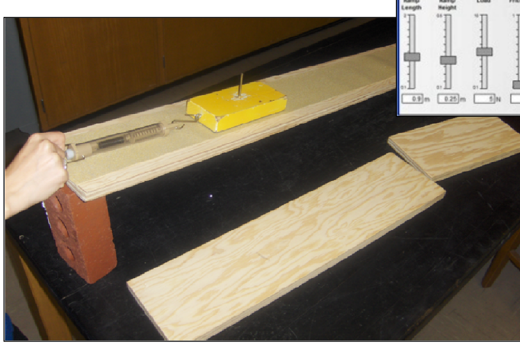
Curriculum

- **CoMPASS** (Concept Mapped Project-based Activity Scaffolding System) (Puntambekar, Stylianou & Hübsher, 2004)
  - Inclined Plane unit
- Explores how length, height, surface of inclined plane affect force and work needed and mechanical advantage of inclined plane

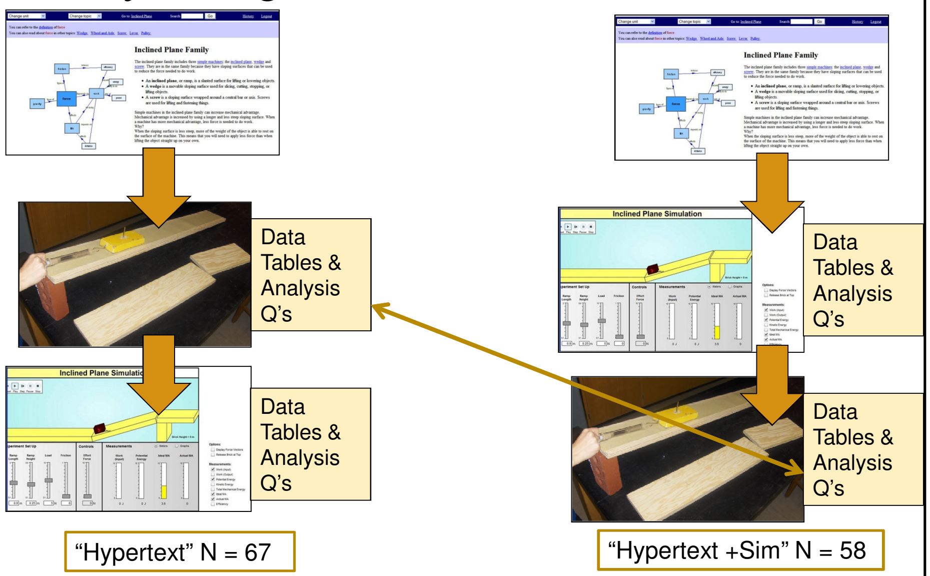


Manipulatives





Study Design



Participants

- Enrolled in conceptual-based physics laboratory
  - Four sections
  - Taught by undergraduate teaching assistants
- Experiments completed as part of laboratory
  - Two sections in Hypertext group
  - Two section Hypertext+Sim group

Analysis

- Categorized students' responses to open-ended analysis questions
- Used chi-square test for independence to determine if there was a difference in the types of responses provided by Hypertext and Hypertext+Sim groups
  - For significant result, examined adjusted residuals to determine which cells contributed to the significant difference (Haberman, 1973)

Analysis Questions

- Students responded to 18 analysis questions
  - Force needed to lift load*
  - Work needed to lift load*
  - Change in load's potential energy*
  - Comparison of work and potential energy$
  - Ideal mechanical energy*
  - Actual mechanical energy*

* How does changing each parameter (length, height or surface) affect the quantity?

$ How does changing the friction of the surface affect the relationship?

Results By Question

Q#	Physical Quantity	Parameter	χ2	p-value	Effect Size
Q1L	**Force**	**Length**	**χ2(2, N=108) =13.2**	**.001**	**.35**
Q1H*	Force	Height	χ2(2, N=109) =4.1	.162	.20
Q1S	Force	Surface	χ2(1, N=108) =.7	.404	.08
Q2L	**Work**	**Length**	**χ2(2, N=108) =20.1**	**<.001**	**.43**
Q2H*	Work	Height	χ2(2, N=108) =.7	.753	.08
Q2S	Work	Surface	χ2(1, N=108) =1.5	.221	.12
Q3L*	Potential Energy	Length	χ2(1, N=107) =1.3	.437	.11
Q3H*	Potential Energy	Height	χ2(1, N=107) =1.1	.363	.10
Q3S*	Potential Energy	Surface	χ2(1, N=106) =1.3	.438	.11
Q4A*	**Work/Potential Energy**	**Rough**	**χ2(3, N=108) =21.2**	**<.001**	**.44**
Q4B	**Work/Potential Energy**	**Smoother**	**χ2(3, N=108) =29.4**	**<.001**	**.52**
Q4C	**Work/Potential Energy**	**No friction**	**χ2(2, N=107) =31.4**	**<.001**	**.54**
Q5L	**Ideal MA**	**Length**	**χ2(1, N=107) =7.0**	**.008**	**.26**
Q5H	Ideal MA	Height	χ2(1, N=107) =.6	.426	.08
Q5S	Ideal MA	Surface	χ2(1, N=103) =3.1	.079	.17
Q6L	**Actual MA**	**Length**	**χ2(2, N=108) =10.7**	**.005**	**.31**
Q6H*	Actual MA	Height	χ2(2, N=108) =2.9	.280	.17
Q6S*	Actual MA	Surface	χ2(2, N=108) =6.0	.063	.24
Note: Asterisk indicates exact test was used. Bold indicates significant at the p <.005 level.					

Hypertext + Sim Supports Dynamic Transfer

Question: Comparison of work & potential energy for different surfaces

- *Friction present*

Response	Group more likely?	
	Hypertext	Hypertext+Sim
Work is greater than PE		x
Work is equal to PE		x
Work increases & PE stays the same	x	
Other		

Hypertext + Sim Supports Dynamic Transfer

Question: Comparison of work & potential energy for different surfaces

- *Surface gets smoother*

Response	Group more likely?	
	Hypertext	Hypertext+Sim
Work & PE get closer		x
Work is equal to PE		x
Work decreases & PE stays the same	x	
Other		

Hypertext + Sim Supports Dynamic Transfer

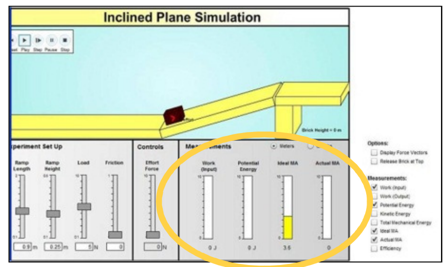
Question: Comparison of work & potential energy for different surfaces

- *Frictionless*

Response	Group more likely?	
	Hypertext	Hypertext+Sim
Work is equal to PE		x
Work decreases & PE stays the same	x	
Other		

Hypertext + Sim Supports Dynamic Transfer

- Result:
  - Hypertext+Sim students more likely to describe *relationship* of work and potential energy
  - Hypertext students more likely to discuss work and potential energy *separately*



- Possible Explanation
  - Simulation bar chart display provides “focal point for coordination”

Different Responses to Anomalous Data

Question: How does increasing *length* of IP affect *work*

- Would like students to focus on similarity of work values for different lengths in physical experiment

Response	Group more likely?	
	Hypertext	Hypertext+Sim
Work would increase		x
Work would stay the same	x	
Work would decrease		x

- Similar finding when students were asked to compare work and potential energy for a frictionless surface

Different Responses to Anomalous Data

- Result
  - Hypertext+Sim students more likely to focus on *similarity* of work values or work & potential energy values
- Possible Explanation
  - Chinn & Brewer's framework of possible responses to anomalous data
    - Hypertext+Sim sequence students encounter easy to interpret data *before* ambiguous data. May reinterpret physical data to fit theory developed from simulation.

Hypertext Performs Better on Length Questions

Question: How does increasing *length* of IP affect *force*

Response	Group more likely?	
	Hypertext	Hypertext+Sim
Force would decrease	x	
Force would stay the same		
Force would increase		x

Hypertext Performs Better on Length Questions

Question: How does increasing *length* of IP affect *ideal mechanical advantage*

Response	Group more likely?	
	Hypertext	Hypertext+Sim
IMA would increase	x	
Other		

Hypertext Performs Better on Length Questions

Question: How does increasing *length* of IP affect *actual mechanical advantage*

Response	Group more likely?	
	Hypertext	Hypertext+Sim
AMA would decrease		x
AMA would stay the same		
AMA would increase	x	

Hypertext Performs Better on Length Q's

- Finding
  - Students in Hypertext group were more likely to provide a correct description of the relationship between length and
    - Force
    - Ideal mechanical advantage
    - Actual mechanical advantage
- Possible Explanation
  - Students may be more aware of length in physical experiment
  - Force and mechanical advantage can be "felt" in physical experiment

Conclusions

- Prior virtual experience influenced descriptions of data from physical experiment
  - More useful comparisons between work and potential energy
  - Supports finding of Zacharia & Anderson, 2003
- Students with prior virtual experience had more *incorrect* descriptions relating to **length** and **force** or **MA**
- Prior virtual experience may help students to interpret the data from a physical experiment in a more scientific manner

Future Work

- Explore alternate interpretations of data
  - E.g. Hypertext+Sim had more time on task

- Explore students' explanations of the relationships involving work and potential energy
  - Do explanations of Hypertext+Sim group show evidence of considering the role of friction in the physical experiment?