Qualitative Analysis of the Effects of Sequence of Physical and Virtual Activities on Student Conceptual Understanding in Mechanics

Adrian Carmichael
Jacquelyn J. Chini, N. Sanjay Rebello
Kansas State University

Sadhana Puntambekar
University of Wisconsin, Madison

Research Questions

• How does the temporal order of physical and virtual experiments affect students’ understanding?

• How do students react to anomalous experimental data from physical and virtual experiments?
**Previous Research**

- Zacharia, Olympiou, & Papaevipidou (2008)
- Heat and temperature lab
- Group 1 used physical manipulatives
- Group 2 used physical then virtual manipulatives
- Results: Group 2 performed better on a conceptual test

**Theoretical Framework**

Responses of Students to Anomalous Data:

- Ignore
- Reject
- Exclude from the domain
- Hold in abeyance
- Reinterpret and retain
- Reinterpret data and make peripheral changes
- Accept and change theory

Factors That Affect Response to Anomalous Data

1. Prior knowledge
2. Processing Strategy
3. Characteristics of Data
   - Credibility
   - Ambiguity


Experimental Design

<table>
<thead>
<tr>
<th>VP Sequence (N=71)</th>
<th>PV Sequence (N=61)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual-Physical</td>
<td>Physical-Virtual</td>
</tr>
<tr>
<td>Sequence</td>
<td>Sequence</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Test</td>
<td>Physical Experiment</td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Predictions &amp; CoMPASS</td>
<td>Mid-Test</td>
</tr>
<tr>
<td>Virtual Experiment</td>
<td>Physical Experiment</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Experiment</td>
<td>Virtual Experiment</td>
</tr>
<tr>
<td></td>
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<tr>
<td>Post-Test</td>
<td></td>
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</tbody>
</table>
CoMPASS Interactive Concept Maps

work in Pulley

A pulley requires force in order to do work. This energy is transferred by the force you apply when pulling 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:

\[ \text{work} = \text{force} \times \text{distance} \]

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 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 wraps through the pulley, the number of the pulley on the surface of the rope wraps together and counts force. Forces is shown in the diagram. The relationship of states "pulley" to increase. A pulley helps you are doing work, you can reduce the amount for lifting.

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

Physical and Virtual Manipulatives

Pulley Simulation

**Pulley System**
- Single Fixed
- Free Fixed
- Single Inclined
- Single Tilted
- Double Compound
- Triple Compound

**Experiment Set Up**
- Load
- Distance to Lift
- Distance to Drag

**Control**
- Effort Distance
- Load Distance
- Drag Distance
- Effort
- Load
- Drag

**Measurements**
- Load: 4.5 N
- Distance to Lift: 1 m
- Distance to Drag: 1 m
- Effort: 2.25 N
Overall Results

Results by Concept Tested

Focus on work questions

• Pre-to mid-: sig. increase both
• Mid-to post-: no change both

• Pre-to mid-: sig. increase VP
• Mid-to post-: sig. increase PV
Worksheet Question About Work

- Worksheet Question 4: “Based on your data, when you changed the pulley setup, how did it affect the work required to lift the object? Why do you think that is?”

- **work stayed same**
- **work changed slightly**
- **work changed**
- **other**

![Worksheet Question 4 (PV Sequence)](image)

![Worksheet Question 4 (VP Sequence)](image)

**Work Changed to Work Stayed the Same**

Changes in Answers on Test Q 9

**Pre- to Mid**

- PV: work different (Pre) to work different (Mid)
- VP: work different (Pre) to work same (Mid)

<table>
<thead>
<tr>
<th>Response</th>
<th>% Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Work Same&quot; (PRE) to &quot;Work Same&quot; (MID)</td>
<td>p = .015</td>
</tr>
<tr>
<td>&quot;Work Diff.&quot; (PRE) to &quot;Work Diff.&quot; (MID)</td>
<td>p &lt; .001</td>
</tr>
<tr>
<td>&quot;Work Diff.&quot; (PRE) to &quot;Work Same&quot; (MID)</td>
<td>p &lt; .001</td>
</tr>
<tr>
<td>&quot;Work Same&quot; (PRE) to &quot;Work Diff.&quot; (MID)</td>
<td>p = 0.046</td>
</tr>
</tbody>
</table>
Changes in Answers on Test Q 9

Changes to TQ9 Response

PV: either different (Mid) to different (Post) OR Different (Mid) to Same (Post)

VP: same (Mid) to same (Post)

- t-test (Two Tailed, Unequal Variances)
  - p = .001
  - p = .032
  - p ≤ .001
  - p = 0.29

Factors That Affect Response to Anomalous Data

1. Prior knowledge
2. Processing Strategy
3. Characteristics of Data
   - Credibility
   - Ambiguity

Sample Data

<table>
<thead>
<tr>
<th></th>
<th>Work value measured in PHYSICAL experiment</th>
<th>Work value measured in VIRTUAL experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Fixed</td>
<td>.49 J</td>
<td>.50 J</td>
</tr>
<tr>
<td>Single Movable</td>
<td>.52 J</td>
<td>.50 J</td>
</tr>
<tr>
<td>Single Compound</td>
<td>.38 J</td>
<td>.50 J</td>
</tr>
<tr>
<td>Double Compound</td>
<td>.54 J</td>
<td>.50 J</td>
</tr>
</tbody>
</table>

Ambiguity in Data

Physical: Higher Ambiguity

Virtual: Lower Ambiguity
Ambiguity in Data, Pre to Mid

Pre- to Mid-

PV Sequence: Saw higher ambiguity physical data and most stayed with previous ideas.

VP Sequence: Saw lower ambiguity virtual data and more changed ideas.

Ambiguity in Data, Mid to Post

Mid- to Post-

VP Sequence: Most say work is the same after seeing higher ambiguity physical data.

PV Sequence: After seeing lower ambiguity virtual data, some change ideas while others remain the same.
• Significant association between score on Q9 of post test and order of experiments performed. ($\chi^2(1) = 3.91, p = .05$)
• Odds ratio test indicates 1.45 times higher chance of answering question correctly in VP sequence than PV sequence.

Conclusions

• Virtual data
  – lower ambiguity
  – more likely to change students’ conceptions.

• Physical data
  – more ambiguity
  – less likely to change students’ conceptions

• VP sequence more likely to help students answer question about work correctly.
Future Work

- Confidence ratings
- Epistemological survey
- Explanation on test answers