Comparing Students’ Performance with Physical and Virtual Manipulatives in a Simple Machines Curriculum
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Abstract
We compare the effects of physical versus virtual manipulatives in an inclined plane curriculum for students enrolled in a conceptual-based introductory physics laboratory. ANCOVA with pre-test score as a covariate showed that post-test scores for students who completed activities about length and height with virtual manipulatives (M = 77.5, SD = 0.028) were significantly higher than those of students who performed the same activities with physical manipulatives (M = 66.2, SD = 0.019), F(1, 63) = 15.2, p < .001, r = .43. Individual post-test questions that attributed to performance spread are identified and analyzed. We then analyze the manipulatives through the lens of dynamic transfer in an effort to explain the difference in students’ performance.

Research Motive
• Investigate how student learning is supported by interaction with physical and virtual manipulatives
• Previous studies in physics have shown mixed results
  - Virtual outperforms physical (see: Finkelstein et al., 2005; Zacharia, 2007; Zacharia, Olympiou, & Papaevripidou, 2008)
  - No performance difference (see: Zacharia & Constantinou, 2008; Klahr, Triona & Williams, 2007)

Context of Study
• CoMPASS (Concept Map Project-based Activity Scaffolding System) inclined plane curriculum

Study Design & Test Results
• Participants: five sections of introductory conceptual-based physics students in laboratory
  • Completed two of three experiments due to time constraints

Table: ANCOVA with pre-test score as a covariate

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Effect</th>
<th>F</th>
<th>p</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length/Height Pre-test</td>
<td>F(1, 63) = 15.2</td>
<td>&lt; .001</td>
<td>.44</td>
<td></td>
</tr>
<tr>
<td>Length/Friction Pre-test</td>
<td>F(1, 78) = 17.5</td>
<td>&lt; .001</td>
<td>.43</td>
<td></td>
</tr>
</tbody>
</table>

• Pearson’s chi-square test was used to identify individual questions on which students who used the simulation to perform the Length & Height activities significantly outperformed students who used the physical equipment

Table: Chi-square analysis

<table>
<thead>
<tr>
<th>Question</th>
<th>χ^2</th>
<th>p</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>χ^2(1) = 21.1</td>
<td>&lt; .001</td>
<td>13.9</td>
</tr>
<tr>
<td>7</td>
<td>χ^2(1) = 5.5</td>
<td>0.019</td>
<td>3.6</td>
</tr>
<tr>
<td>14</td>
<td>χ^2(1) = 44.8</td>
<td>&lt; .001</td>
<td>177.8</td>
</tr>
</tbody>
</table>

Q6. You used a 5 m long ramp with no friction to move an object into a van. If you used a 10 m long ramp with no friction to move the object into the same van, the work needed would:

- A. Increase
- B. Decrease
- C. Stay the same
- D. Not enough information

Q7. Jane is lifting a box straight up to a height of 2 meters. Mary is using the ramp shown below. If friction is not a factor, what can you tell about the work done by Jane and Mary?

- A. Jane is doing more work
- B. Mary is doing more work
- C. Jane and Mary are doing the same work
- D. Not enough information

Q14. An object sits at the top of a frictionless ramp. How does the object’s potential energy compare to the work required to move it to the top of the ramp?

- A. The object’s potential energy is greater than the required work
- B. The object’s potential energy is less than the required work
- C. The object’s potential energy is the same as the required work
- D. Not enough information

Characteristics of Environment for Dynamic Transfer
- C1. Focus on the physical world.
- C2. Immediate feedback is available.
- C3. Collaboration is encouraged.
- C4. Powerful tools reduce drudgery.
- C5. Understand the specific and familiar before moving to the more general and abstract.
- C6. Students are actively engaged in exploring and constructing their own understanding.
- C7. Useful models for forming concepts are made visible.
- C8. Students are constrained in productive ways.

Discussion
• Students’ performance on Q6 and Q14 can be linked to the type of manipulative used. Students who used the virtual manipulative saw only a frictionless environment, while students who used the physical manipulative typically chose answers based on the data from the physical experiment.

Theory: Dynamic Transfer and Properties of Successful Computer Use
• Dynamic transfer involves application of component competencies in an environment to yield new concepts. In contrast, similarity transfer involves application of well-formed concepts to a new situation (Schwartz, Varma, and Martin, 2008). Specific properties of the environment support dynamic transfer, as shown below.
  - We have built a “master list” of the reasons computers can be potentially useful learning tools from the physics education research literature (Thornton and Sokoloff, 1990; Redish, Saul and Steinberg, 1997; Finkelstein et al., 2005), shown below.
  - We find significant overlap between these characteristics and the properties of an environment that supports dynamic transfer (Schwartz, Varma, and Martin, 2008).

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