Problem solving strategies in an online homework environment: “Student Choice and Analytics”

Daniel Seaton, Yoav Bergner, Carie Cardamone, Saif Rayyan, Andrew Pawl, Raluca Teodorescu, and David Pritchard

Department of Physics
Massachusetts Institute of Technology
Cambridge, MA 02139
Online Environment using LON-CAPA

- Integrated Learning Environment for Mechanics
  - Built within LON-CAPA
  - E-text with instructor videos
  - Concept questions
  - Easy, Medium, Hard homework problems
Problem Categorization in Homework

<table>
<thead>
<tr>
<th>Difficulty</th>
<th>Cognitive Processes</th>
<th>Declarative Knowledge</th>
<th>Mental Procedures</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy</td>
<td>recall, execution,</td>
<td>definitions,</td>
<td>single rules</td>
<td>evaluate definitions, identify appropriate systems, perform simple calculations, match basic graphs with verbal descriptions, match arrows with relevant forces</td>
</tr>
<tr>
<td></td>
<td>representation,</td>
<td>vocabulary terms,</td>
<td>and basic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ranking, analyzing</td>
<td>basic facts,</td>
<td>algorithms</td>
<td></td>
</tr>
<tr>
<td></td>
<td>errors</td>
<td>simple time</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>sequences</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>same as Easy +</td>
<td>complex facts</td>
<td>complex algorithms</td>
<td>choose an appropriate problem solving strategy, perform two-step calculations, compare physical quantities and outcomes, over-informed scenarios</td>
</tr>
<tr>
<td></td>
<td>integration</td>
<td>and time sequences</td>
<td>and tactics</td>
<td></td>
</tr>
<tr>
<td>Hard</td>
<td>same as Easy +</td>
<td>more complex facts</td>
<td>complex procedures</td>
<td>evaluate solutions, match complex diagrams with verbal descriptions, match problems with their strategies, perform multi-step and limiting case calculations, multiple object scenarios</td>
</tr>
<tr>
<td></td>
<td>integration</td>
<td>and time sequences,</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>principles and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>generalizations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Problems categorized by Raluca Teodorescu based on her thesis work.
- Categorization provides opportunity to explore problem difficulty and student choice.

Course Implementation at MIT

- ILEM / LON-CAPA homework
  - Easy (+1), Medium (+2), Hard (+3)
  - Students must attain 15 points per assignment
  - Students generally have to work in at least two folders

- Spring 2011, MIT 8.011 (~60 Students)
  - Reform course for students needing to re-take introductory physics at MIT
  - ILEM / LON-CAPA used to prep students each week, only required for 5 units
  - Class time used for highly interactive group problem solving sessions (minimal lecture)

- Data Mining LON-CAPA Activity Logs!!!
Problem Categorization

LON-CAPA Difficulty
$\text{Diff}_{LC} = \text{incorrect/total}$

Item Response Theory using Rasche Model

Time per problem and time per submission
Student Behavior and Performance

- Z-score student groups based on overall performance
- Motivation
  - ~ 70% students gained more than 15 points on 3 or more assignments
- Efficiency
  - Similar value across all groups

## Student Choice - Initial / Final Categories

- What categories do students start with? End with?

<table>
<thead>
<tr>
<th>Unit</th>
<th>Initial Category</th>
<th>Final Category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Easy</td>
<td>Med</td>
</tr>
<tr>
<td>Newton’s Laws</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>Dynamics &amp; Modeling</td>
<td>43</td>
<td>2</td>
</tr>
<tr>
<td>Momentum</td>
<td>45</td>
<td>0</td>
</tr>
<tr>
<td>Mechanical Energy</td>
<td>45</td>
<td>4</td>
</tr>
<tr>
<td>Torque &amp; Rotation</td>
<td>48</td>
<td>2</td>
</tr>
</tbody>
</table>

- Survey information being analyzed from January course.

- Student number conserved between initial and final state, but not necessarily between units.
Comparison with Traditional Homework

• Future work:
  - We have built some nice tools for analyzing student interactions with homework in LON-CAPA
  - Now we need to assess traditional homework with these tools, then compare / contrast with our easy, medium, hard homework method
  - Will be looking at data sets from MSU, UGA, and MIT
Thanks for your time!

- Collaborators

**Mass. Institute of Tech.**
- David E. Pritchard
- Analia Barrantes
- Yoav Bergner
- Saif Rayyan

**George Washington Univ.**
- Raluca Teodorescu
- MSU / Sabbatical at MIT
- Gerd Kortemeyer
- Stefan Dröschler

**Brown University**
- Carie Cardamone

**University of Wisc. - Platteville**
- Andrew Pawl

- Free-online mechanics course!!!  Enrollment starts now!!!

  - relate.mit.edu/physicscourse