Developing a Useful Instrument to Assess Student Problem Solving

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Problem Solving Measure

- Problem solving is one of the primary teaching goals, teaching tools, and evaluation techniques of physics courses.

- Issues:
  - There is no standard way to evaluate problem solving that is valid, reliable, and easy to use.
  - A single numerical score gives an inadequate description of a student’s skill at solving problems.

- A more detailed and meaningful measure of problem solving would be useful for both research and instruction.

- How do we measure a complex skill such as problem solving?
What is *problem solving*?

- “*Problem solving* is the process of moving toward a goal when the path to that goal is uncertain” (Martinez, 1998, p. 605)

- What is a *problem* for one person might not be a problem for another person.

- Problem solving involves decision-making. If the steps to reach a solution are immediately known, this is an *exercise* for the solver.

Problem Solving Process

1. Identify & define the problem
2. Analyze the situation
3. Generate possible solutions/approaches
4. Select approach & devise a plan
5. Carry out the plan
6. Evaluate the solution

**Instrument at a glance (Rubric)**

<table>
<thead>
<tr>
<th>CATEGORY:</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>NA(P)</th>
<th>NA(S)</th>
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<tbody>
<tr>
<td>Useful Description</td>
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<td>Logical Progression</td>
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**Want**
- *Minimum* number of categories that include relevant aspects of problem solving
- *Minimum* number of scores that give enough information to improve instruction
- *Minimum* training to use
# Rubric Scores (in general)

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<tr>
<th></th>
<th>5</th>
<th>4</th>
<th>3</th>
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<tbody>
<tr>
<td></td>
<td>Complete &amp; appropriate</td>
<td>Minor omissions or errors</td>
<td>Parts missing and/or contain errors</td>
<td>Most missing and/or contain errors</td>
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<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>0</th>
<th>NA Prob</th>
<th>NA Solver</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>All inappropriate</td>
<td>No evidence / missing</td>
<td>Not necessary for this problem</td>
<td>Not necessary for this solver</td>
</tr>
</tbody>
</table>
A block of mass $m = 2\ \text{kg}$ slides down a frictionless ramp of height $h = 2\ \text{m}$. Use conservation of energy to determine the speed of the block at the bottom of the ramp.
Range of detail in solutions

Useful Description: unnecessary for this solver NA(S)
Developing the Rubric

- **Draft instrument** (based on lit. & past research)
  - Write draft → test out → revise………….x 8

- **Preliminary testing**
  - Distinguish between instructor & student solutions? YES!
  - Score agreement between two raters - good

- **Pilot testing**
  - Graduate students used rubric before & after brief training
  - Results:
    - confusion about NA, influenced by grading experience, multi-part problems difficult to score, score agreement improved slightly with training

- **Revised pilot + Field testing**
  - Revise training materials and re-pilot with graduate students and/or faculty
  - Collect & score exam copies for semester
Work in Progress!

Materials on the Web:

http://groups.physics.umn.edu/physed
(Click on Jennifer Docktor)

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ADDITIONAL SLIDES
References


http://groups.physics.umn.edu/physed
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Rubric Categories (based on research literature)

- **Useful Description**
  - organize information from the problem statement symbolically, visually, and/or in writing.

- **Physics Approach**
  - select appropriate physics concepts and principles to use

- **Specific Application of Physics**
  - apply physics approach to the specific conditions in problem

- **Mathematical Procedures**
  - follow appropriate & correct math rules/procedures

- **Logical Progression**
  - (overall) solution progresses logically; it is coherent, focused toward a goal, and consistent

*Note: 4 of the 5 categories are qualitative*
Problem Solving Process (Physics)

Understand / Describe the Problem

- Redescribe information from the problem statement (pictures, words)
- Introduce symbolic notation & identify target quantity
- Identify key concepts

Devise a Plan

- Use your knowledge of concepts to relate target to known information

Carry Out the Plan

- Execute math procedures to isolate target quantity (symbols, then numbers)
- Monitor progress

Look Back

- Check answer (units, reasonableness, limiting or extreme cases)

Polya (1957); F. Reif & J. Heller (1982, 1984)
Expert-novice characteristics

Inexperienced or “novice” problem solvers:
- Little representation (jump to equations)
- Inefficient approaches (formula-seeking, solution pattern matching) based on objects in the problem
- Do not evaluate solution

Experienced or “expert” problem solvers:
- Low-detail overview of the problem before equations
  - qualitative analysis
- Principle-based approaches
- Evaluate their solution
