Developing a Useful Instrument to Assess Student Problem Solving

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Problem Solving

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

- The goal is to develop a robust instrument to assess students’ written solutions to physics problems, and obtain evidence for reliability and validity.

- The instrument should be general
  - not specific to instructor practices or techniques
  - applicable to a range of problem topics and types

- This talk describes a test of the utility of the rubric
  - The rubric gives useful information to focus instruction
  - The rubric gives information to improve problem construction
### Instrument at a glance (Rubric)

<table>
<thead>
<tr>
<th>CATEGORY: (based on literature)</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>Physics Approach</td>
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<td>Specific Application</td>
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<td>Math Procedures</td>
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<td>Logical Progression</td>
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**SCORE**

- **Minimum number of categories that include relevant aspects of problem solving**
- **Minimum number of scores that give enough information to improve instruction**
# Rubric Scores (in general)

<table>
<thead>
<tr>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
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<tbody>
<tr>
<td>Complete &amp; appropriate</td>
<td>Minor omission or errors</td>
<td>Parts missing and/or contain errors</td>
<td>Most missing and/or contain errors</td>
<td>All inappropriate</td>
<td>No evidence of category</td>
</tr>
</tbody>
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## NOT APPLICABLE (NA):

<table>
<thead>
<tr>
<th>NA - Problem</th>
<th>NA - Solver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not necessary for this problem <em>(i.e. visualization or physics principles given)</em></td>
<td>Not necessary for this solver <em>(i.e. able to solve without explicit statement)</em></td>
</tr>
</tbody>
</table>
4 Tests during the semester

Problems graded in the usual way by teaching assistants

After they were graded, I used the rubric to evaluate 8 problems spaced throughout the semester

Approximately 150 student solutions per problem
Example Test Questions

A block of mass $m = 3 \text{ kg}$ and a block of unknown mass $M$ are connected by a massless rope over a frictionless pulley, as shown below. The kinetic frictional coefficient between the block $m$ and the inclined plane is $\mu_k = 0.17$. The plane makes an angle $30^\circ$ with horizontal. The acceleration, $a$, of the block $M$ is $1 \text{ m/s}^2$ downward.

(A) Draw free-body diagrams for both masses. [5 points]
(B) Find the tension in the rope. [5 points]
(C) If the block $M$ drops by 0.5 m, how much work, $W$, is done on the block $m$ by the tension in the rope? [15 points]

A block of known mass $m$ and a block of unknown mass $M$ are connected by a massless rope over a frictionless pulley, as shown. The kinetic frictional coefficient between the block $m$ and the inclined plane is $\mu_k$. The acceleration, $a$, of the block $M$ points downward.

(A) If the block $M$ drops by a distance $h$, how much work, $W$, is done on the block $m$ by the tension in the rope? Answer in terms of known quantities. [15 points]
Grader Scores

Numeric, prompted:
Several people received the full number of points, some about half.

Symbolic:
Fewer students could follow through to get the correct answer.

AVERAGE: 15 points

AVERAGE: 16 points
Rubric Scores

- **Useful Description:** Free-body diagram
- **Physics Approach:** Deciding to use Newton’s 2nd Law
- **Specific Application:** Correctly using Newton’s 2nd Law
- **Math Procedures:** solving for target
- **Logical Progression:** clear, focused, consistent

2/15/2009  Jennife
Findings about the Problem Statement

- Both questions exhibited similar problem solving characteristics shown by the rubric.

**However**

- *prompting* appears to mask a student’s inclination to draw a free-body diagram
- the *symbolic* problem statement might interfere with the student’s ability to construct a logical path to a solution
- the *numerical* problem statement might interfere with the student’s ability to correctly apply Newton’s second law

- In addition, the numerical problem statement causes students to manipulate numbers rather than symbols
Findings about the Rubric

- The rubric provides significantly more information than grading that can be used for coaching students
  - Focus instruction on physics, math, clear and logical reasoning processes, etc.

- The rubric provides instructors information about how the problem statement affects students’ problem solving performance
  - Could be used to modify problems
References


http://groups.physics.umn.edu/physed docktor@physics.umn.edu
Additional Slides
Rubric Category Descriptions

- **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
## Problem Characteristics that could Bias Problem Solving

### Description:
- Picture given
- Familiarity of context
- Prompts symbols for quantities
- Prompt procedures (i.e. Draw a FBD)

### Physics:
- Prompts physics
- Cue focuses on a specific objects

### Math:
- Symbolic vs. numeric question
- Mathematics too simple (i.e. one-step problem)
- Excessively lengthy or detailed math
<table>
<thead>
<tr>
<th>USEFUL DESCRIPTION</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>NA(Problem)</th>
<th>NA(Solver)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The description is useful, appropriate, and complete.</td>
<td>The description is useful but contains minor omissions or errors.</td>
<td>Parts of the description are not useful, missing, and/or contain errors.</td>
<td>Most of the description is not useful, missing, and/or contains errors.</td>
<td>The entire description is not useful and/or contains errors.</td>
<td>The solution does not include a description and it is necessary for this problem/solver.</td>
<td>A description is not necessary for this solver.</td>
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<tr>
<td>PHYSICS APPROACH</td>
<td>The physics approach is appropriate and complete.</td>
<td>The physics approach contains minor omissions or errors.</td>
<td>Some concepts and principles of the physics approach are missing and/or inappropriate.</td>
<td>Most of the physics approach is missing and/or inappropriate.</td>
<td>All of the chosen concepts and principles are inappropriate.</td>
<td>The solution does not indicate an approach, and it is necessary for this problem/solver.</td>
<td>An explicit physics approach is not necessary for this solver.</td>
<td></td>
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<tr>
<td>SPECIFIC APPLICATION OF PHYSICS</td>
<td>The specific application of physics is appropriate and complete.</td>
<td>The specific application of physics contains minor omissions or errors.</td>
<td>Parts of the specific application of physics are missing and/or contain errors.</td>
<td>Most of the specific application of physics is inappropriate and/or contains errors.</td>
<td>The entire specific application is inappropriate and/or contains errors.</td>
<td>The solution does not indicate an application of physics and it is necessary.</td>
<td>Specific application of physics is not necessary for this solver.</td>
<td></td>
</tr>
<tr>
<td>MATHEMATICAL PROCEDURES</td>
<td>The mathematical procedures are appropriate and complete.</td>
<td>Appropriate mathematical procedures are used with minor omissions or errors.</td>
<td>Parts of the mathematical procedures are missing and/or contain errors.</td>
<td>Most of the mathematical procedures are missing and/or contain errors.</td>
<td>All mathematical procedures are inappropriate and/or contain errors.</td>
<td>There is no evidence of mathematical procedures, and they are necessary.</td>
<td>Mathematical procedures are not necessary for this solver.</td>
<td></td>
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<tr>
<td>LOGICAL PROGRESSION</td>
<td>The entire problem solution is clear, focused, and logically connected.</td>
<td>The solution is clear and focused with minor inconsistencies</td>
<td>Parts of the solution are unclear, unfocused, and/or inconsistent.</td>
<td>Most of the solution parts are unclear, unfocused, and/or inconsistent.</td>
<td>The entire solution is unclear, unfocused, and/or inconsistent.</td>
<td>There is no evidence of logical progression, and it is necessary.</td>
<td>Logical progression is not necessary for this problem. (i.e., one-step)</td>
<td></td>
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<tr>
<td>2/15/2009 Jennifer Docktor, University of Minnesota</td>
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