Robust Assessment Instrument for Student Problem Solving

Jennifer L. Docktor, Kenneth Heller, Patricia Heller, Tom Thaden-Koch, Jun Li, Jay Dornfeld

University of Minnesota
http://groups.physics.umn.edu/physed/

Physics Problem Solving Rubric:

<table>
<thead>
<tr>
<th>Physics Approach</th>
<th>Usefulness Description</th>
<th>Specific Application of Physics</th>
<th>Mathematical Procedures</th>
<th>Logical Progression</th>
<th>Your Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>NA (Prob)</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>NA (Solve)</td>
</tr>
</tbody>
</table>

**Motivation:**
Problem solving is an important aspect of physics education. Testing whether it is improved by instruction requires an assessment instrument. This instrument must reflect the complex nature of problem solving yet be simple enough to map onto educational practice. It must also be general enough to be independent of any particular pedagogy, and simple enough so any instructor can use it.

**Goal:**
Design a robust instrument to evaluate written solutions to physics problems, for use in physics education research and instruction.

The instrument must satisfy criteria for:
- **validity** – the instrument measures what it claims to measure (face, content, construct, criterion-related)
- **reliability** – stability of scores over times and across different raters (intrarater and interrater)

**Specific Application of Physics**
The solution includes an appropriate and complete application of principles to the specific conditions in this problem. One relationship or condition is missing or confusing, or an error is made in the application of physics to this problem. More than one relationship or condition is missing or confusing, or an error is made in the application of physics to this problem. The application of physics to this problem is not specified. Specific application of physics is not necessary for this problem (i.e. basic principles are sufficient). Specific application of physics is not necessary for this problem as indicated by the overall solution process.

**Mathematical Procedures**
Suitable mathematical procedures are used that include or support the statements and/or the answer to the problem. Suitable mathematical procedures are used with minor (or no) errors. Almost all mathematical procedures are used with major errors. Mathematical procedures are not necessary for this problem, or the solution is not necessarily a very small part of the solution. Mathematical procedures are not necessary for this problem as indicated by the overall solution process.

**Logical Progression**
The solution is focused and organized with minor incoherence and/or extraneous steps that don’t guide the solution. The solution is focused and organized with multiple incoherence and/or extraneous steps that don’t guide the solution. There are multiple incoherence and/or extraneous steps that don’t guide the solution. Nothing written can be interpreted as logical progression. Logical progression is not necessary for this problem as indicated by the overall solution process.

**Example Student Solution:**
To raise money for a University scholarship fund, the new IT dean has volunteered to bungee jump from a crane. To add some interest, the jump will be made from 42 m above a pool of water. A 30 m bungee cord would be attached to the dean. First you must convince the dean that your plan is safe for a person of his mass, 70 kg.

**Test the Rubric:**
- **Instructor**
  - **Professor Solutions to Textbook Problems**
    - Calculus-Based Mechanics Homework
    - Algebra-Based Mechanics Final Exam
  - **Student Solutions**
    - 5 Problems x 20 Student Solutions

**Interrater Reliability:**
Independent scoring of student solutions by a graduate student PER researcher and a high school physics teacher:

- **Rubric discriminates between instructor and student solutions. (validity)**
- **Rubric does not depend on the amount of writing. (validity)**
- **Independent interrater reliability is good, and would improve with training.**
- **More work to be done!**