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Robust Assessment Instrument for Student Problem Solving

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More Details ***Poster: PST4-25 5-6 p.m.***

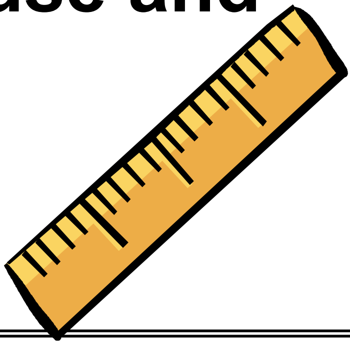
Problem Solving

- Problem solving (qualitative and quantitative) is one of the primary teaching goals, teaching tools, and evaluation techniques of physics courses.
- There is no standard way to evaluate problem solving that is valid, reliable, and easy to use.
  - student interviews are time consuming & difficult
  - existing rubrics are time consuming & difficult
- Need an assessment instrument for both research and instruction.
- Must consider issues of validity and reliability
  - *Validity* is the degree to which the score interpretation is supported by empirical evidence & theoretical backing.
  - *Reliability* is the stability of scores across multiple raters.

Project Goals

- Develop a robust instrument to assess students' written solutions to physics problems, and determine reliability and validity.
- The instrument should be general
  - not specific to instructor practices or techniques
  - applicable to a range of problem topics and types
- Develop materials for appropriate use and training.

Not the most precise evaluation of problem solving ….looking for a ruler, not an electron microscope!



Instrument at a glance (Rubric)

SCORE ←

CATEGORY: *(based on literature)*	4	3	2	1	0	NA (P)	NA (S)
Useful Description							
Physics Approach							
Specific Application							
Math Procedures							
Logical Progression							

Initial Version

Note: 4 of the 5 categories are qualitative

Want

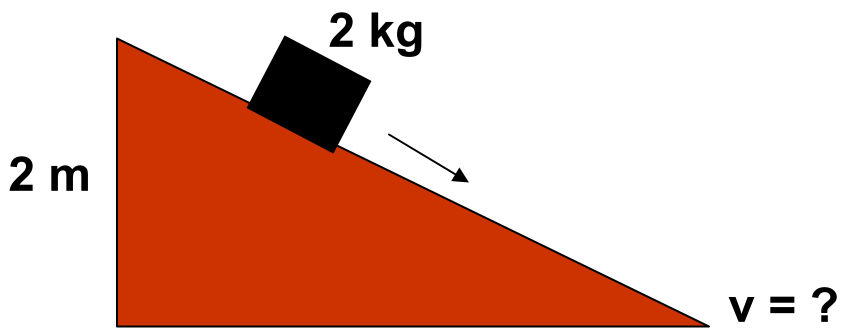
- ***Minimum** number of categories that include relevant aspects of problem solving*
- ***Minimum** number of scores that give enough information to improve instruction*
- ***Minimum** training to use*

Rubric Scores (in general)

4	3	2	1
Complete & appropriate	Minor omissions or errors	Parts missing and/or contain errors	Most missing and/or contain errors

0	NA Prob	NA Solver
All incorrect or all missing	Not necessary for this problem	Not necessary for this solver

Example of NA (Problem)



Useful Description:
visual & symbolic representation given

A block of mass *m* = 2 kg slides down a frictionless ramp of height *h* = 2 m. Use conservation of energy to determine the speed of the block at the bottom of the ramp.

Physics Approach:
physics concept or principle stated in problem

Pilot Study Description

- Eight experienced graduate student teaching assistants used the initial rubric to score students' written solutions to final exam problems.
- Four volunteers scored mechanics problem solutions & four scored E&M solutions.
- After 8 solutions were scored, training consisted of example scores and rationale for the first 3 solutions. Then 5 solutions were re-scored, and 5 new solutions were scored.
- They provided written feedback on the rubric categories and scoring process.

All Training in Writing: Example

CATEGORY **SCORE** **RATIONALE**

Training includes the actual student solution

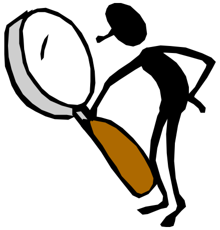
Student # 2	Score	Notes
Physics Approach	4	Kinematics is appropriate before spring stretch; conservation of energy approach is explicitly stated
Useful Description	1	missing variable definitions; used "h" and "x" w/multiple values; picture is missing variable labels and height/stretch for part b)
Specific App. of Physics	2	Does not identify "initial" and "final" energy terms; part b) is missing a mgh term; used incorrect stretch value in part b)
Mathematical Procedures	2	Important algebraic mistakes when solving for k (did not need to take square root and incorrectly drops root from k)
Logical Organization	2	Should have checked units for k equation in part a) – might have caught inconsistencies;

Inter-rater Agreement

	BEFORE TRAINING		AFTER TRAINING	
	Perfect Agreement	Agreement Within One	Perfect Agreement	Agreement Within One
Useful Description	38%	75%	38%	80%
Physics Approach	37%	82%	47%	90%
Specific Application	45%	95%	48%	93%
Math Procedures	20%	63%	39%	76%
Logical Progression	28%	70%	50%	88%
OVERALL	34%	77%	44%	85%
Weighted kappa	*0.27±0.03*		*0.42±0.03*	

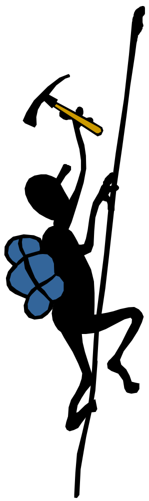
Fair agreement → ***Moderate agreement***

Findings



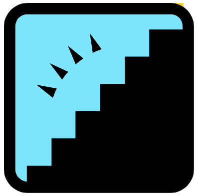
- **NA categories and the score zero were largely ignored, even after training.**
  - ***"[the training] Would be more helpful if it covered the 0-4 range for each category…No example of NA(P) means I still don't know how/if to apply it."***
- **Graduate student raters were influenced by their traditional grading experiences.**
  - ***"I don't think credit should be given for a clear, focused, consistent solution with correct math that uses a totally wrong physics approach"***
- **The rubric works best for problems without multiple parts.**
  - ***"[difficult] Giving one value for the score when there were different parts to the problem."***

Rubric Revisions



- The wording was made more parallel in every category.
- The scoring scale was increased by 1. The former "0" score was separated into two, one for all inappropriate and one for all missing
- The NA(Problem) and NA(Solver) categories were included more prominently in the rubric.
- The Useful Description category was moved before Physics Approach.
- Logical organization was renamed logical progression

Next Steps



- **Expand training** materials to include a description of the rubric's purpose and a greater range of score examples, especially for NA scores.
- **Re-test** the revised rubric and training materials with graduate students and faculty to assess reliability.
- **Compare scores** from the rubric with another measure of problem solving (validity measures).

References

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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

Range of detail in solutions

$\leftarrow F_e$ · $qE = F_e = ma$

$$E = \frac{ma}{q} \qquad v_f^2 = v_i^2 + 2a\Delta x \quad (v_i = 0)$$

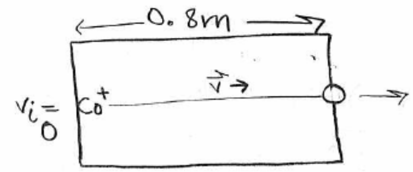
$$a = \frac{v_f^2}{2\Delta x}$$

$$E = \frac{m v_f^2}{q\, 2\Delta x} \equiv \frac{[kg]\cdot[m]^2}{[s]^2\,[C]\,[m]} = \frac{N}{C} \qquad \frac{V}{m} = \frac{N}{C} \qquad N = \frac{kg\, m}{s^2}$$

units ok ✓

$$\boxed{E = 1162\ \frac{N}{C}}$$

Useful Description: unnecessary for this solver NA(S)



$s = 0.8$ m
$v_f = 8 \times 10^4$ m/s
$m_{co} = 28$ g/mol

Question: Calculate the direction and magnitude of the electric field needed so that Co^+ ions created at rest at one end will have a speed of 8×10^4 m/s when they exit the other side

Approach: Use conservation of energy

system: Co^+ particle

initial time: right as Co^+ enters the box

final time: right as Co^+ leaves the box

$E_i = 0 \qquad v_i = 0$

$E_f = \frac{1}{2}mv^2 \qquad E_{in}$ = electric potential energy, $E_{out} = 0$

Electric potential energy $= \Delta V q = -q\int \vec{E}\cdot ds$

because the electric field is constant

$PE_e = -qE\int ds$

$PE_e = -qEs$ ← just want magnitude so can leave negative sign off

$E_f - E_i = E_{in} - E_{out}$ check units

$\frac{1}{2}mv^2 = qEs \qquad \frac{1}{2}mv^2 \rightarrow$ energy units

$$E = \frac{\frac{1}{2}mv^2}{qs} \qquad \frac{E\cdot s}{V\cdot C},\ q = \text{energy units}$$

units ok ✓

$$|E| = \frac{\frac{1}{2}mv^2}{qs} = \qquad J = N\cdot m$$

$CO - e^- = CO^+$

$.028\ kg - 9.11\times10^{-31}\ kg = 0.028\ kg$

$$|E| = \frac{\frac{1}{2}(0.028\ kg)(8\times10^4\ m/s)^2}{(1.602\times10^{-19}\ C)(0.8\ m)}$$

$$\boxed{|E| = 6.99\times10^{26}\ N/C}$$