Developing a Useful Instrument to Assess Student Problem Solving

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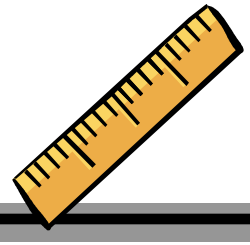
Problem Solving



- 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)

SCORE

CATEGORY: ***(based on literature)***	5	4	3	2	1	0	NA (P)	NA (S)
Useful Description								
Physics Approach								
Specific Application								
Math Procedures								
Logical Progression								

Want

- ***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)

5	4	3	2	1	0
Complete & appro-priate	Minor omission or errors	Parts missing and/or contain errors	Most missing and/or contain errors	All inappro-priate	No evidence of category

NOT APPLICABLE (NA):

NA - Problem	NA - Solver
Not necessary for this problem *(i.e. visualization or physics principles given)*	Not necessary for this solver *(i.e. able to solve without explicit statement)*

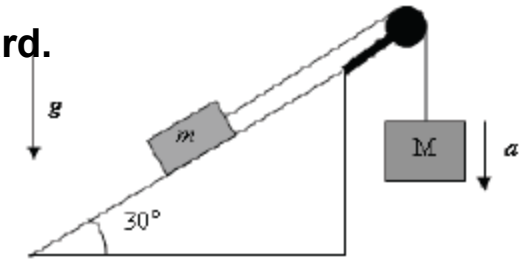
Calculus-Based Course for Science & Engineering @ UMN

- 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

NUMERIC

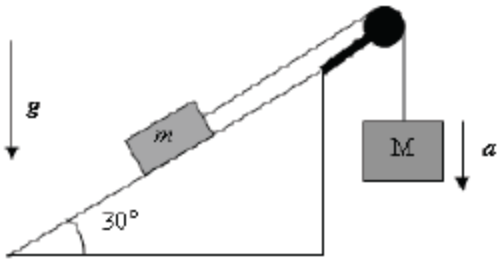
A block of mass m = 3 kg and a block of unknown mass M are connected by a massless rope over a frictionless pulley, as shown below. The kinetic frictional coefficient between the block m and the inclined plane is $\mu_k = 0.17$. The plane makes an angle 30° with horizontal. The acceleration, a, of the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

SYMBOLIC

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 μk. The acceleration, a, of the block M points downward.

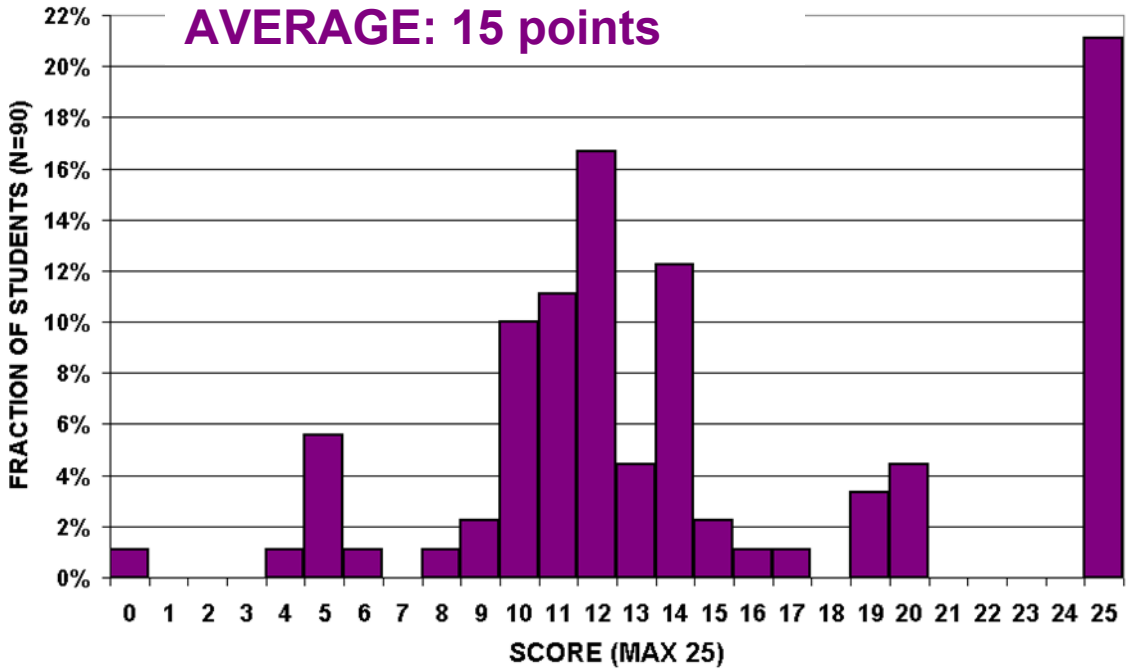


(A) If the block M drops by a distance h, how much work, W, is done on the block m by the tension in the rope? Answer in terms of known quantities. [15 points]

Grader Scores

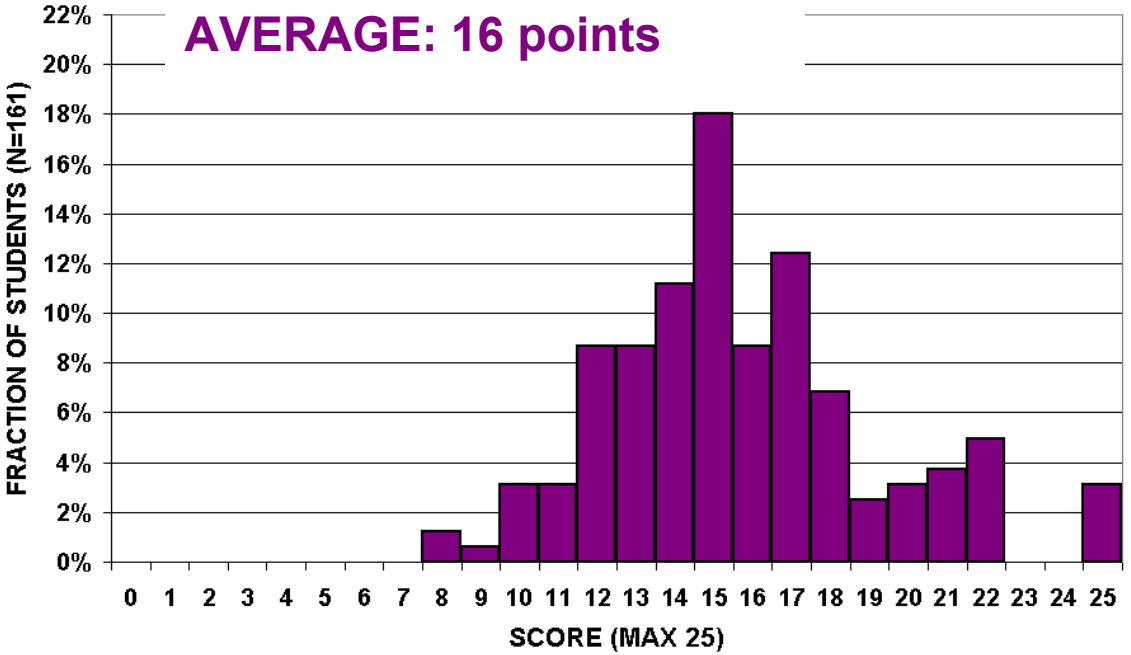
Numeric, prompted:

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



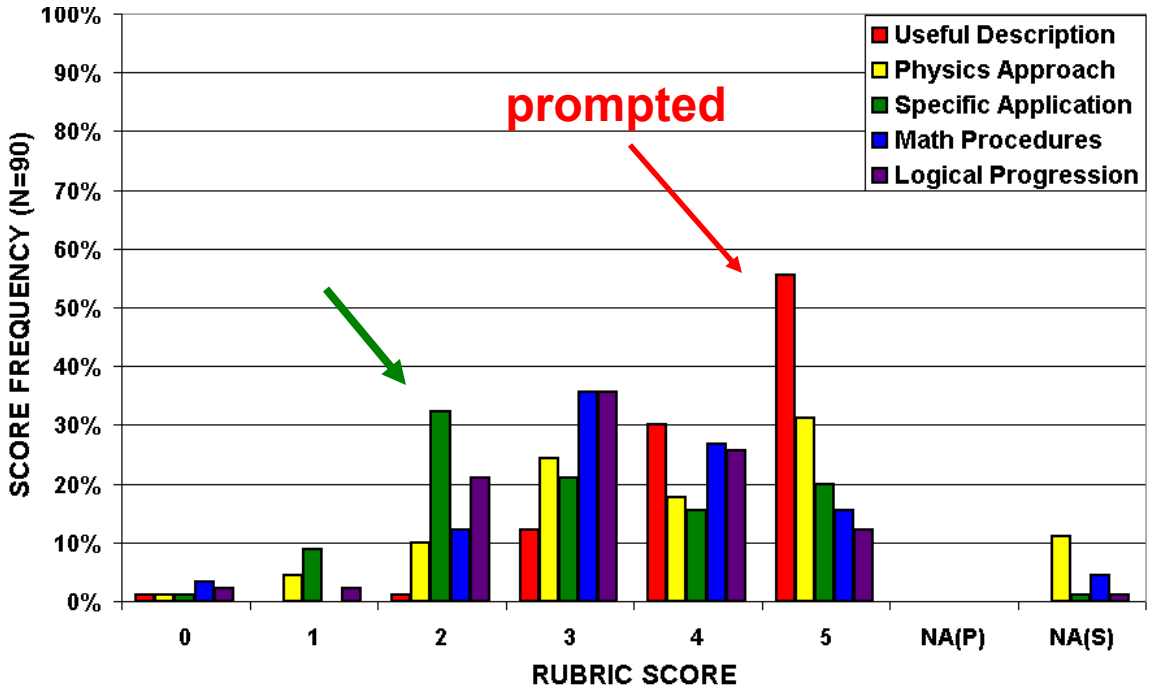
Symbolic:

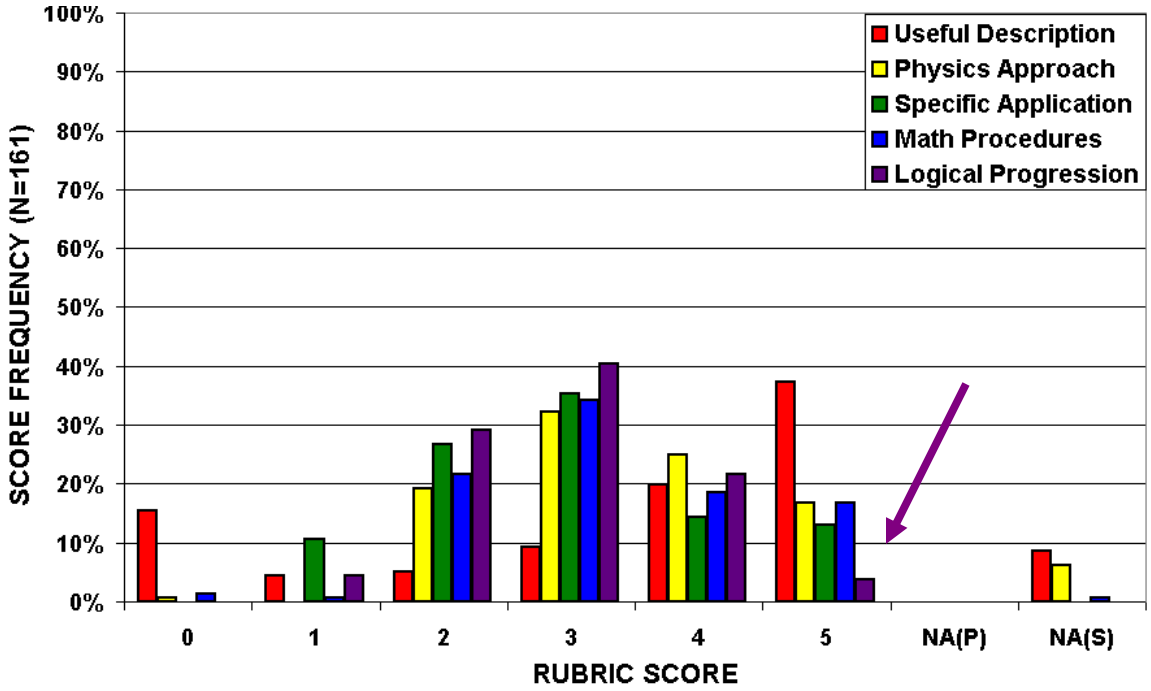
Fewer students could follow through to get the correct answer.



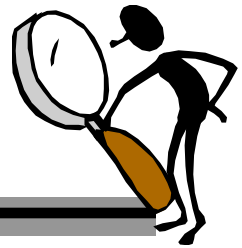
Rubric Scores

- **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





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

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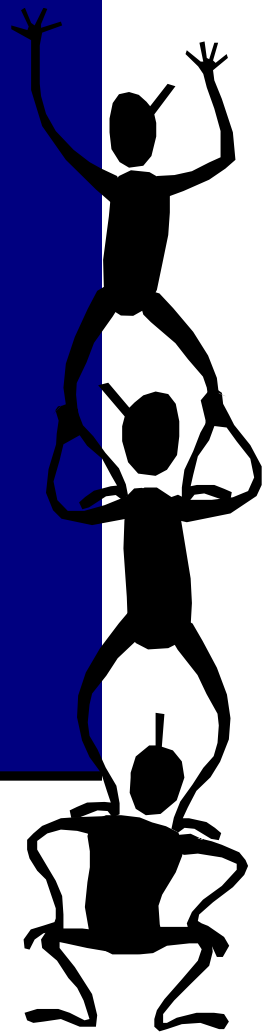

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Additional Slides

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

	5	4	3	2	1	0	NA(Problem)	NA(Solver)
USEFUL DESCRIPTION	The description is useful, appropriate, and complete.	The description is useful but contains minor omissions or errors.	Parts of the description are not useful, missing, and/or contain errors.	Most of the description is not useful, missing, and/or contains errors.	The entire description is not useful and/or contains errors.	The solution does not include a description and it is necessary for this problem /solver.	A description is not necessary for this problem. (i.e., it is given in the problem statement)	A description is not necessary for this solver.
PHYSICS APPROACH	The physics approach is appropriate and complete.	The physics approach contains minor omissions or errors.	Some concepts and principles of the physics approach are missing and/or inappropriate.	Most of the physics approach is missing and/or inappropriate.	All of the chosen concepts and principles are inappropriate.	The solution does not indicate an approach, and it is necessary for this problem/ solver.	An explicit physics approach is not necessary for this problem. (i.e., it is given in the problem)	An explicit physics approach is not necessary for this solver.
SPECIFIC APPLICATION OF PHYSICS	The specific application of physics is appropriate and complete.	The specific application of physics contains minor omissions or errors.	Parts of the specific application of physics are missing and/or contain errors.	Most of the specific application of physics is missing and/or contains errors.	The entire specific application is inappropriate and/or contains errors.	The solution does not indicate an application of physics and it is necessary.	Specific application of physics is not necessary for this problem.	Specific application of physics is not necessary for this solver.
MATHE-MATICAL PROCEDURES	The mathematical procedures are appropriate and complete.	Appropriate mathematical procedures are used with minor omissions or errors.	Parts of the mathematical procedures are missing and/or contain errors.	Most of the mathematical procedures are missing and/or contain errors.	All mathematical procedures are inappropriate and/or contain errors.	There is no evidence of mathematical procedures, and they are necessary.	Mathematical procedures are not necessary for this problem or are very simple.	Mathematical procedures are not necessary for this solver.
LOGICAL PROGRESSION	The entire problem solution is clear, focused, and logically connected.	The solution is clear and focused with minor inconsistencies	Parts of the solution are unclear, unfocused, and/or inconsistent.	Most of the solution parts are unclear, unfocused, and/or inconsistent.	The entire solution is unclear, unfocused, and/or inconsistent.	There is no evidence of logical progression, and it is necessary.	Logical progression is not necessary for this problem. (i.e., one-step)	Logical progression is not necessary for this solver.