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/

Project Description:

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 physics instructor can use it.

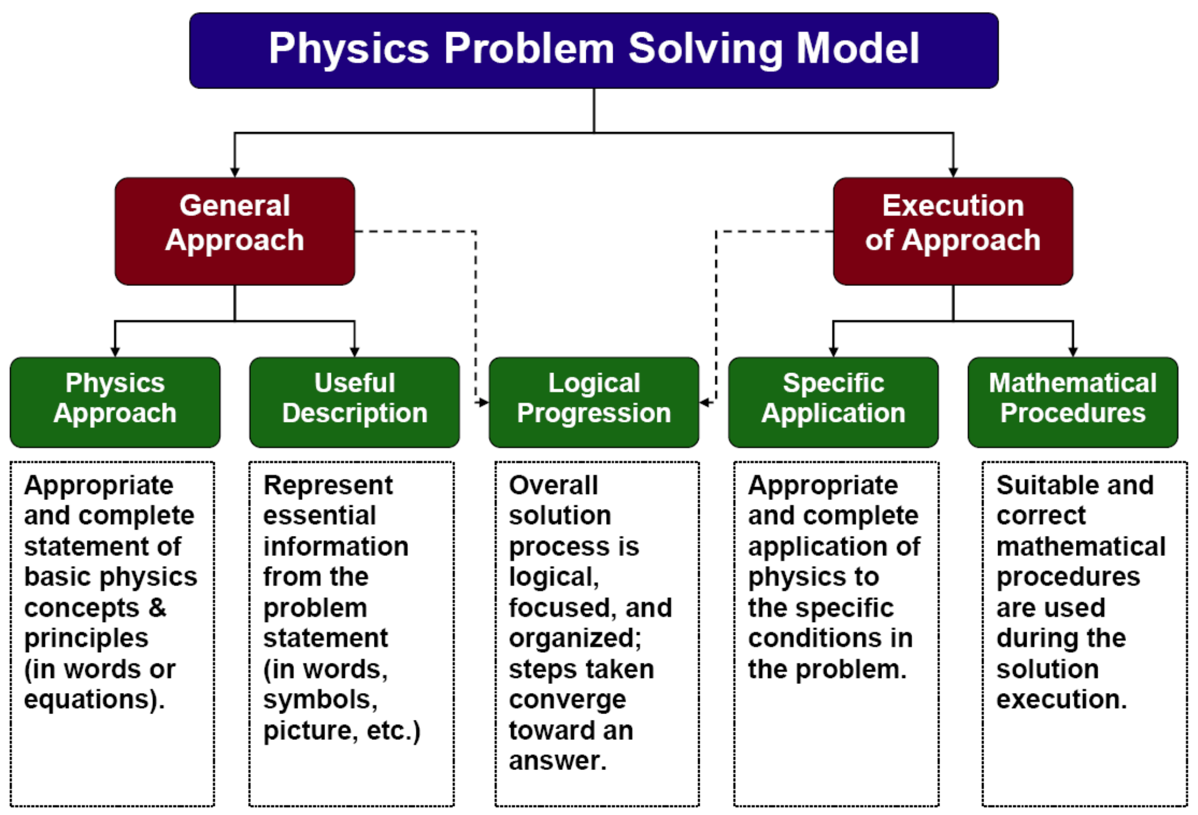
Goal:

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 time and across different raters (intrarater and interrater)*



References:

Blue, J. M. (1997). *Sex differences in physics learning and evaluations in an introductory course.* Unpublished doctoral dissertation, University of Minnesota, Twin Cities.

Bolton, J., Keynes, M., & Ross, S. (1997). Developing students' physics problem-solving skills. *Physics Education, 32*(3), 176-185.

Cohen, L., Manion, L., & Morrison, K. (2000). *Research methods in education* (5th ed.) New York, NY: RoutledgeFalmer.

Foster, T. (2000). *The development of students' problem-solving skills from instruction emphasizing qualitative problem-solving.* Unpublished doctoral dissertation, University of Minnesota, Twin Cities.

Heller, P., Keith, R., & Anderson, S. (1992). Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving. *American Journal of Physics, 60*(7), 627-636.

Reif, F., & Heller, J.I. (1982). Knowledge structure and problem solving in physics. *Educational Psychologist, 17*(2), 102-127.

Saunders, K.P. et al. (2003). Using rubrics to facilitate students' development of problem solving skills. *Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition, Nashville, Tennessee.*

Woods, D.R. (1987). Problem solving in practice. In D. Gabel (Ed.) *What research says to the science teacher: Volume five, problem solving* (pp. 97-121). Washington, D.C.: National Science Teachers Association.

Grant No. 9981043

docktor@physics.umn.edu

Physics Problem Solving Rubric:

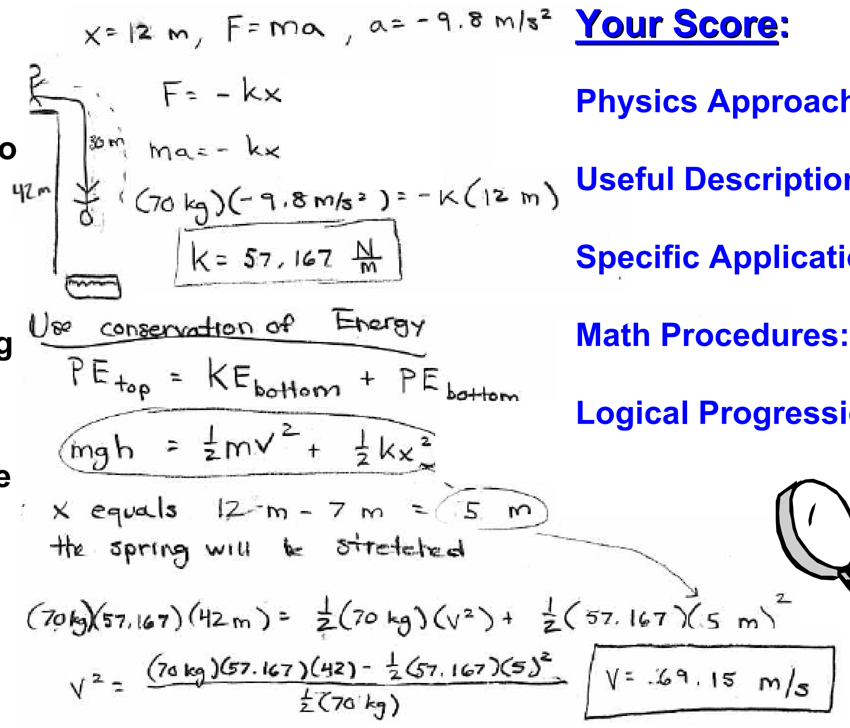
	4	3	2	1	0	NA (Prob)	NA (Solver)
Physics Approach	The solver has explicitly stated an appropriate and complete physics approach.	The overall solution indicates one basic physics concept or principle of the approach is missing or inappropriate.	The overall solution indicates more than one basic physics concept or principle of the approach is missing or inappropriate.	The overall solution indicates a fundamental misunderstanding of physics concepts or principles for the chosen approach.	The solution does not indicate a basic physics approach, and it is necessary for this problem / student.	A physics approach is not necessary for this problem. (i.e., has already been stated in the problem or textbook heading)	An explicit physics approach is not necessary for this solver, as indicated by the overall solution process.
Useful Description	The solution includes an appropriate and useful problem description.	One part of the description is missing or inappropriate.	More than one part of the description is missing or indicates a misinterpretation of the problem statement.	The description indicates a fundamental misunderstanding.	The solution does not include a description, and it is necessary for this problem / student.	A description is not necessary for this problem. (i.e., it has already been given to the solver)	A description is not necessary for this solver, as indicated by the overall solution process.
Specific Application of Physics	The solution indicates an appropriate and complete application of physics to the specific conditions in this problem.	One relationship or condition is missing or indicates an error in the application of physics to this problem.	More than one relationship or condition is missing or indicate errors in the application of physics to this problem.	The application of physics to this problem indicates a fundamental misunderstanding.	The solution does not indicate a specific application of physics and it is necessary for this problem / student.	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 solver, as indicated by the overall solution process.
Mathematical Procedures	Suitable mathematical procedures are used that result in a reasonable answer or the answer is unreasonable and noticed.	Suitable mathematical procedures are used with minor error(s).	Suitable mathematical procedures are used with error(s) or the answer is unreasonable and unnoticed.	Attempted mathematical procedures are inappropriate. (i.e., violate a fundamental rule of arithmetic)	There is no evidence of mathematical procedures in the problem solution and it is necessary for this problem / student.	Mathematical procedures are not necessary for this problem, or constitute a very small part of the solution.	Mathematical procedures are not necessary for this solver, as indicated by the overall solution process.
Logical Progression	The entire problem solution is focused and organized logically. The steps taken might not be linear, but guide the solver toward an answer.	The solution is focused and organized with minor inconsistencies and/or extraneous steps that don't guide the solution.	The solution is focused and organized with multiple inconsistencies and/or extraneous steps that don't guide the solution.	Parts of the solution are focused and organized. There are multiple inconsistencies and/or extraneous steps that don't guide the solution.	Nothing written can be interpreted as logical progression. The entire solution is unorganized and contains obvious logical breaks.	Logical progression is not necessary for this problem or constitutes a very small part of the solution (i.e., one-step problem).	Logical progression is not necessary for this solver, 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. Your plan has the dean stepping off a platform and being in free fall for 30 m before the cord begins to stretch.

a) Determine the spring constant of the bungee cord so that it stretches only 12m, which will just keep the dean out of the water.

b) Using the result of a), find the dean's speed 7m above the water.



Your Score:

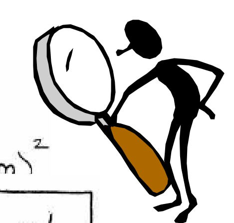
Physics Approach: ___

Useful Description: ___

Specific Application: ___

Math Procedures: ___

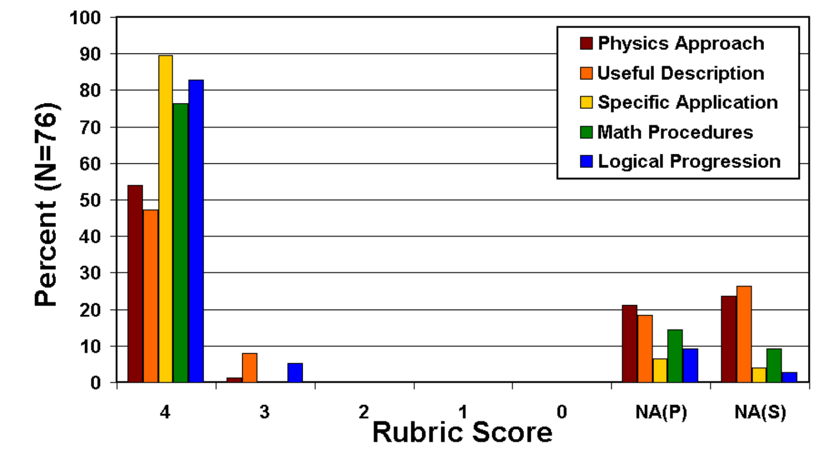
Logical Progression: ___



Testing the Rubric:

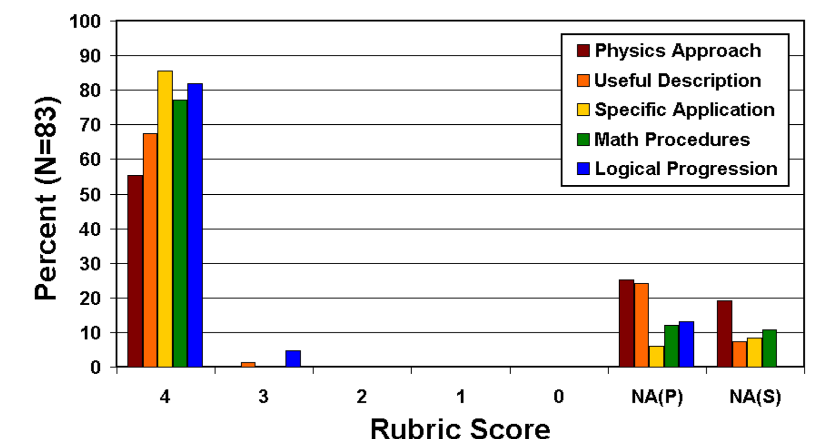
Instructors

Halliday, Resnick, Walker Instructor Solns (38 Chapters x 2 problems each)



Sparse Solutions

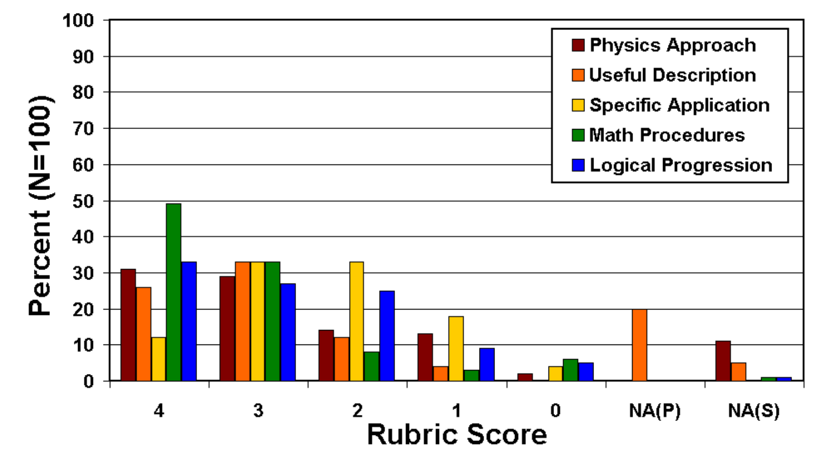
Professor Solutions to Textbook Problems Calculus-Based Mechanics Homework



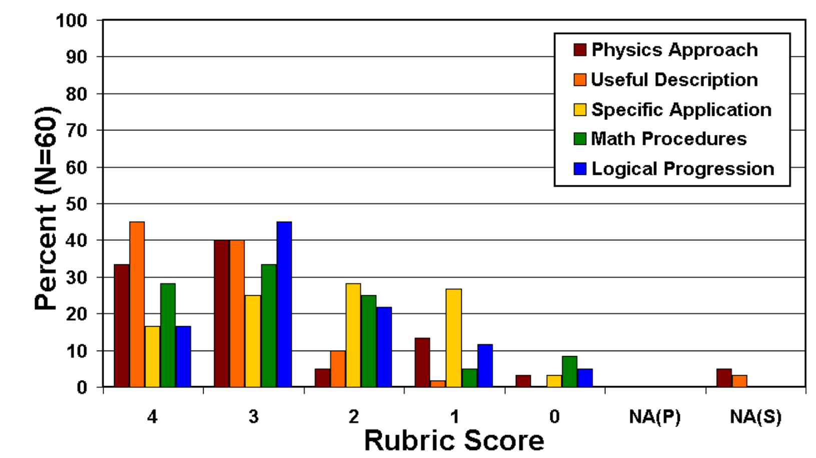
Detailed Solutions

Students

Calculus-Based Mechanics Final Exam 5 Problems x 20 Student Solutions

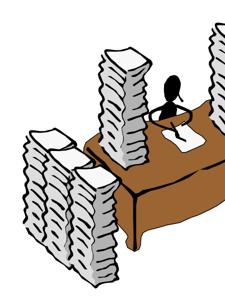


Algebra-Based Mechanics Final Exam 3 Problems x 20 Student Solutions



Interrater Reliability:

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



Category (N=160)	% agree (exact)	% agree (within 1)	Cohen's Kappa
Physics Approach	71.3	97.1	0.62
Useful Description	75.0	99.2	0.63
Specific Application	61.3	96.9	0.48
Math Procedures	65.6	99.4	0.51
Logical Progression	63.1	96.9	0.49
OVERALL	*67.3*	*98.5*	*0.55*

Physics Approach, Useful Description: **Substantial Agreement**

Specific Application, Math Procedures, Logical Progression, Overall: **Moderate Agreement**

A First Look:

- **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!**