Robust Assessment Instrument for Student Problem Solving

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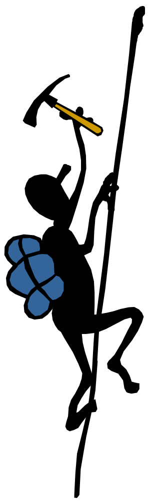
Project Description

Goal:

- **Design a robust instrument to evaluate written solutions to physics problems, for use in physics education research and instruction.**
- **The instrument should be *general* (not specific to instructor practices or technique)**
- **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)*



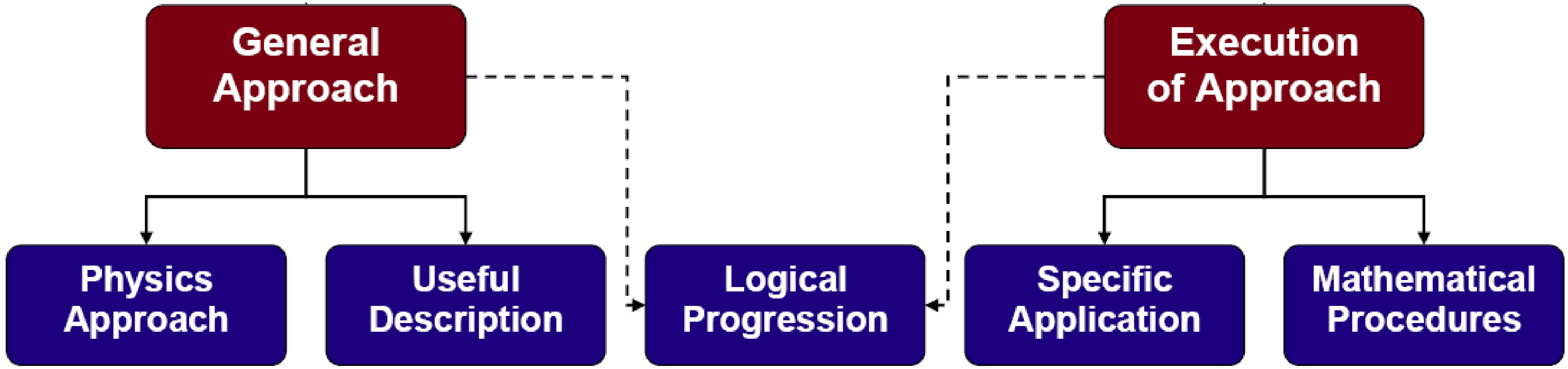
Solution characteristics

Inexperienced problem solvers:

- Little representation (jump quickly to equations)
- Haphazard formula-seeking and solution pattern matching

Experienced problem solvers:

- Low-detail overview of the problem before equations
  - *qualitative analysis* aids in selecting relevant physics principles
- Correctly apply physics to specific conditions in problem
- Some processes are automatic / implicit



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Rubric Scores (in general)

4	3	2	1	0
Complete & appropriate	Minor errors (one part missing or inappropriate)	More than one error	Fundamental misunder-standing	Is not expressed

NA(Problem)	NA(Solver)
Not necessary for this problem	Explicit statement not necessary for this solver

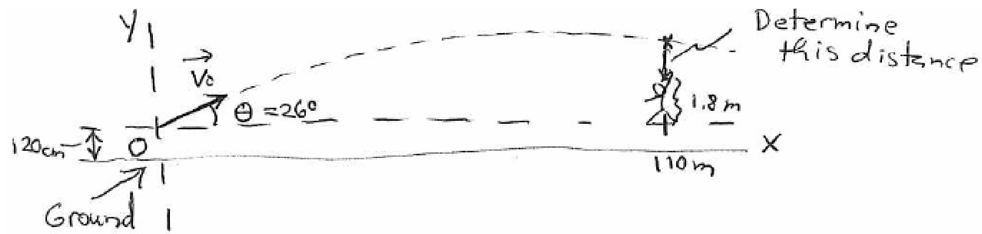
One Category: Logical Progression

4	3	2	1	0
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 inconsis-tencies and/or extraneous steps that don't guide the solution.	The solution is focused and organized with multiple inconsis-tencies and/or extraneous steps that don't guide the solution.	Parts of the solution are focused and organized. There are multiple inconsis-tencies 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.

A batter in a baseball game hits the ball over the center field fence for a home run. The ball is struck 120 cm above the ground with an initial velocity of 40 m/s at an angle of 26º above the horizontal. A player on the other team makes a great effort to catch the ball, but it flies well above him. At a point just in front of the center field fence, 110 m from where the ball was hit, he leaps straight upward so that his glove reaches a point 3.0 m above the ground. How far above his glove does the ball pass?

Example Instructor Solution

Physics Approach:	NA(S)
Useful Description:	4
Specific Application:	4
Math Procedures:	4
Logical Progression:	4



Ball is hit at $t_0 = 0\,s$ $x_0 = 0\,m$ $y_0 = 0\,m$

with initial velocity

$\vec{V_0}$: $V_0 = 40\,\frac{m}{s}$ $\theta = 26°$

$V_{0x} = V_0 \cos\theta = 35.95\,\frac{m}{s}$ $V_{0y} = V_0 \sin\theta = 17.53\,\frac{m}{s}$

It passes over the fielder at

$t = ?$ $x = 110\,m$ $y = ?$

The target is $y - 1.8\,m$.

$x = V_{0x} t$ $y = V_{0y} t - \frac{1}{2} g t^2$

$t = \frac{x}{V_{0x}}$ $y = V_{0y} \frac{x}{V_{0x}} - \frac{1}{2} g \left(\frac{x}{V_{0x}}\right)^2$

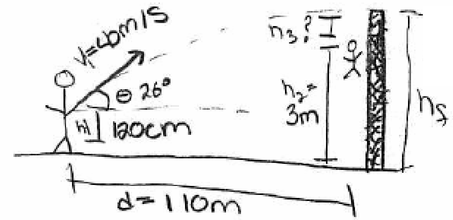
$t = \frac{110\,m}{35.95\,\frac{m}{s}}$ $y = 17.53\,\frac{m}{s}\,\frac{110\,m}{35.95\,\frac{m}{s}} - \frac{1}{2}(9.8\,\frac{m}{s^2})\left(\frac{110\,m}{35.95\,\frac{m}{s}}\right)^2$

$t = 3.060\,s$ $y = 7.76\,m$

Height above glove is $7.76\,m - 1.8\,m = \underline{6.0\,m}$

A batter in a baseball game hits the ball over the center field fence for a home run. The ball is struck 120 cm above the ground with an initial velocity of 40 m/s at an angle of 26º above the horizontal. A player on the other team makes a great effort to catch the ball, but it flies well above him. At a point just in front of the center field fence, 110 m from where the ball was hit, he leaps straight upward so that his glove reaches a point 3.0 m above the ground. How far above his glove does the ball pass?

Example Student Solution



Q: How far above his glove does the ball pass?

$V_i = 40 m/s$ $h_1 = 120cm$

$\theta = 26°$ $h_2 = 3m$ $d = 110m$

$h_f = ?$ $h_3 = ?$

$V^2 - V_0^2 = 2a(x - x_0)$

① $h_3 = h_f - h_2$

$V^2 - (40m/s)^2 = 2(9.8m/s^2)(110m - 0m)$

$V^2 = -2156 + (40m/s)^2$

$\sqrt{V^2} = \sqrt{556}$ $V_f = 23.58m/s$

$V_i^2 - V_0^2 = 2a(y - y_0)$

$(23.58m/s)^2 - (40m/s)^2 = 2(9.8)(y - 1.2)$

$556m/s - 1600m/s = 19.6(y - 1.2m)$

$53.27 = y - 1.2m$

$y = 54.47m = h_f$

$V = V_0 + at$

$23.58m/s = 40m/s + (9.8)t$

$t = 1.67sec$

$h_3 = h_f - h_2$

$h_3 = 54.47m - 3m$

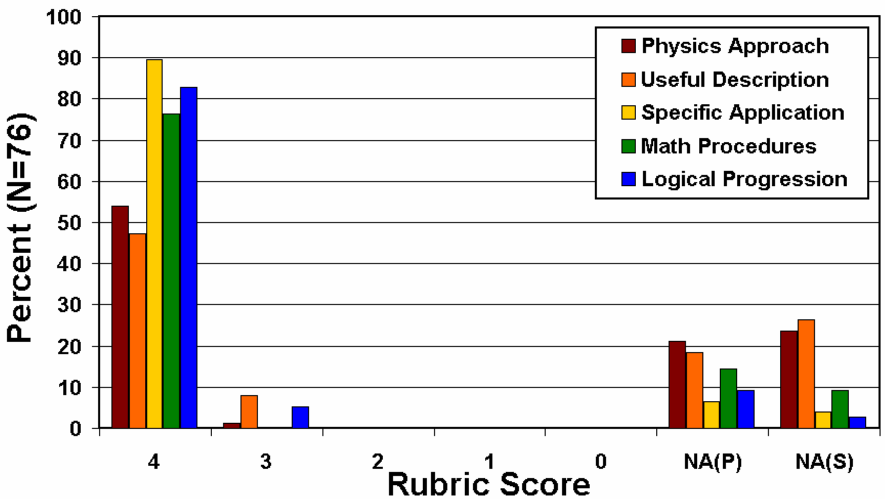
$h_3 = 51.47m$

This is not a logical answer! its too large!

Physics Approach:	1
Useful Description:	3
Specific Application:	1
Math Procedures:	3
Logical Progression:	3

Instructors

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



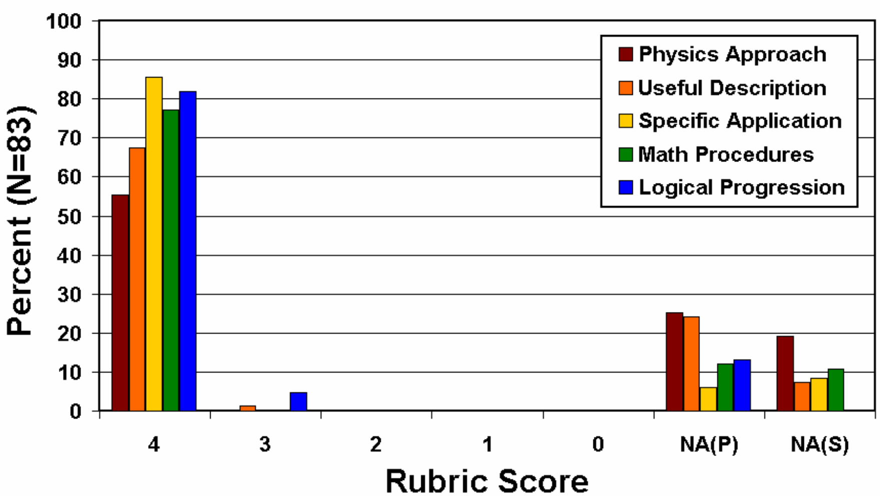
Halliday, Resnick, & Walker

5th Edition of Text (1997)

Instructor Solution CD-ROM

*Solutions sparse

Professor Solutions to Textbook Problems
Calculus-Based Mechanics Homework



Calc-Based Mechanics Professor

Solutions to Textbook Problems

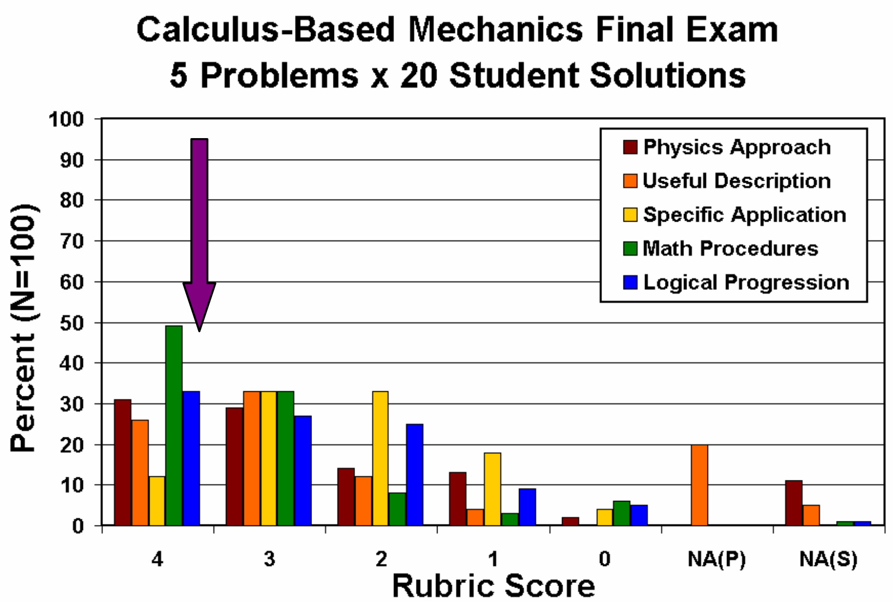
Homework, Spring 2007

*Solutions more detailed

Students

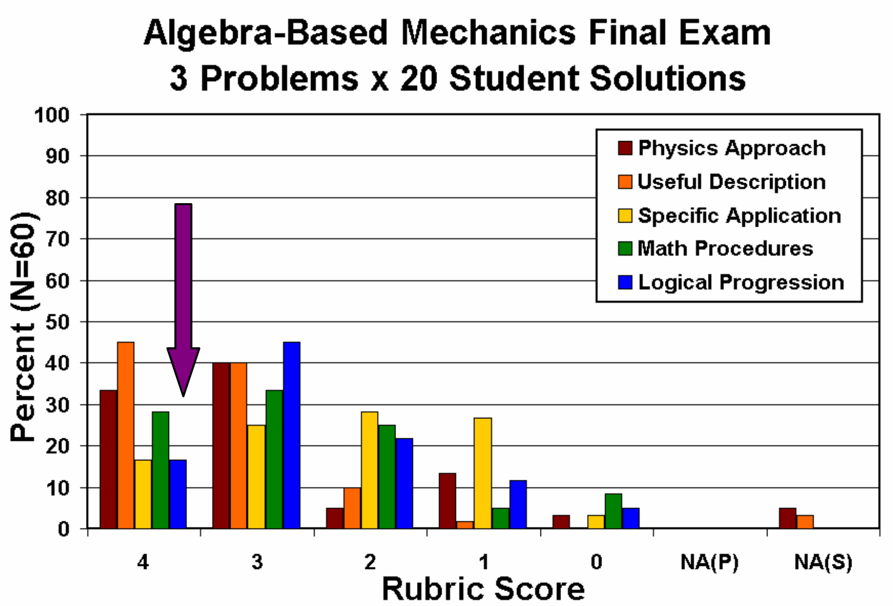
Data from Fall 2004

- One class of 241 students
- (788 total calc-based students)
- 60% freshmen, 25% sophomore, 7% junior, 4 % senior
- 70% science, math, engineering



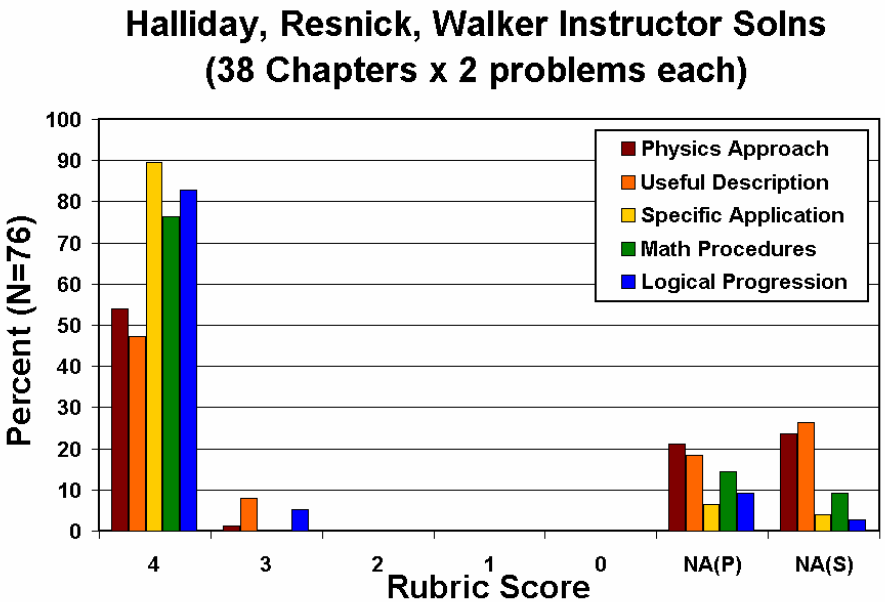
Data from Fall 2004

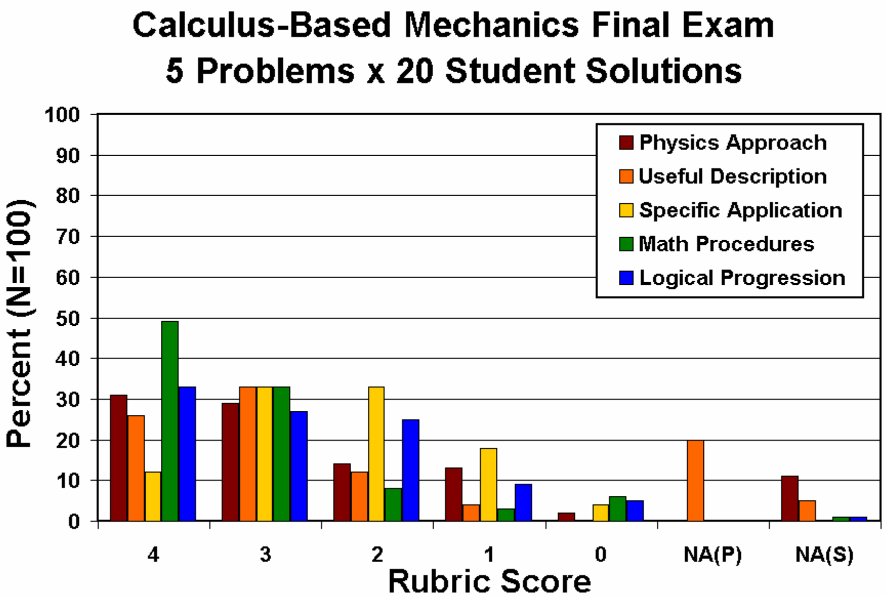
- One class of 167 students
- (258 total alg-based students)
- 15% freshmen, 50% soph, 15% junior, 10% senior
- 62% pre-architecture, kinesiology, ag/animal science

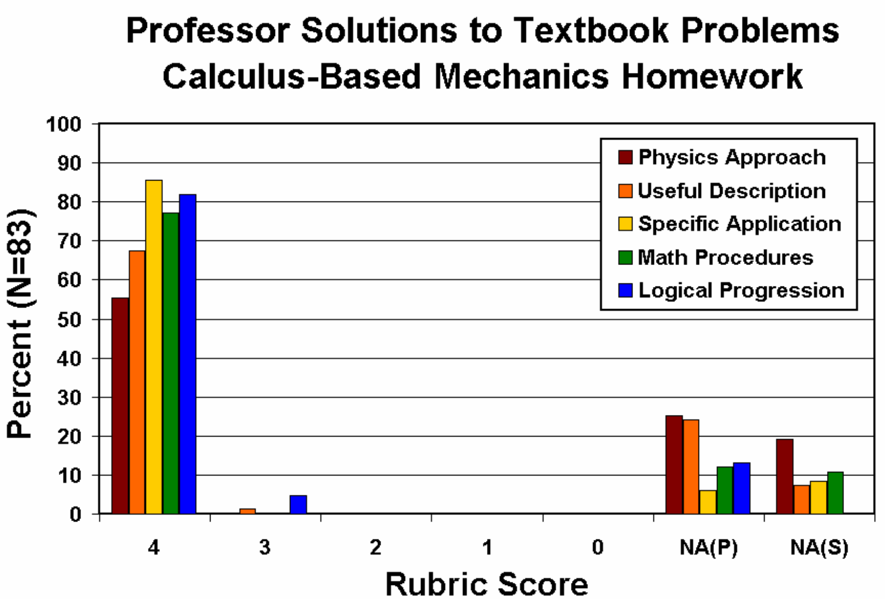


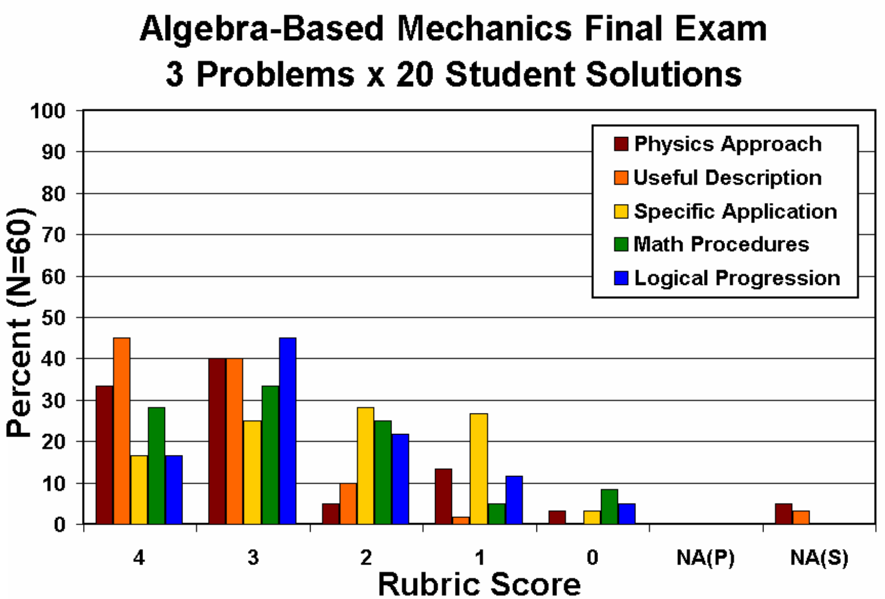
Instructors

Students









Inter-rater Reliability

Independent scoring of student solutions by a PER graduate student and a high school physics teacher (N=160)

Category	% 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*

Kappa:

<0 No agreement

0-0.19 Poor

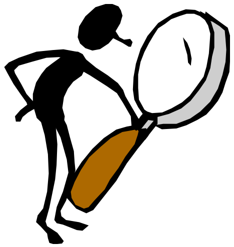
0.20-0.39 Fair

0.40-0.59 Moderate

0.60-0.79 Substantial

0.80-1 Almost perfect

A First Look



- The rubric discriminates between instructor and student solutions. (criterion-related validity)
- The rubric does not depend on the amount of writing.
- Independent interrater reliability is good, and would improve with training.
- More work to be done!
  - Continue testing the rubric on student solutions: different topics, courses, exams (quizzes).
  - Review of the rubric categories and content by faculty and problem solving researchers. (face & content validity)
  - Interrater reliabilty testing with and without training.
  - Revisions to the rubric.

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