Measuring development of introductory physics students' problem-solving skills

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Goal

Establish a baseline of the evolution of students' problem solving skills in an introductory physics class. This can be used to assess the impact of instructional changes (such as the use of computer problem-solving coaches).

Sample

- 38 students from one section (total 108 students) of a Spring 2011 calculus-based introductory mechanics class for engineers and physical science majors at the University of Minnesota.
- 2 problems from each of 4 quizzes given at approximately 3-week intervals assessed using a problem-solving rubric.

Physics Background	Tier1	Tier2	Tier3
A-None	0	10%	11%
B-Yes, regular high school only	75%	60%	67%
C-Yes, advanced placement high school only	17%	10%	11%
D-Yes, college only	8%	10%	11%
E-Yes, both college and high school	0	10%	0

Table 1. Background data of the 38 students in the sample

	Useful Description (UD)	Physics Approach (PA)	Specific Application of Physics (SAP)	Mathematical Procedure (MP)	Logical Progression (LP)
5	Useful, appropriate and complete.				
4	Contains minor omissions and/or errors.				
3	Parts of the description/approach/etc. are missing and/or contain errors.				
2	Most of the description/approach/etc. are missing and/or contain errors.				
1	Not useful, inappropriate and/or inconsistent.				
0	Does not include a description/approach/etc.				
NA(S)/NA(P)	Not applicable to the solver/problem.				

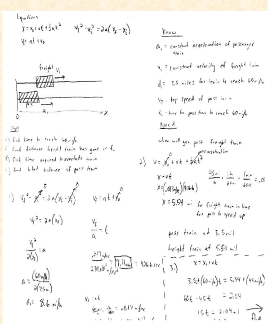
Fig. 1. Problem-solving rubric

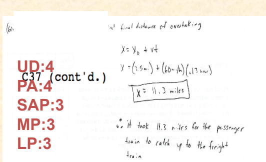
Quiz1 Problem1

Just as a passenger train that you boarded a few moments before is beginning to pull out of the station, it is passed by a freight train traveling at 45mi/h along a parallel track in the same direction that your train is headed. If your train undergoes constant acceleration, how far will you have traveled before your train passes the freight train, assuming that the freight train's speed remains constant? All that you know about your train's acceleration is that it takes 3.5 miles for the train to reach a speed of 60mi/h, starting from rest.

Quiz4 Problem1

A 13-kg cubic block, 30cm on a side, is at rest on a level floor. A 400-g glob of putty is thrown at the block perpendicular to one face of the block so that the putty travels horizontally, hits the block in the center of the face, and sticks to it. The block and putty slide 15cm along the floor. If the coefficient of kinetic friction is 0.40, what is the initial speed of the putty?





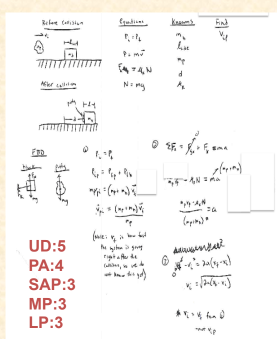


Fig. 2. Sample student solutions scored with the rubric.

Analysis

- Two experienced assessors independently applied the rubric to the written solutions of 38 students for each problem, then compared and discussed their ratings before moving on to the next problem.
- The agreement between the two raters after discussion was greater than 99%.

Results

Qualitative differences between tiers

As can be seen from Fig. 4, the problem solutions of students in Tier 1 earned noticeably higher rubric scores than those of students in Tier 3, even though the grades assigned by the TAs were obtained independently of the rubric scores.

Evolution of problem-solving skills

Fig. 5 shows that there is no evidence of any gain or loss in any of the 5 rubric categories over the course of the semester.

Qualitative differences between tiers

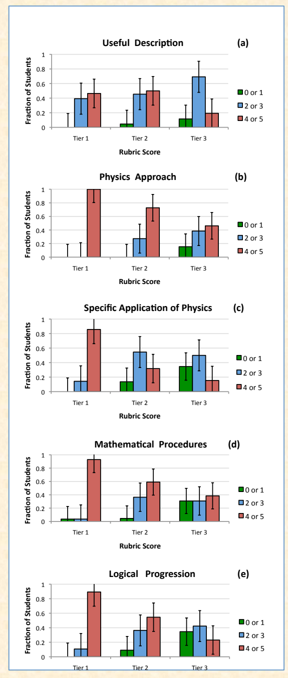


Fig. 4 (a-e). Fraction of students from each tier with scores in each bin for the two problems of quiz 1.

Evolution of scores

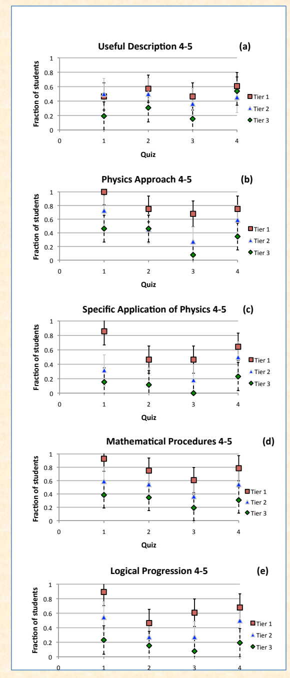


Fig. 5 (a-e). Fraction of students from each tier scoring a 4 or 5 in the categories and on the quizzes shown.

Summary

- The problem solving rubric distinguishes between students who perform at different levels in solving problems.
- The scores achieved by students remain constant as a function of time across all categories.
- Future work includes measuring a baseline in the second (E&M) semester, in mechanics courses taught in the fall, and measuring the impact of students' use of computer problem-solving coaches.

References

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2. J. Docktor, Development and validation of a physics problem-solving assessment rubric. Unpublished doctoral dissertation, University of Minnesota, Twin Cities. 2009. Available: http://groups.physics.umn.edu/physed/People/Docktor_dissertation_submitted%20final.pdf

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