Identifying Differences in Diagnostic Skills of Physics Students
Part 1: Developing A Rubric

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MOTIVATION

Problem solving is a learning opportunity:
students need to reflect to learn from their solution / mistakes [1]

Yet, for many, problem solving is a MISSED learning opportunity: Many students are not able to effectively take advantage of this opportunity, either because they lack reflective practices/skills or because they don't have a perception of problem solving as a reflective process, or the self esteem needed to cope with the frustration embedded in it.

Instruction can deliberately prompt students to make use of PS as a learning opportunity:
scaffolding aligned with cognitive apprenticeship [2]

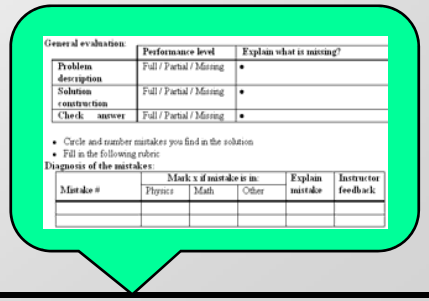
What are students able to diagnose if deliberately prompted to self- diagnose, and if so, how much support is needed? [3]

1. Larkin et al. 1980; 2. Collins et al. 1989; 3. Yerushalmi et al. 2007, Singh et al. 2007

RESEARCH DESIGN:

ALTERNATE SELF DIAGNOSIS (SD) TASKS

Goal: recitation sections deliberately prompted to self-diagnose, given varying levels of support – who will perform the best?

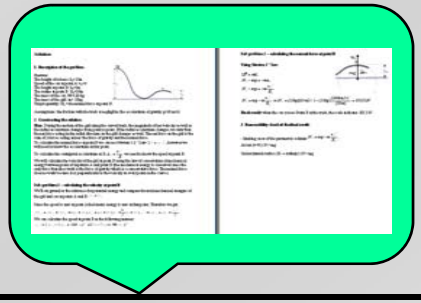

General evaluation:

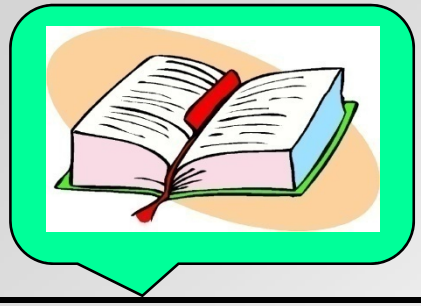
	Performance level	Explain what is missing?
Problem description	Full / Partial / Missing	•
Solution construction	Full / Partial / Missing	•
Check answer	Full / Partial / Missing	•

- Circle and number mistakes you find in the solution
- Fill in the following rubric

Diagnosis of the mistakes:

Mistake #	Mark x if mistake is in: Physics	Math	Other	Explain mistake	Instructor feedback





Maximum support	Medium support	Minimum support
1st stage: Students attempt a quiz problem 2nd stage (next training session): Students are asked to circle mistakes in their photocopied solutions and explain what they did wrong		
Instructor outlines the correct solution, Students fill in a self-diagnosis rubric	Instructor provides a written sample solution	Students can use their notes + text books

WHAT ARE STUDENTS ABLE TO DIAGNOSE IN ALTERNATIVE SELF DIAGNOSIS TASKS?

- We need a rubric that will allow us
  - to map student's knowledge to expert **ideal knowledge** (what correct ideas needed to solve the problem are reflected in student's solution and diagnosis)
  - to describe the **novice knowledge per se** (what ideas the student believes are needed to solve the problem are reflected in his/her solution and diagnosis) [4]
- We require the rubric to be:
  - Valid: reflect students' diagnostic ability
  - Reliable: objective and consistent
  - Versatile: generic / specific

4. Chi, 1997

GENERAL - ideal knowledge				I-quiz	S-quiz	I-SD
Physics	invoking	Appropriate principles				
		Justification				
		compactness				
	applying					
Presenting reasoning	Desc-ription	drawing knowns				
	plan	Target + intermediate variables	Explicit mention principles required for finding variables Efficiency – not leaving in surplus equations			
	checking	Units, limit case				
Total Scores (Phy. Score, Pres. Score)						

I - Instructor

S - Student

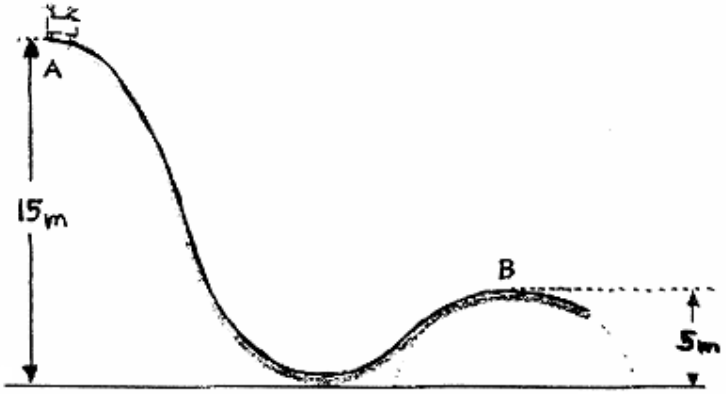
SD – Self diagnosis

specific

SAMPLE PROBLEM ⇒ SPECIFIC

- Problem: Girl on rollercoaster going over a circular bump – at peak of bump, how does weight change on a scale? (i.e. solve for normal force at this point)

A friend told a girl that he had heard that if you sit on a scale while riding a roller coaster, the dial on the scale changes all the time. The girl decides to check the story and takes a bathroom scale to the amusement park. There she receives an illustration (see below), depicting the riding track of a roller coaster car along with information on the track (the illustration scale is not accurate). The operator of the ride informs her that the rail track is smooth, the mass of the car is 120 kg, and that the car sets in motion from a rest position at the height of 15 m. He adds that point B is at 5m height and that close to point B the track is part of a circle with a radius of 30 m. Before leaving the house, the girl stepped on the scale which indicated 55kg. In the rollercoaster car the girl sits on the scale. Do you think that the story she had heard about the reading of the scale chaging on the roller coaster is true? According to your calculation, what will the scale show at point B?



SPECIFIC - ideal knowledge				I-quiz	S-quiz	I-SD
Physics	invoking	Appropriate principles	EC 2nd law			
		Justification	Justify CE			
		compactness				
	applying		EC 2nd law			
Presenting reasoning	Desc-ription	drawing knowns	FBD, a_c, axis PE = 0, R, knowns			
	plan	Target + intermediate variables Principles Efficiency	F_N A_c V			
	checking	Units, limit case				
Total Scores (Phy. Score, Pres. Score)						

Work done by non conservative force W_{nc}= 0 because normal force is ⊥ to path of motion

SPECIFIC novice knowledge per se				I-quiz	S-quiz	I-SD
Physics	invoking	Appropriate principles	EC 2nd law			
		Justification	Justify CE			
		compactness				
	applying		EC 2nd law			
Presenting reasoning	Desc-ription	drawing knowns	FBD, a_c, axis PE = 0, R, knowns			
	plan	Target + intermediate variables Principles Efficiency	F_N A_c V			
	checking	Units, limit case				
Total Scores (Phy. Score, Pres. Score)						

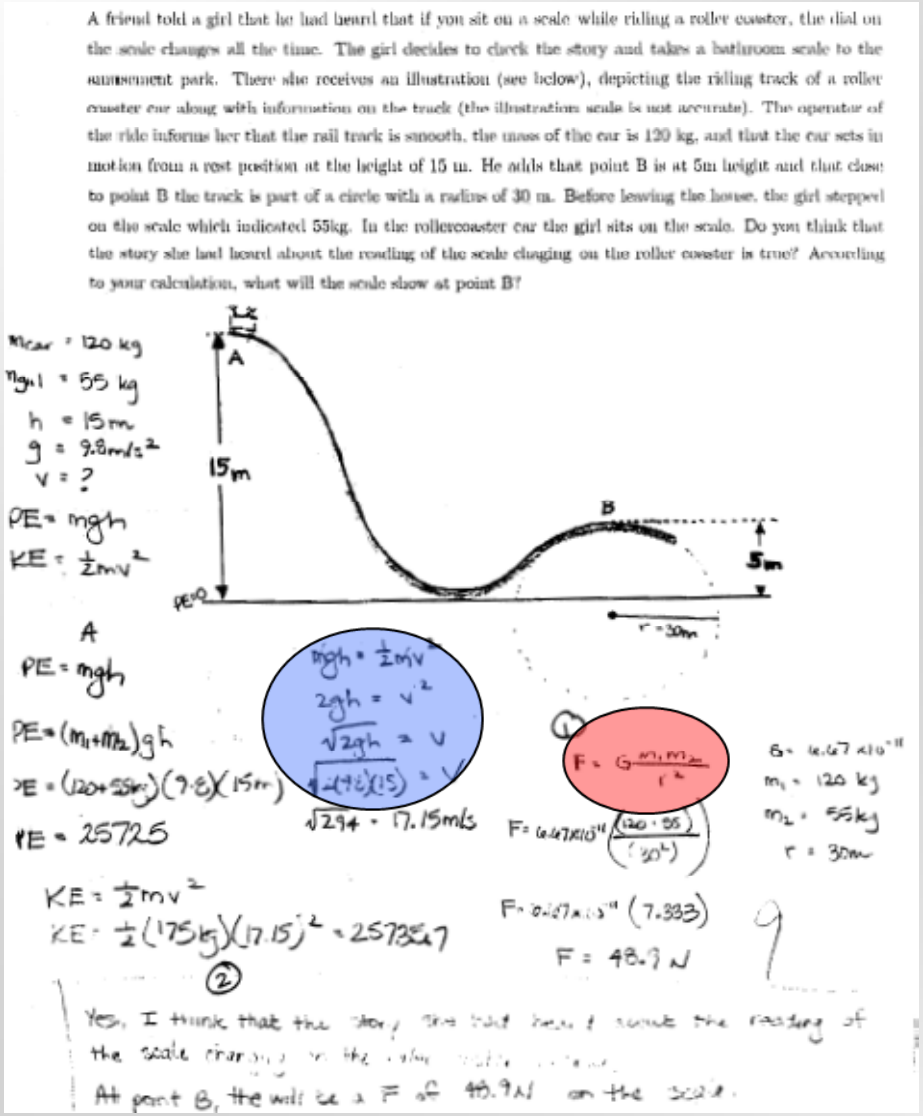
Students' common mistakes

EC	EC replaced by kinematics equation
	…
2nd law	Referring to centripetal force as a physical force
	No N
	Wrong signs of forces
	…

Reliability necessitated fewer categories (80% inter-rater agreement)

Validity required more categories

SAMPLE DATA – STUDENT SOLUTION FOR QUIZ PROBLEM, GROUP B



A friend told a girl that he had heard that if you sit on a scale while riding a roller coaster, the dial on the scale changes all the time. The girl decides to check the story and takes a bathroom scale to the amusement park. There she receives an illustration (see below), depicting the riding track of a roller coaster car along with information on the track (the illustrations scale is not accurate). The operator of the ride informs her that the rail track is smooth, the mass of the car is 120 kg, and that the car sets in motion from a rest position at the height of 15 m. He adds that point B is at 5m height and that close to point B the track is part of a circle with a radius of 30 m. Before leaving the house, the girl stepped on the scale which indicated 55kg. In the rollercoaster car the girl sits on the scale. Do you think that the story she had heard about the reading of the scale changing on the roller coaster is true? According to your calculation, what will the scale show at point B?

$m_{car} = 120$ kg
$m_{girl} = 55$ kg
$h = 15$m
$g = 9.8 m/s^2$
$v = ?$
$PE = mgh$
$KE = \frac{1}{2}mv^2$

A
B
15m
5m
r = 30m

A
$PE = mgh$
$PE = (m_1+m_2)gh$
$PE = (120+55)(9.8)(15m)$
$PE = 25725$

$mgh = \frac{1}{2}mv^2$
$2gh = v^2$
$\sqrt{2gh} = v$
$\sqrt{2(9.8)(15)} = v$
$\sqrt{294} = 17.15 m/s$

$KE = \frac{1}{2}mv^2$
$KE = \frac{1}{2}(175kg)(17.15)^2 = 25735.7$

②

$F = G\frac{m_1 m_2}{r^2}$
$F = 6.67\times10^{-11}\frac{(120\cdot55)}{(30^2)}$
$F = 6.67\times10^{-11}(7.333)$
$F = 48.9$ N

$G = 6.67\times10^{-11}$
$m_1 = 120$ kg
$m_2 = 55$ kg
$r = 30$m

Yes, I think that the story [illegible] the reading of the scale [illegible]
At point B, the will be a F of 48.9 N on the scale.

Examples:

i) **Did not invoke Newton's 2nd law**

ii) **Invoked EC but did not apply it correctly**

SAMPLE DATA, STUDENT SELF-DIAGNOSIS, GROUP B

	Performance level	?Explain what is missing
Problem description	Full / Partial / Missing Listed all knowns and unknowns.	• Did not look for the Normal force • No free body diagram drawn
Solution construction	Full / Partial / Missing	• Did not write out the steps that were to be taken to solve. • used wrong equations.
Check answer	Full / Partial / Missing	• The is no evidence of an answer check.

- Circle and number mistakes you find in the solution
- Fill in the following rubric

Diagnosis of the mistakes:

Mistake #	:Mark X if mistake is in			Explain mistake	Instructor feedback
	Physics	Math	Other		
1	X	X		used wrong equation needed $F_N - mg = -ma_c = -m\frac{v^2}{r}$	
2	X			needed equation $PE_A = PE_B + KE_B$	
3	X			used total mass instead of just girl to find the force	
4.	X			Did not separate into E_M and E_P	

Examples:

iii) Notices that he did not use Newton's 2nd Law

iv) Notices that he did not draw a FBD

SAMPLE ANALYSIS

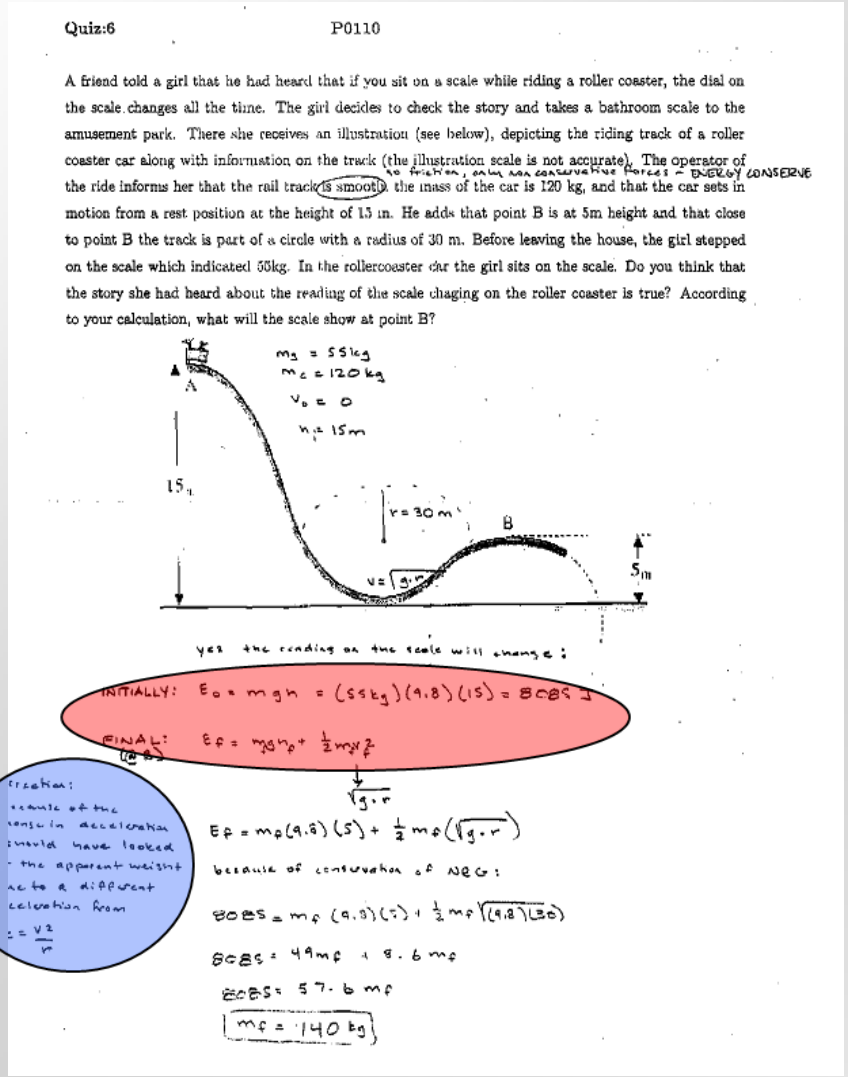
Student, Group B

I – quiz	S – quiz	I – SD
+ / -	X / -	n/a / +
-	X	-
-	-	+
- / n/a	-	++/- / n/a
-, - / +, + / ++/-	X, X / X,X / +	-, - / n/a, n/a / ++/-
- / - / +/- / -	- / X / +/- / X	+ / - / + / -
+/- / -	X / -	+/- / -
0.17, 0.27	**0.33, 0.65**	**0.67, 0.54**

Student, Group D

Rubric scoring				I – quiz	S – quiz	I – SD
Physics	invoking	Appropriate principles	EC / 2^{nd} law	+ / -	X / +/-	n/a / +/-
		Justification	Justify CE	+/-	X	+/-
		compactness		n/a		n/a
	applying		EC / 2^{nd} law	- / n/a	-	++/- / n/a
Presenting reasoning	Desc-ription	drawing known quantities	FBD, a_c, axis / PE = 0, R / knowns	-, -, - / -, +/- / +/-	X,X,X / X,X / X	-, -, - / -, +/- / +/-
	plan	Target + intermediate variables	F_N / Efficiency / v, a_c / Explicit principles	- / + / +/- / -	X / X / X / X	- / n/a / +/- / -
	checking	Units, limit case	Writes units / Checks answer	+/- / -	X / X	+/- / -
Total Scores (Phy. Score, Pres. Score)				**0.3, 0.26**	**0.7, 1.0**	**0.33, 0.19**

SAMPLE DATA – STUDENT SOLUTION FOR QUIZ/SELF-DIAGNOSIS, GROUP D



Quiz:6 P0110

A friend told a girl that he had heard that if you sit on a scale while riding a roller coaster, the dial on the scale changes all the time. The girl decides to check the story and takes a bathroom scale to the amusement park. There she receives an illustration (see below), depicting the riding track of a roller coaster car along with information on the track (the illustration scale is not accurate). The operator of the ride informs her that the rail track is smooth, the mass of the car is 120 kg, and that the car sets in motion from a rest position at the height of 15 m. He adds that point B is at 5m height and that close to point B the track is part of a circle with a radius of 30 m. Before leaving the house, the girl stepped on the scale which indicated 55kg. In the rollercoaster car the girl sits on the scale. Do you think that the story she had heard about the reading of the scale chaging on the roller coaster is true? According to your calculation, what will the scale show at point B?

Examples:

i) **Invoked CE but did not apply it correctly**

ii) **Noticed centripetal acceleration and apparent weight but didn't cite Newton's 2nd Law**

iii) **Did not address presentation at all in SD (not found on the student's work)**

SUMMARY

Rubric is:

- **Valid: 4 instructors found it to reflect students' diagnostic ability**
- **Reliable: 2 researchers agreed to 80%**
- **Versatile: generic / specific**
- **expert ideal knowledge / novice knowledge per se**

Want to know what the rubric shows for the study?

Watch for the poster nearby

“Part 2: Students’ Self-Diagnostic Performance Given Alternative Scaffolding Tasks”

Want to know the effect of Self diagnosis on Transfer problems (midterm)?

Come to PERC targeted poster session

“From Diagnostic Skills to Potential Success in the Physics Classroom”

Thursday 8:30 – 10:00 am

3:00 – 4:30 pm