Developing reasoning and metacognitive skills through reflective lab reports

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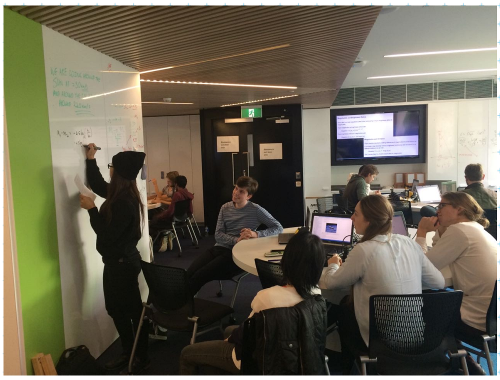
Context: PACE (Physics and Astronomy Collaborative-learning Environment) studios at Monash built in 2014



- Elective 1st year unit, mainly engineering students (~75%), enrolment around 200 students
- Covers: Newtonian mechanics, Electromagnetism (previously Waves & Optics), and Quantum Mechanics

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Usual set-up of the courses:

Lectures – information transfer

Tutorials – working on problem sets related to concepts from the lectures

Assessed via the mid-semester test and exam

(80%)

We are assessing different skills, but the reasoning used should be the same!

Labs – learning about experimental side of physics – and uncertainties, uncertainties, uncertainties

Assessed via lab reports (20%)

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The McGraw Center for Teaching & Learning
328 Frist Campus Center
www.princeton.edu/mcgraw

Novice versus Expert Problem Solvers

Novices and experts approach problems very differently. Broadly speaking, distinctions between their approaches include:

Novices...	Experts...
• Memorize how to solve specific problems. Ex.: "Use $mgh = \frac{1}{2}mv^2$"	• Believe that you can solve most problems by memorizing only a few central principles. Ex.: "Use conservation of Energy"
• Identify problems in terms of surface elements. Ex.: "This is an inclined plane problem."	• Identify problems using principles by which you can solve them. Ex.: "This is a friction and gravity problem."
• Believe that most problems are too difficult for them to solve.	• Are confident that they can solve problems, work a long time before giving up, and do not believe that this is a waste of time.
• Do not think about how they solve problems but instead just plow through them.	• Are able and willing to evaluate their own thinking.
• Move on to the next problem without considering possible connections between them or the concepts that may inform them.	• After solving problems, review why the question was important, asking why the professor gave the assignment.

What is the issue I wanted to address:

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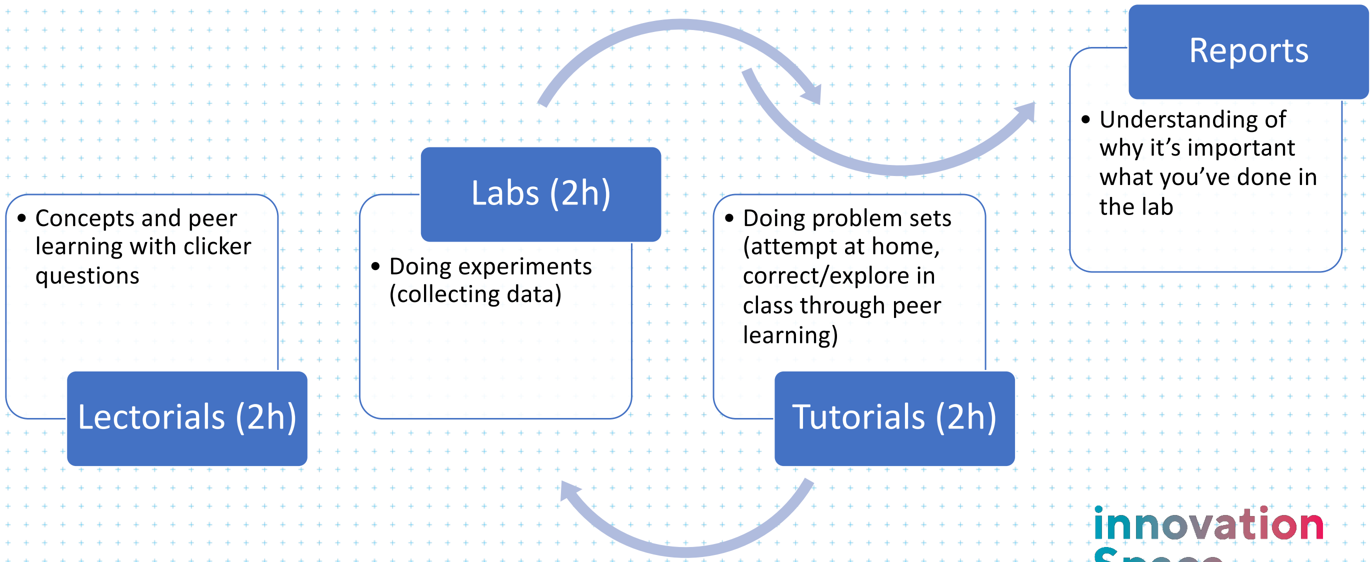
Setting up active learning cycle



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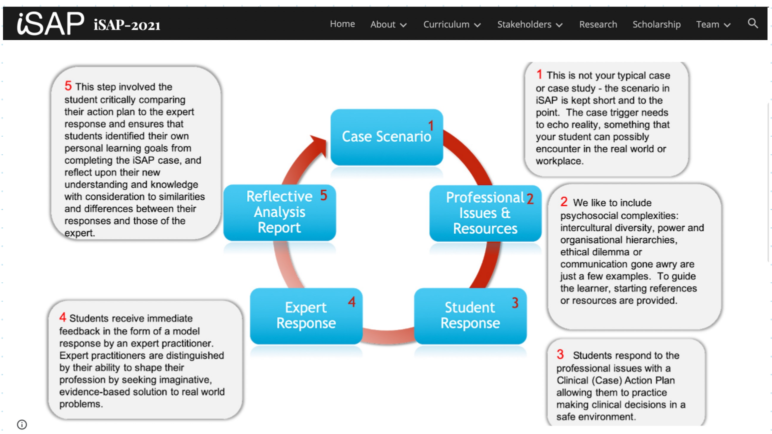
Using dual feedback

Integrating Science and Practice (iSAP): An Interactive Case-Based Clinical Decision-Making Radiography Training Program

Williams, I., Schliephake, K., Heinrich, L. M., & Baird, M. A. (2017)



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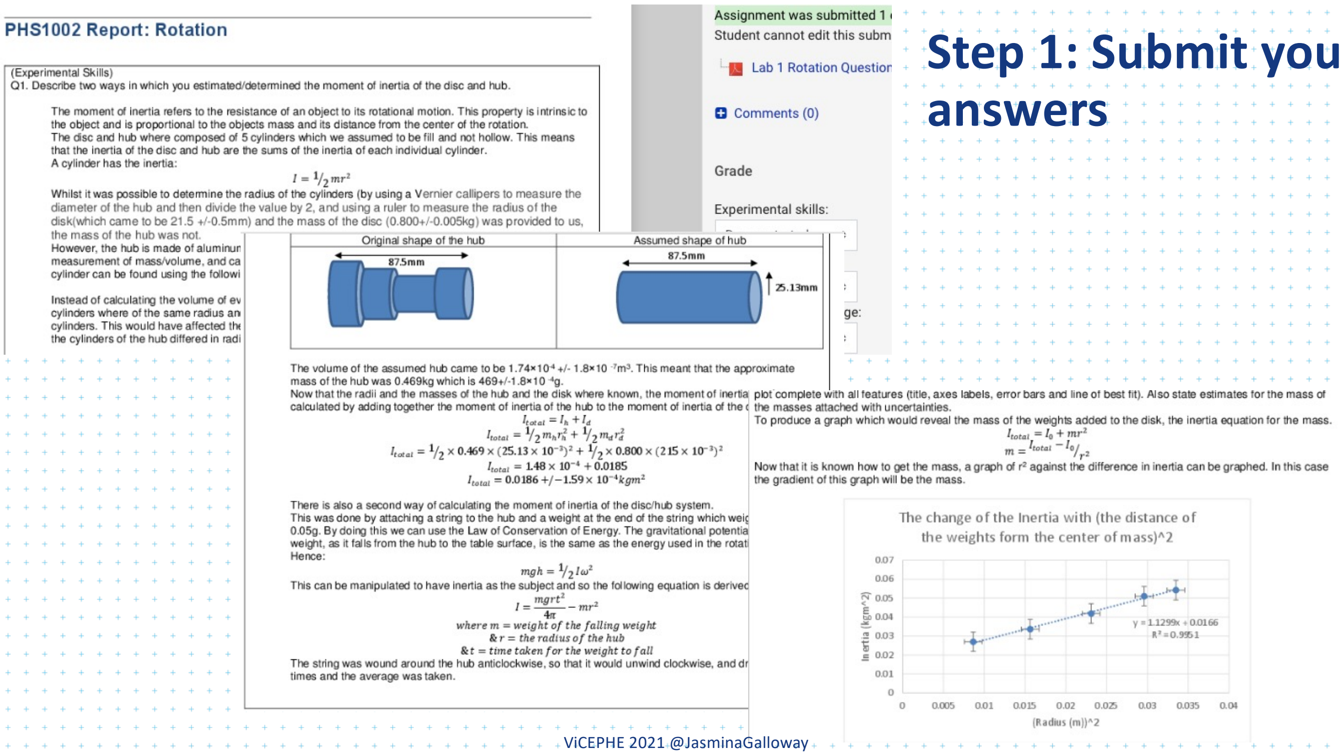

Step 1: Submit your answers

Questions are "tagged":

(Experimental Skills)
Q1. Describe two ways in which you estimated/determined the moment of inertia of the disc and hub.

(Technical Analysis)
Q2. Describe the logic behind the plot you made to determine the mass of the masses attached to the disc. Show the plot complete with all features (title, axes labels, error bars and line of best fit). Also state estimates for the mass of the masses attached with uncertainties based on the fit results (from Excel's LINEST function).

(Synthesizing Knowledge and Critical Thinking)
Q3. Why was it important that the weights be placed on the disc symmetrically?

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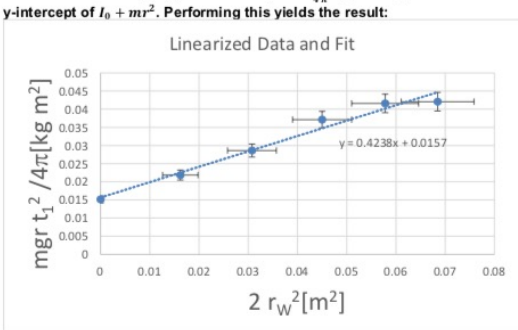
Step 2: Read an explanation from an "expert" and reflect:

(Technical Analysis)
Q2. Describe the logic behind the plot you made to determine the mass of the masses attached to the disc. Show the plot complete with all features (title, axes labels, error bars and line of best fit). Also state estimates for the mass of the masses attached with uncertainties based on the fit results (from Excel's LINEST function).

EXPERT ANSWER
Since now we would have an expression for the moment of inertia of the disc and masses as:
$I_T = I_0 + I_w = \frac{(m\,g\,r\,t_1^2)}{4\,\pi} - mr^2$ **and the masses add inertia of** $I_W = 2\,m_w\,r_w^2$ **we have**
$I_0 + 2\,m_w r_w^2 = \frac{(m\,g\,r\,t_1^2)}{4\,\pi} - mr^2$ **which we can rearrange to** $2\,m_w r_w^2 + I_0 + m\,r^2 = \frac{(m\,g\,r\,t_1^2)}{4\,\pi}$
Thus we can plot say $2\,r_w^2$ **as the x axis, and** $\frac{m\,g\,h}{4\,\pi}t_1^2$ **as the y axis. This will be linear with a slope of** m_W **and a y-intercept of** $I_0 + mr^2$**. Performing this yields the result:**



And results in linest output:

	Slope (Mw [kg])	Intercept [kg m^2]
Value	0.42	0.016
Uncertainty	0.03	0.001

Reflection Questions:

(Experimental Skills)
Q1. How does your answer compare to the expert's? Does your answer clearly describe the details of the method including what to measure and how to then determine the moment of inertia from these quantities? Have you clearly identified variables measured and used and any assumptions made?

(Technical Analysis)
Q2. How does your answer compare to the expert's? Does your answer explain how to isolate the mass of the weights added? Have you included all elements required for the plot and remembered to use Linest to determine the line of best fit and the uncertainties? (Note: your axes may not be the same but is your plot still linear? Does the fit provide the mass of the weights in some way?)

Synthesizing Knowledge and Critical Thinking)
Q3. How does your response compare to the experts? Have you explained the physical relevance of placing the weights symmetrically?

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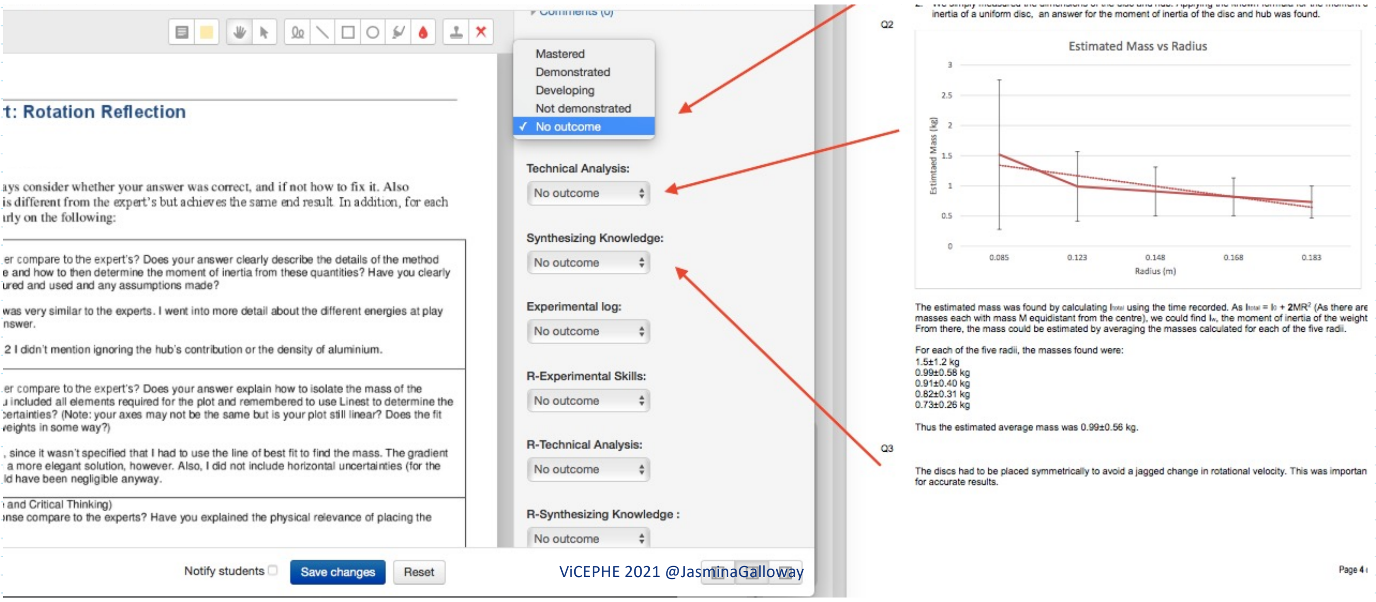
Step 3: Both reports are now marked

- "Tags" for each question – marked according to mastery



Workshop 3			
Submit Report W3	–	–	
Content knowledge: spectrum	Demonstrated	Not demonstrated–Mastered	Demonstrated (218)
Content knowledge: light	Mastered	Not demonstrated–Mastered	Mastered (218)
Reasoning skills	Developing	Not demonstrated–Mastered	Demonstrated (218)
Observational skills	Mastered	Not demonstrated–Mastered	Demonstrated (218)
Synthesising Knowledge	Not demonstrated	Not demonstrated–Mastered	Demonstrated (218)
Problem Solving Skills	Mastered	Not demonstrated–Mastered	Demonstrated (218)
Workshop 3 total grade (/18) Simple weighted mean of grades. Include empty grades.	**12.00**	**0–18**	**11.65 (238)**
Workshop 4			
Submit Report W4	–	–	

Students can easily see the level of their mastery in Moodle gradebook

(and compare how they've done in respect to the rest of the cohort)

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Rubric is simple (on purpose)

What are we looking for in the answers to reports' questions:			
Mastered	Demonstrated	Developing	Not demonstrated
Adressed all the points of Physics/Method/Interpretation, in sufficient detail, with evidence/support, and good clarity.	Adressed all the of Physics/Method/Interpretation with evidence and support, but with occasional lack of clarity, or with minor error in calculations or processing of evidence OR good answer to slightly misinterpreted question.	Neglected to provide support for comments about Physics/Method/Interpretation or missing some key ideas of the Physics/Method/Interpretation, OR good answer to totally misinterpreted question, OR decent answer to a slightly misinterpreted question.	No response OR missed the point of the question.

What are we looking for in the reflections:			
Mastered	Demonstrated	Developing	Not demonstrated
Noted similarities in concepts and did not emphasize irrelevant differences, noted differences in Physics/Method/Interpretation present in original answer or all such differences noted and understood.	Noted similarities in Physics/Method/Interpretation, but also worried about irrelevant differences, or didn't notice a small but important difference in Physics/Method/Interpretation.	Noted some similarities and differences, but didn't notice or highlight some fundamental differences in Physics/Method/Interpretation.	No response, or a response that focused only on irrelevant details of presentation instead of noticing glaring differences in Physics/Method/Interpretation.

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… and dual feedback

Students are provided with dual feedback **(**Laurillard 2012**)**:

1) their *intrinsic* feedback from the comparison, and

2) *external* feedback from the instructor on both their original answers, as well as their reflection

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Did it work?

Top five themes identified from student responses to open-ended survey questions:

Q1: Which aspect(s) of this unit did you find most effective?

	Old way	1st run	2nd run
	2016	**2017**	**2018**
Number of responses/number of students (per cent)	65/195 (33%)	102/184 (55%)	153/229 (67%)
The top 5 emerging themes for Q1 - what is effective?			
Labs	15 (23%)	29 (28%)	28 (18%)
Lab reports	n/a	5 (5%)	18 (12%)
Tutorials	5 (8%)	10 (10%)	37 (24%)
Intercative lectures/lectorials	3 (5%)	6 (6%)	31 (20%)
Pre-lecture videos	n/a	13 (13%)	4 (3%)

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What did students think?

- *The feedback method is very impressive. Because we can find out **our weaknesses and strengths** in this unit.*
- *I thought it was great that a lot of our in–class assessment had a **focus on demonstrating that we were in the process of learning the material**, i.e. the answer didn't necessarily have to be correct – as long as we'd made a good effort and recognised our mistakes, we'd get a decent grade. This took the pressure off the assignments a little, thus letting us have more time to focus on learning the material.*
- *Cancel reflection reports, we are scientists not writers."*

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