Learning via online mechanics tests: update and extension

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Contentions

a. Students find mechanics hard because it's synoptic.
b. Students go wrong at specific points triggered by lack of mastery of basic skills and knowledge, often from algebra and calculus.
c. Student errors are not random but arise from mal-rules.
d. These mal-rules can be usefully categorised.
e. Testing via CAA with extensive feedback can be effective.

Part 1: Technical Issues

- Randomisation

A golf ball is thrown horizontally and hits the ground a horizontal distance of 17m from the thrower 2s later.

Find the speed and height of projection.

Ignore the effect of air resistance and take the numerical value of g to be $9.8ms^{-2}$.

Give your answer to 2 decimal places and include the minus sign where necessary.

The speed of projection is _____ ms^{-1} and the height of projection is _____ m.

Submit

A stone is thrown horizontally and hits the ground a horizontal distance of 13m from the thrower 6s later.

Find the speed and height of projection.

Ignore the effect of air resistance and take the numerical value of g to be $9.8ms^{-2}$.

Give your answer to 2 decimal places and include the minus sign where necessary.

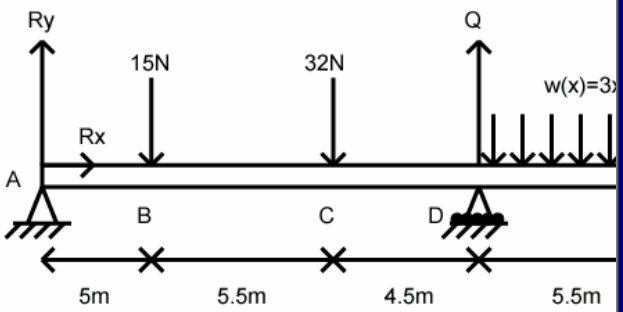
The speed of projection is _____ ms^{-1} and the height of projection is _____ m.

Submit

Dynamic functionality

Determine the reactions.

Give your answers to 2 decimal places.



Your answers were wrong. Your answers 1, 2 and 3 should have been: 0, 37

The beam is in equilibrium, so,

$$F_{\text{total}} = R_x\mathbf{i} + \left[R_y + Q - 15 - 32 - \int_{15}^{20.5} w(x)dx\right]\mathbf{j} = 0$$

$$\Rightarrow R_x\mathbf{i} + \left[R_y + Q - 15 - 32 - \int_{15}^{20.5} 3x\,dx\right]\mathbf{j} = 0$$

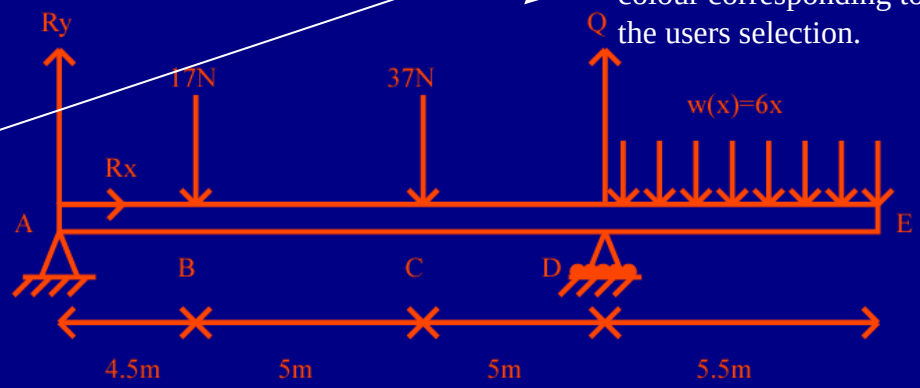
Now,

$$\int_{15}^{20.5} 3x\,dx = \frac{3}{2}\left[x^2\right]_{15}^{20.5} = 292.875$$

Colour, size and font selection follows through to the MathML coding.

Determine the reactions.

Give your answers to 2 decimal places.



Schematic has increased in size and changed colour corresponding to the users selection.

Your answers were wrong. Your answers 1, 2 and 4 should have been: 0, 712.47, and -89.22.

The beam is in equilibrium, so,

$$F_{\text{total}} = R_x\mathbf{i} + \left[R_y + Q - 17 - 37 - \int_{14.5}^{20} w(x)dx\right]\mathbf{j} = 0$$

$$\Rightarrow R_x\mathbf{i} + \left[R_y + Q - 17 - 37 - \int_{14.5}^{20} 6x\,dx\right]\mathbf{j} = 0$$

Now,

$$\int_{14.5}^{20} 6x\,dx = 3\left[x^2\right]_{14.5}^{20} = 569.25$$

Mal-rules in action

Three forces $\mathbf{F}_1 = 6\mathbf{i} + 4\mathbf{j} + 5\mathbf{k}$, $\mathbf{F}_2 = 10\mathbf{i} + 12\mathbf{j} + 11\mathbf{k}$ and $\mathbf{F}_3 = 16\mathbf{i} + 19\mathbf{j} + 20\mathbf{k}$ act at points with position vectors

$\mathbf{r}_1 = 24\mathbf{i} + 26\mathbf{j} + 22\mathbf{k}$, $\mathbf{r}_2 = 31\mathbf{i} + 32\mathbf{j} + 30\mathbf{k}$ and $\mathbf{r}_3 = 42\mathbf{i} + 40\mathbf{j} + 37\mathbf{k}$ respectively.

Find an expression for the cosine of the angle between $\mathbf{F}_1$ and $\mathbf{F}_2$.

- $\frac{60\mathbf{i}+48\mathbf{j}+55\mathbf{k}}{\sqrt{77}\sqrt{365}}$ → Returned vector expression when calculating dot product.
- $\frac{-528}{\sqrt{77}\sqrt{365}}$ → Calculation error: When using the formula $|\mathbf{F}_1 - \mathbf{F}_2| = |\mathbf{F}_1|^2 + |\mathbf{F}_2|^2 - 2|\mathbf{F}_1||\mathbf{F}_2|\cos\theta$, students added the two forces on the left hand side.
- $\frac{163}{\sqrt{77}\sqrt{365}}$ → Correct
- $\frac{495}{\sqrt{77}\sqrt{365}}$ → $\mathbf{F}_1.\mathbf{F}_2 = (a_1 + a_2 + a_3)(b_1 + b_2 + b_3)$
- None of these!
- I don't know!

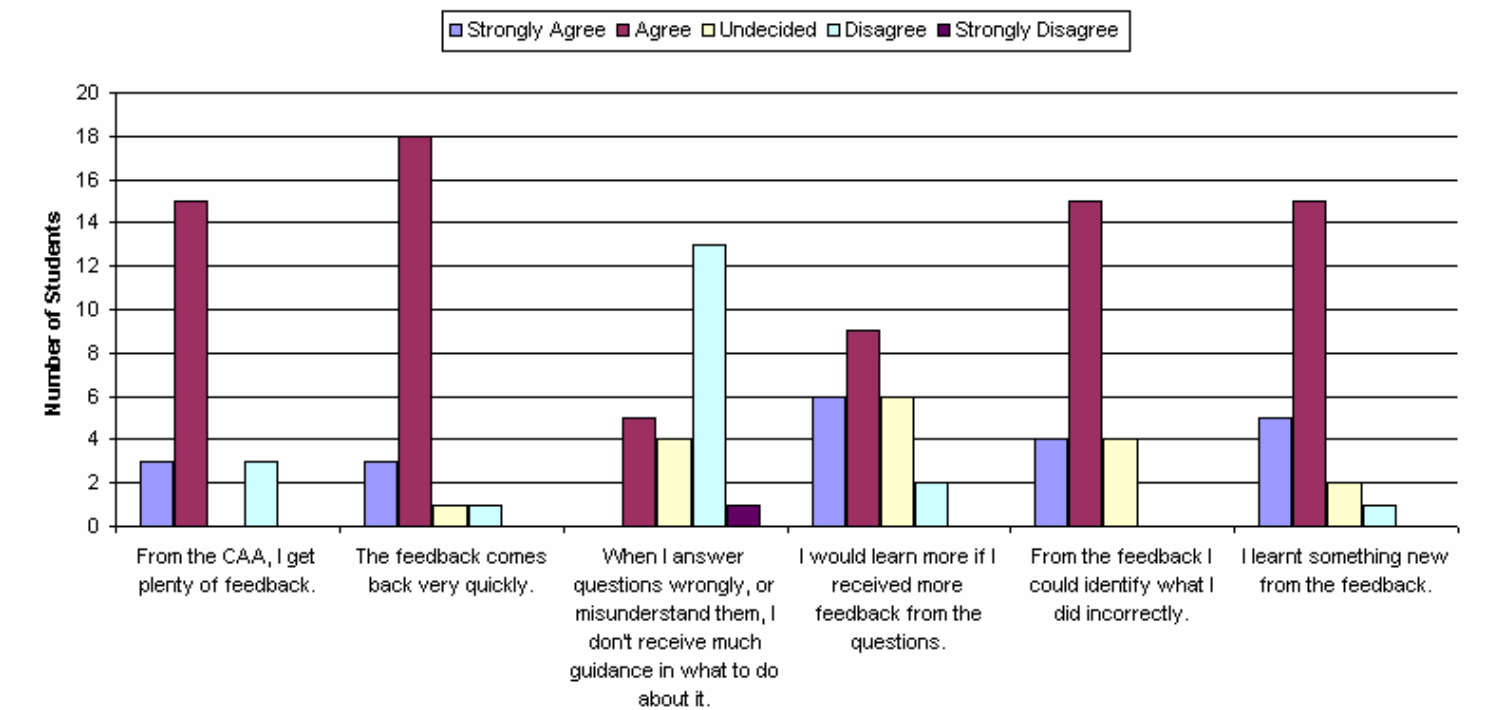
Part 2: Results of trials

- Error taxonomy

Error Type	Classification
Assumption	Students assume certain things that are not true, for example, in projectile questions, that vertical velocity is equal to initial velocity.
Calculation	Method correct but calculation errors are made.
Copying	Copying values incorrectly.
Definition	Not knowing the definition of terms given in question text, e.g. magnitude.
Formulas	Incorrectly stating/recalling formulas.
Incorrect Values Used	Using incorrect values in method, for example, when substituting values into formulas.
Knowledge	Knowledge students are lacking that would enable them to answer questions.
Methodology	Students attempt to use an incorrect method to answer a question.
Modelling	Generic definition, e.g. ignoring forces, such as gravity, acting on particles.
Procedural	Method student attempts to use is correct but can only do initial/certain stages of the method. They stop halfway through when they do not know the stages that follow or when they are unable to interpret initial results.
Reading	Reading the question text incorrectly and confusing the value of variables.
Trigonometry	Basic definitions of cosine, sine and tan incorrect. This is most apparent in questions where students are required to resolve forces.

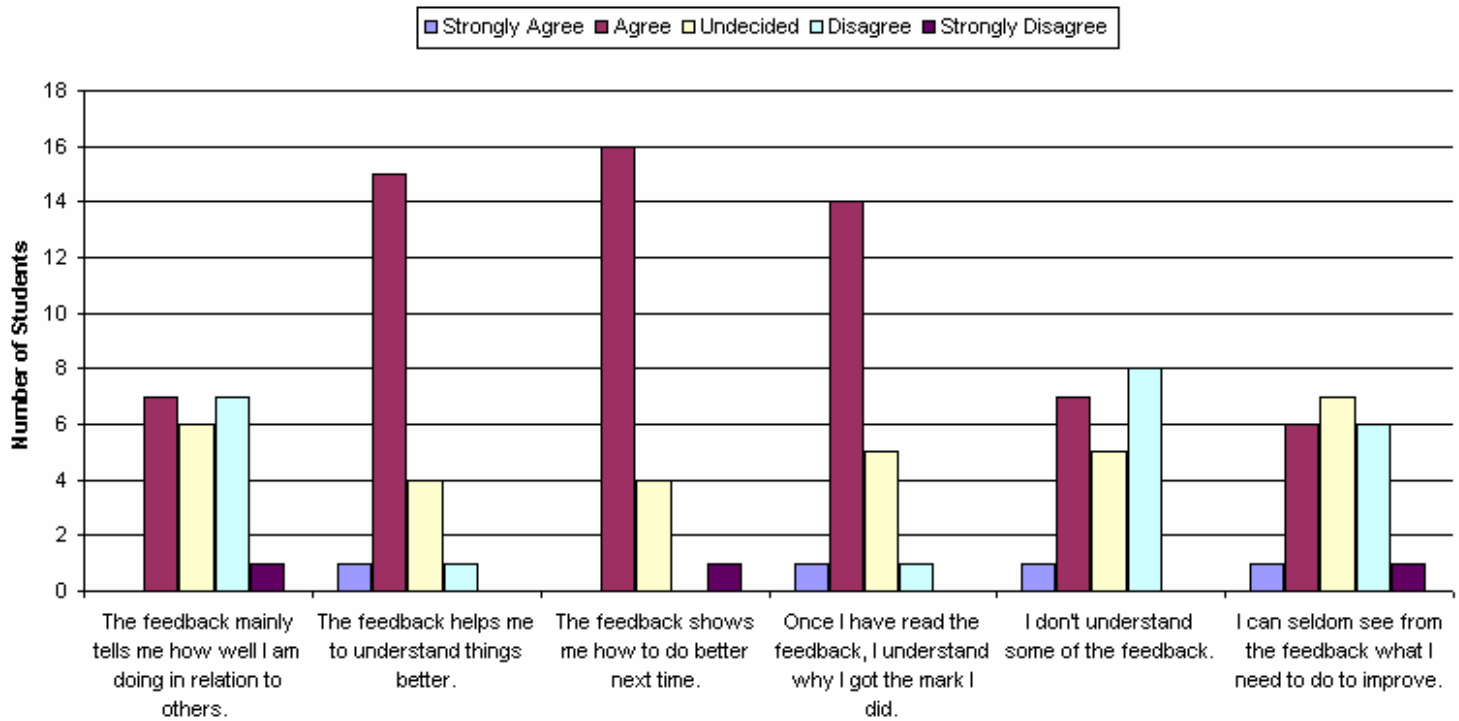
Efficacy of feedback: what do students say about it (FAST Project)

- Quantity and timing of the feedback

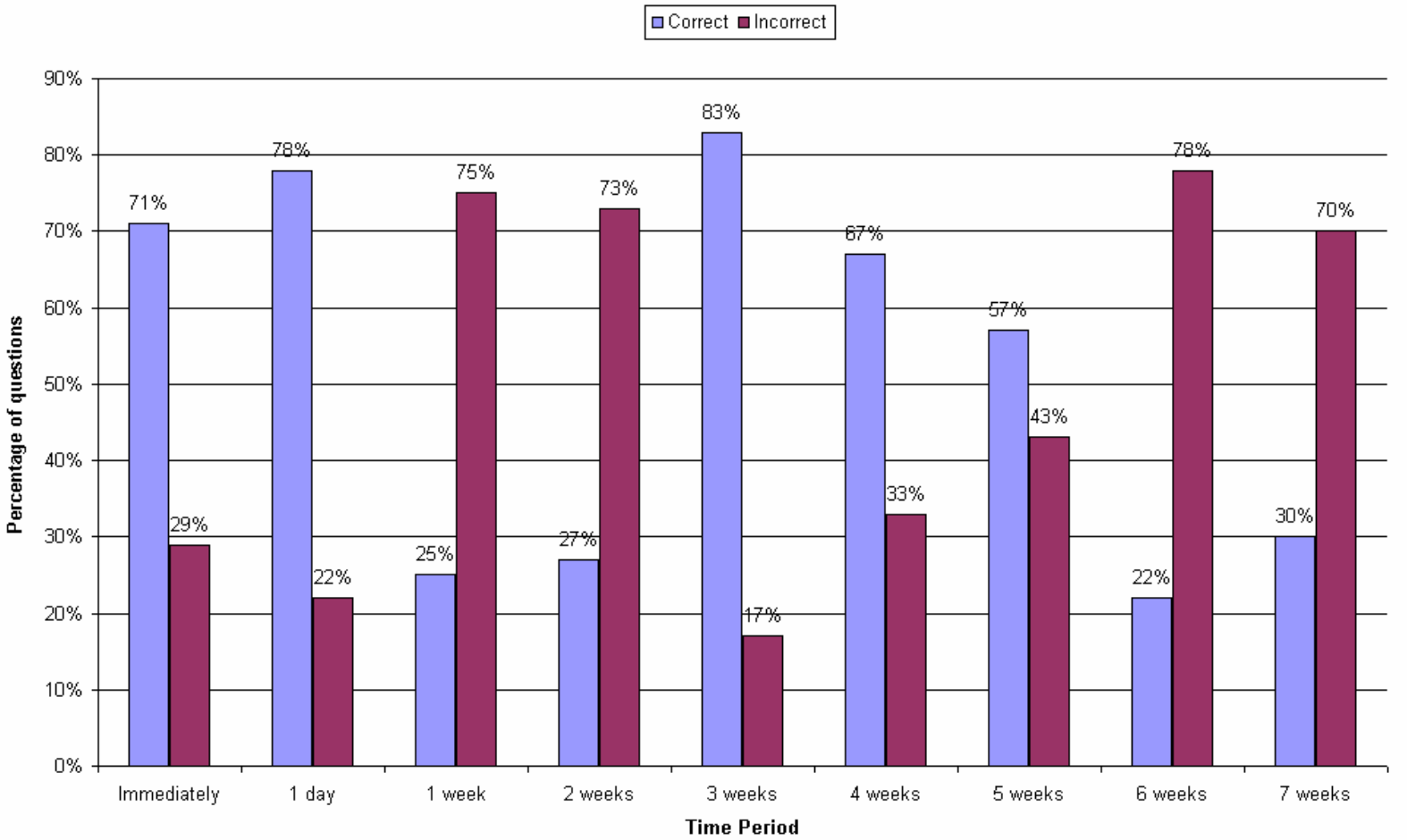


Efficacy of feedback: what do students say about it

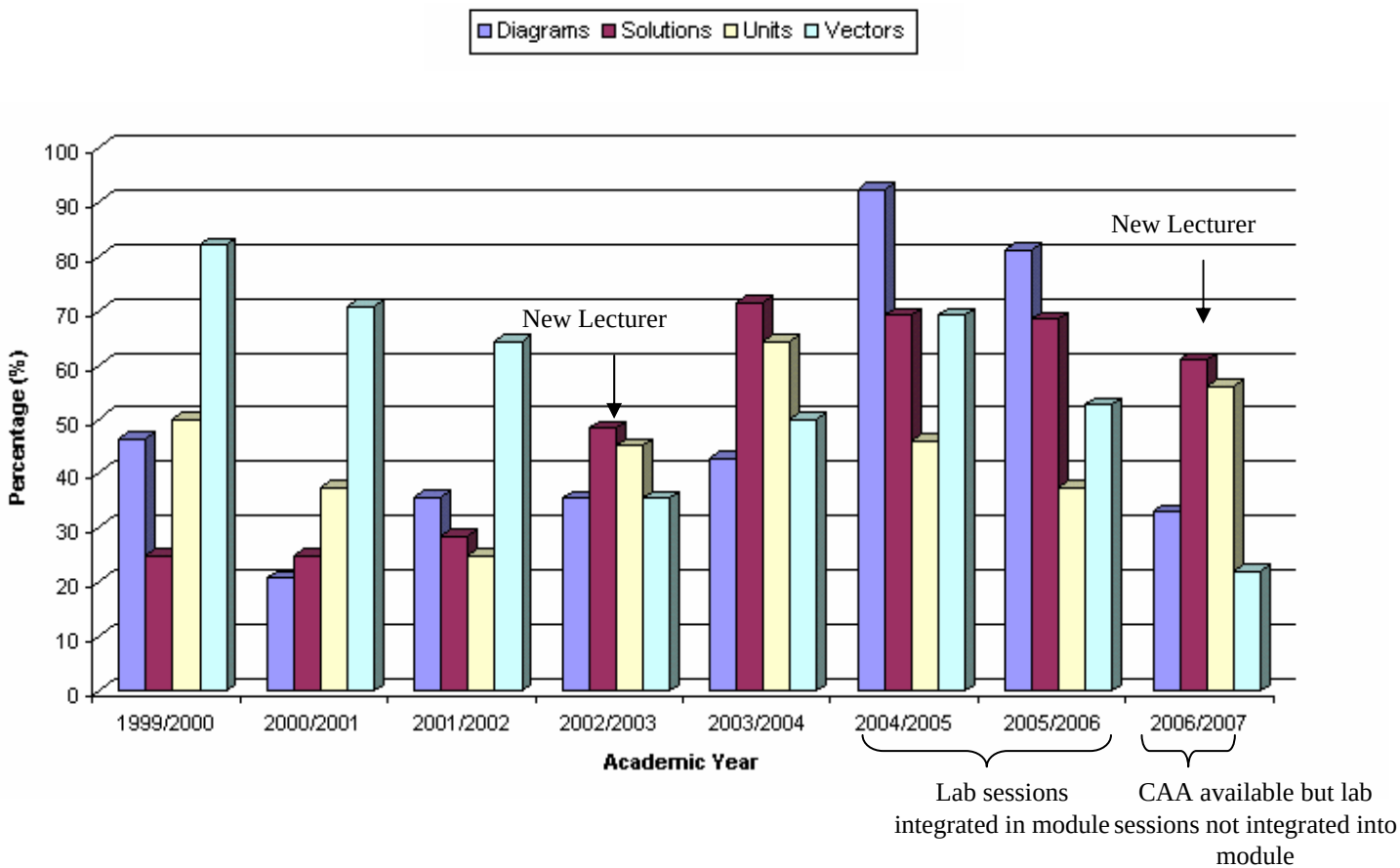
- Quality of the feedback



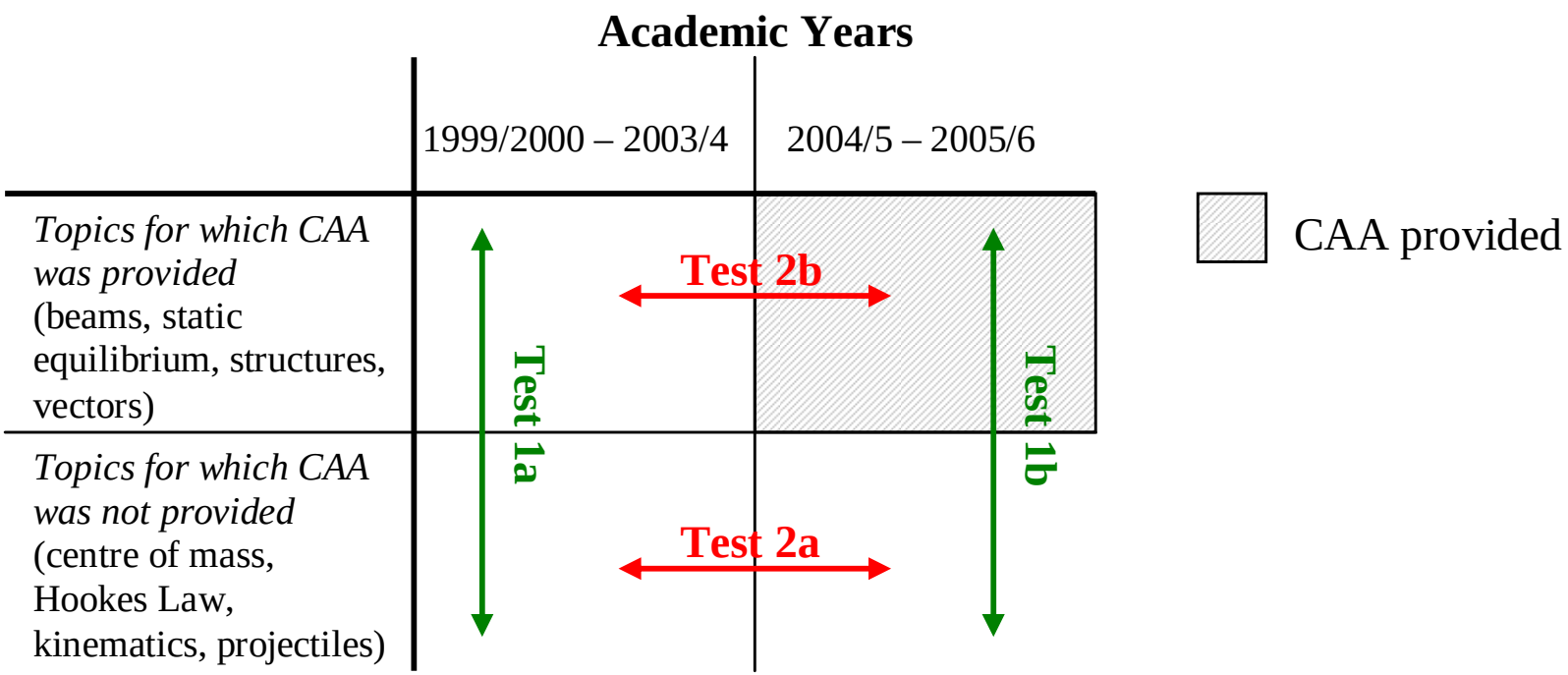
Efficacy of feedback: how long do students retain it



Efficacy of feedback: Indicators for understanding exam scripts



Efficacy of feedback: Analysis of marks



Conclusion

- Mal-rules apply in other areas of maths (science?)
- Error taxonomy applies in other areas of maths (science?).
- CAA is a popular resource to use.
- CAA is effective, if skills are tested and full feedback is given.