How do students process a worked example?

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Introduction

While trying to learn from worked examples in our classroom, students seem to discuss and ask about information in the mathematical sections far more often than the conceptual information and justifications in the text explanations.

Our tacit assumption during instruction was that the students were essentially ignoring the text and focusing primarily on the mathematical steps as more valuable (in their eyes) to obtaining a solution.

To test the validity of this assumption, we designed a study to explore two questions

Do students focus primarily on the symbols in reading worked examples?

Does having a specific problem in mind change the way students process the examples?

Sample Worked Example

A block of mass $M = 0.2$ kg is released from rest on a frictionless ramp at a height $H = 0.5$ m. At the bottom of the ramp, the block is caught by a rod-pendulum with a cup at its end as shown. The rod-pendulum has moment of inertia $I = 0.36$ kg·m^2 and length $l = 0.9$ m. What is the angular velocity of the pendulum immediately after the cup catches the block?

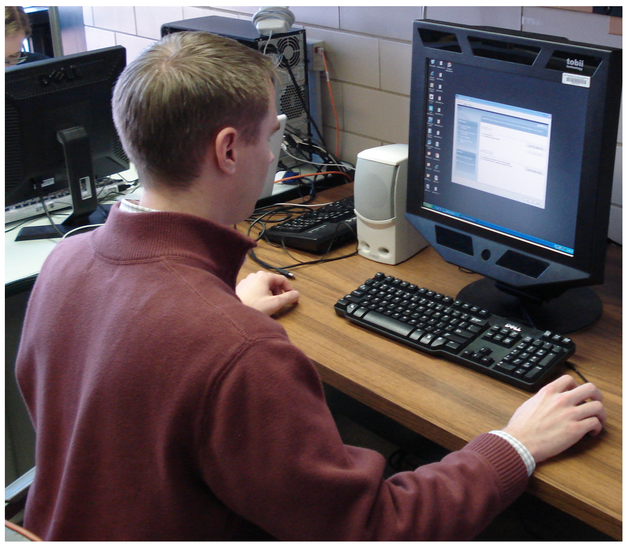
Conservation of mechanical energy can be applied to the block as it slides down the ramp. Mechanical energy is conserved since the only non-conservative force present (the normal force) does no work on the block. (T1)	$E_{i,\text{block}} = E_{f,\text{block}}$ $(KE)_i + (PE)_i = (KE)_f + (PE)_f$ $0 + MgH = (1/2)\,Mv^2 + 0$ (S1) $v = \sqrt{2gH}$
Angular momentum is conserved when the block collides with the pendulum since no external torques deliver any angular impulse to the system. (The force on the pendulum from the pivot acts at the pivot and therefore generates no torque) (T2)	$L_{i\text{system}} = l_{f,\text{system}}$ $L_{i,M} + L_{i,\text{pendulum}} = L_{f,M+\text{pendulum}}$ $lp\sin 90° + 0 = (I_M + I_{\text{pendulum}})\,\omega$ (S2) $lMv = (I_M + I_{\text{pendulum}})\,\omega$
The moment of inertia of the block about the pivot is its mass times the length, l, squared. (T3) The moment of inertia of the pendulum is given.	$I_M = Ml^2 = (0.2\text{ kg})(0.9\text{ m})^2 = 0.162\text{ kg}\cdot\text{m}^2$ $I_{\text{pendulum}} = 0.36\text{kg}\cdot\text{m}^2$ (S3)
Solve for the final angular velocity and insert the given values to obtain a numerical value. (T4)	$\omega = \dfrac{lMv}{I_M + I_{\text{pendulum}}}$ $= \dfrac{lM\left(\sqrt{2gH}\right)}{I_M + I_{\text{pendulum}}}$ $= \dfrac{(0.9\text{ m})(0.2\text{ kg})\sqrt{2\left(9.8\frac{\text{m}}{\text{s}^2}\right)(0.5\text{ m})}}{0.162\text{ kg}\cdot\text{m}^2 + 0.36\text{ kg}\cdot\text{m}^2}$ (S4) $= 1.1\dfrac{\text{rad}}{\text{s}}$

Method

Use an eyetracker to record students' eye-gaze data while they read worked examples on a computer screen

- N = 43 students who completed our calculus based introductory mechanics course
- Each subject assigned to one of two learning tasks

Tobii 1750 Eyetracker

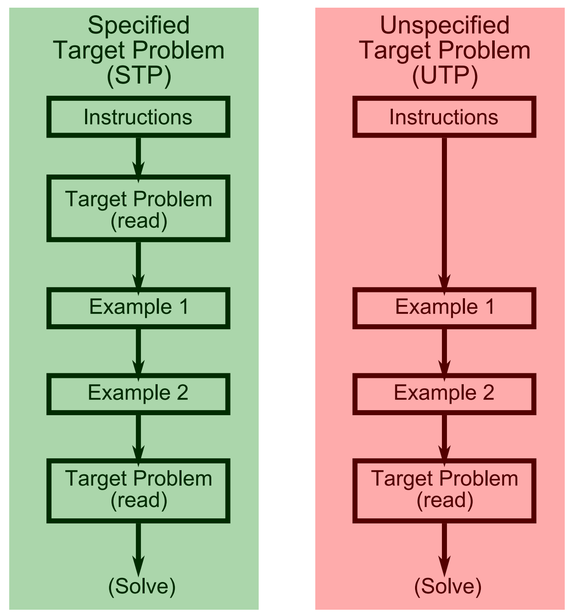


- uses near infrared beams to image the subject's eyes
- subject unencumbered by headgear, allowing natural movement
- instrument records gaze location and duration with a resolution of ~0.5 degree

Two experimental groups

Specified Target Problem
- Have a specific problem in mind when reading the example
- "Homework" type task

Unspecified Target Problem
- Study now to solve an unspecified problem later
- "Quiz" type task



- Each subject underwent the protocol twice, seeing a total of four different worked examples and two target problems

Measures

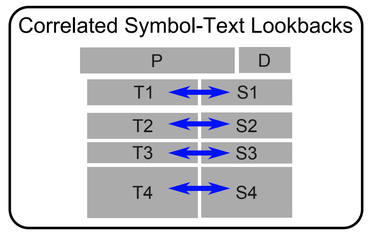
Where do subjects spend the most time looking?

Text fixation time asymmetry

$$a_{\text{text}} = \frac{T_{\text{text}} - T_{\text{symbols}}}{T_{\text{text}} + T_{\text{symbols}}}$$

-1 entire time looking at symbols; 0 equal time looking at text and symbols; +1 entire time looking at text

Do students try to link text and symbol information together, or do they scan them separately?

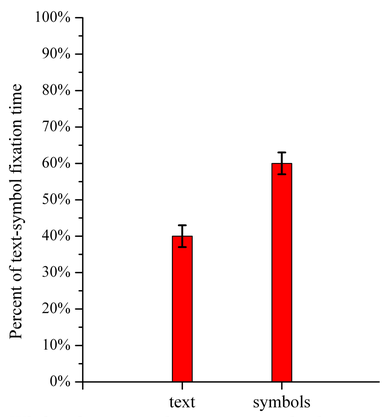


Do students focus primarily on symbols at the expense of the text?

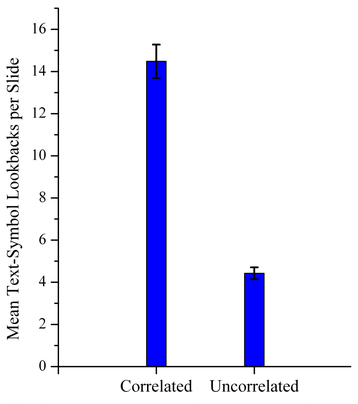
Start Region

End Region	P	D	T	S
P	--	498	368	478
D	531	--	144	378
T	334	152	783	1620
S	456	398	1632	2857

There are nearly as many transitions between text and symbols (3252) as there are within them (3640).



While they spend more time looking at symbols, students still spend a significant fraction of their time looking at the text explanations.



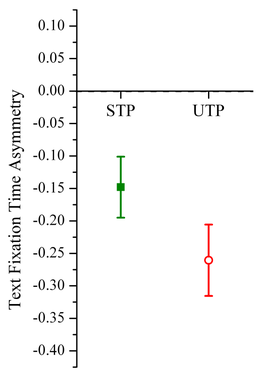
Students are not merely scanning the text and symbols separately; looking between corresponding text and symbol blocks dominates the text-symbol lookbacks.

Students look between symbol and text regions nearly as often as within them.

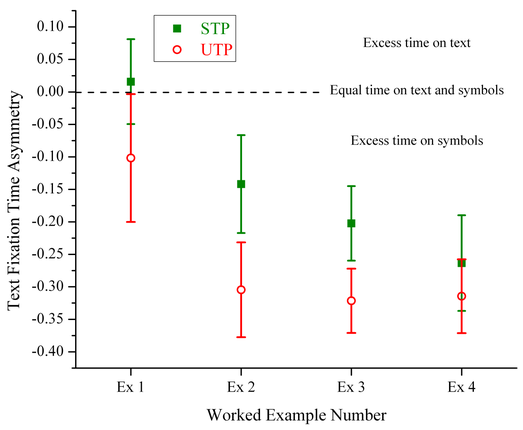
Students spend significant time reading the text explanations.

In addition, the dominance of correlated transitions between text and symbols suggests they are processing *both* types of information together.

Did having a specific problem in mind change student focus?



The difference in group means integrated over all examples is not statistically significant...



...However, looking at each example independently reveals a highly suggestive pattern. While there is significant variability among examples, in every case the specified target problem group spent more time in the text than the unspecified target problem group.

The aggregate means are not statistically distinguishable.

Treated independently, the examples show a consistent shift to greater text time for the specified target group.

Conclusions

Contrary to our expectations, students spend significant time processing both text and symbolic manipulations in worked examples.

Students do not merely scan text and symbolic information independently. Their gaze patterns are instead characterized by many transitions between the two types of information.

While no definitive result was obtained for the effect of having a specific problem in mind, the data are suggestive of a shift toward more time processing text.

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