How prompting force diagrams can push students away from problem-solving expertise

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Prompting Free-Body Diagrams

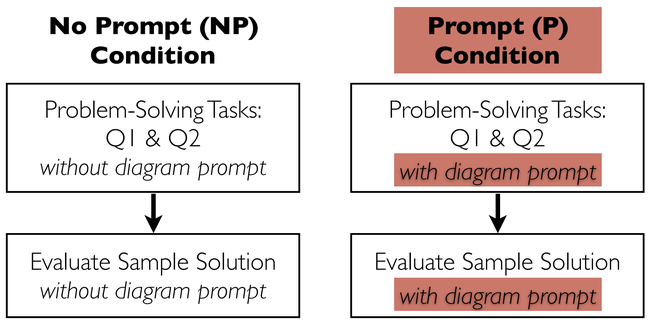
Heckler (2010) found that prompting students to draw free-body diagrams (a standard part of problem-solving procedures) before solving problems increased use of standard procedures and discouraged intuitive solutions.

We replicate and extend Heckler's paradigm, investigating the effect of prompts to draw diagrams on (i) problem-solving approaches, (ii) answer correctness, and (iii) evaluation of informal solutions.

Research Design

Intro mechanics for pre-med, life sciences at a small, private university.
($n_{NP} = 71$, $n_P = 69$)

Students worked individually during first 20 min. of final discussion section.



Summary of Findings

Prompting free-body diagrams leads students to formal procedures.

- Prompting diagrams decreases use of conceptual shortcuts that demonstrate problem-solving expertise.
- Conceptual shortcuts more correct than standard procedural approaches; potentially explains Heckler's (2010) finding that prompting decreases correctness.
- Prompting diagrams lowers student ratings of sample informal solution.
- For students who did not use formal procedures in their own problem solving, prompted students more often cite violation of formal approach in sample informal solution.

Tasks and Sample Responses

Problem-Solving Tasks (Q1 & Q2)

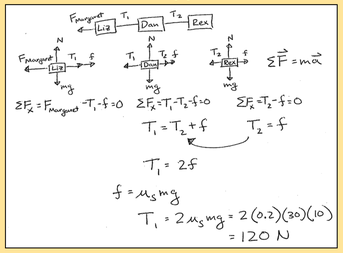
Example: Q1 ("Train")

Three siblings, Margaret, Dan, and Liz, are playing in the basement. With some rope, they attached three boxes together in a line like a train. Liz sits in the first box, Dan in the second, and they put the dog Rex in the third box. Margaret grabs on to the first box and pulls the "train" around the basement. When the kids (and the dog) are sitting in their box, each box has a total mass of 30 kg, and the coefficient of friction for the boxes on the basement floor is uk = 0.2. At one point, Margaret is pulling horizontally and the "train" is moving with constant velocity $v = 2.0$ m/s on the level basement floor.

(a) Draw a free body diagram clearly indicating the forces on Dan's Box.

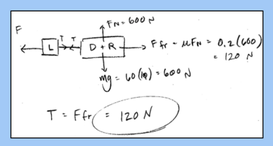
(b) With how much force is the rope from Liz's box pulling on Dan's box? Show your work.

Formal Approach



- General approach analyzing **each separate box**
- Computationally complex

Conceptual Shortcut



- Problem-specific conceptual shortcut to **combine boxes**
- Simplifies calculations

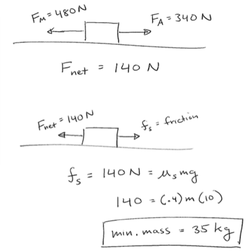
Sample Informal Solution Rating Task

A student has written their solution to a problem in the box below. You will be asked to rate this student's solution below.

Mary Kate is pushing on a box with a force of 480 N in one direction and Ashley is pushing the box with a force of 340 N in the opposite direction. The box is not moving or beginning to move. There is friction between the box and the floor, and the coefficient of static friction is $\mu_s = 0.4$ and the coefficient of kinetic friction is $\mu_k = 0.25$.

(a) Draw a free body diagram clearly indicating the forces.

(b) What is the minimum mass that the box can be in order for it to remain motionless? Show your work.



How would you rate this student's solution?

Very Bad	Bad	OK	Good	Very Good
○	○	○	○	○

Explain your rating:

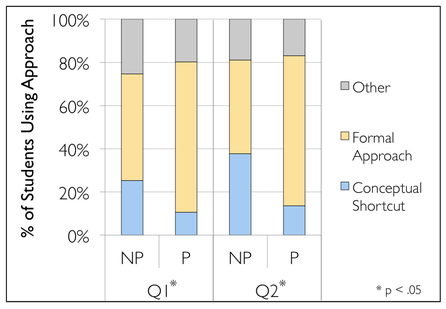
Student written explanations that cite violations of formal approach

- "$F_{net} = 0$, not 140 N"
- "Should write Newton's 2nd law: $F_{net} = ma$."

Results

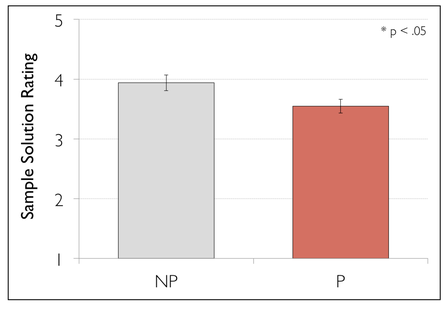
Students who receive a diagram prompt (P) are less likely to use Conceptual Shortcuts over standard Formal Procedures on Q1 and Q2.

(replicates Heckler (2010))



Students who receive a diagram prompt (P) rate the informal sample solution lower.

(1: "Very Bad" to 5: "Very Good")



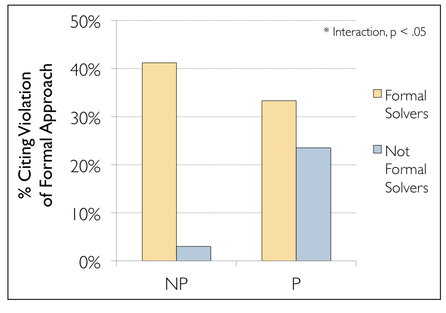
Combine Boxes is more likely to lead to correct answers.

Approach	Percent Correct	
	Q1*	Q2
Conceptual Shortcut	73%	74%
Formal Approach	48%	64%
Other	0%	4%

* p < .05

Students who used the typical formal approach on Q1 and Q2 (*Formal Solvers*) were equally likely to cite a lack of formality in either condition.

For students who were *Not Formal Solvers*, the diagram prompt increased citation of violations of the formal approach.



References and Acknowledgements

Heckler, A. F. (2010). Some Consequences of Prompting Novice Physics Students to Construct Force Diagrams. International Journal of Science Education, 32(14), 1829–1851.

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