Do Problem Diagrams Matter? Answers from MOOC using AB Experiment

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Abstract

While it is common practice to accompany physics problem with a diagram, recent studies have found that in many cases the diagram does little to assist problem solving, and may reduce the incentive for students to draw their own diagram[1-3]. We conducted a series of 6 experiments in our edX MOOC 8.MReVx to answer the following questions:

- How valuable is a "non-essential" diagram (that contains no information not in text) for solving a physics problem?
- Can we encourage students to draw their own diagram by taking away the problem diagram?
- How do students of various physics proficiencies react to the adding/removing of a problem diagram?
- What types of problems require a diagram more than others?

Experiment Design

In 6 experiments involving two questions each, students are randomly partitioned into two groups. Each group receives one problem with a diagram and the other problem without, reversing assignment between groups. After each problem, a survey question is presented to determine if they drew a diagram while solving the problem.

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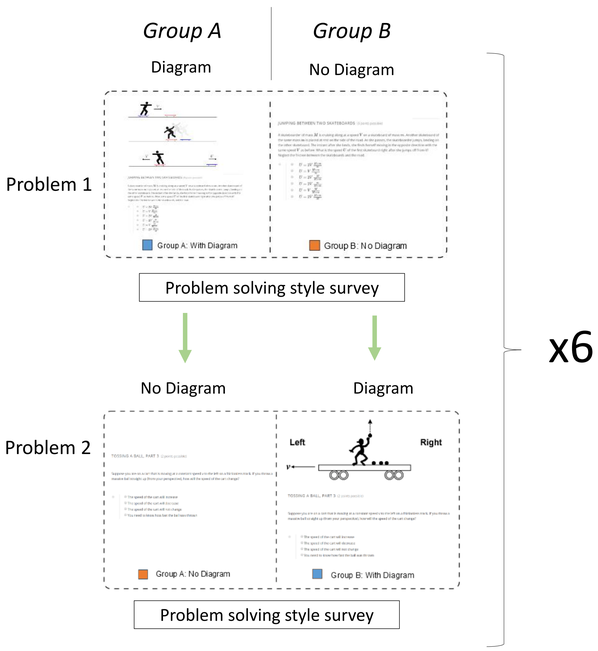


Problem solving style survey:

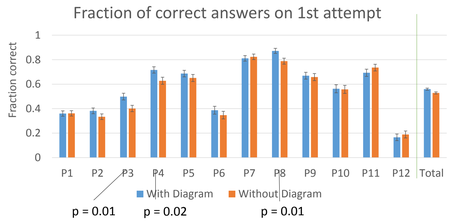
When solving this problem, (check all that apply)

- ○ I drew one or more diagrams
- ○ I wrote down some equations
- ○ I did the problem entirely in my head
- ○ I used some other means to solve the problem

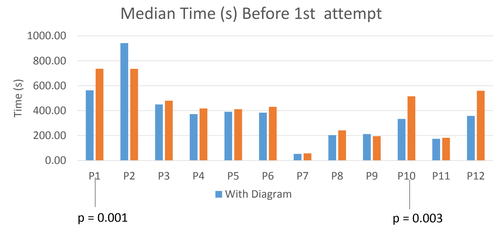
References:

[1] A. Maries and C. Singh, 2013 Phys. Educ. Res. Conf. Proc. 31 (2014).
[2] A. Maries and C. Singh, 282 (2013).
[3] S.-Y. Lin, A. Maries, and C. Singh, **250**, 250 (2013).
[4] K. F. Colvin, J. Champaign, A. Liu, Q. Zhou, C. Fredericks, and D. E. Pritchard, Int. Rev. Res. Open Distrib. Learn. **15**, 1 (2014).

Q: Do diagrams make problem easier? A: Only occasionally.

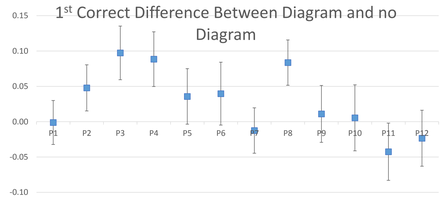


Including a diagram increased the overall likelihood of answering correctly on the first attempt by 3%. 3 out of the 12 problems are sensitive to the condition.



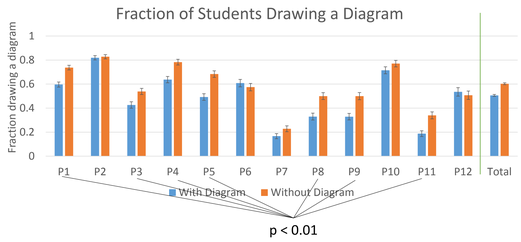
The median time before first attempt is significantly longer for the no-diagram group on only two problems. (Mann-Whitney U test)

Note: The difference in medians does not reflect population difference (p-value from U-test) when the sample distributions are different.

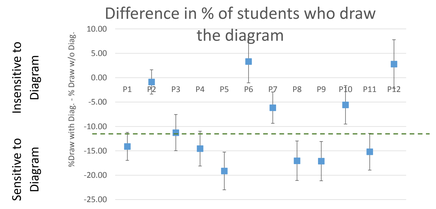


The increase in 1st attempt correct rate between the diagram and no diagram condition is much more significant for some problems than others, and averages 56% vs. 53% overall.

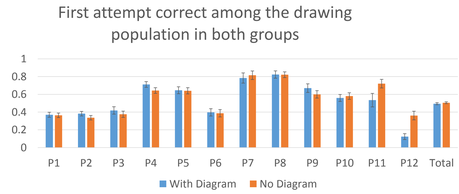
Q: What fraction of students drew their own diagrams? A: 50% drew their own diagrams even when given one! (And 60% when not)



On over half of the problems, students are significantly more likely to draw their own diagram during problem solving.



We plot here the difference in the percentage of students who drew their own diagram between the diagram and no diagram condition. Half of the problems showed a big difference .



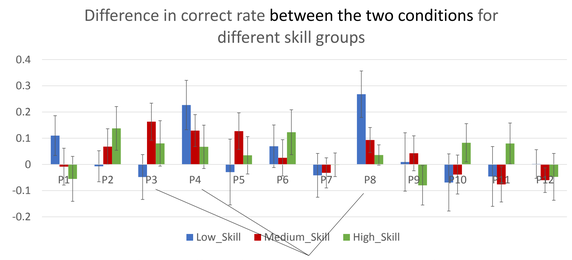
Students who drew a diagram when given one performed equally well on all except 2 problems, compared to students who drew a diagram when not given one.

Q: Are weaker students more sensitive to the absence of a diagram? A: Problem difficulty, sometimes. Decision to draw diagram, no.

Measuring Students' physics ability using Item Response Theory (IRT).
Students' physics ability was measured by IRT based on performance over the entire course. IRT ability θ is a normal distribution with zero mean and standard deviation of 1. [4]

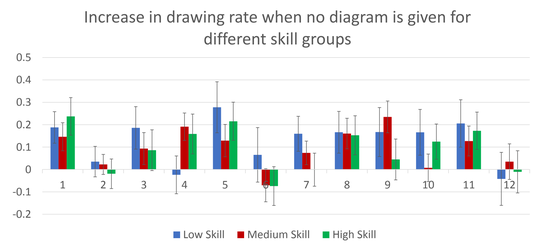
In this study we categorize students based on the following criteria:

Low skilled students: θ < -0.5
Medium skilled students: -0.5 <= θ < 0.5
High skilled students: θ >= 0.5



Significantly different from zero for low or medium skilled students only ($p < 0.05$)

For the high skill group, none of the differences were significantly larger than zero. For median and low skill groups, the diagram condition has significant difference on three problems

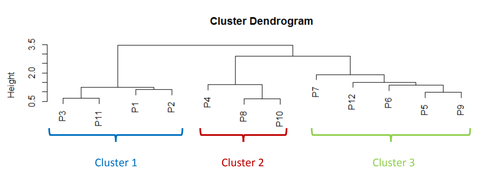


Students elect to draw a diagram (if none given) about 10% more often when none is given. This election does not show any consistent difference between the three skill groups.

Q: What kind of problems need a diagram more than others? A: Either spatially complex or involving ideal physics objects.

Characterizing the problems:
We asked 5 physics experts who are also experienced teachers to evaluate the 12 problem/diagram pairs on a 1-3 scale on 8 criteria:

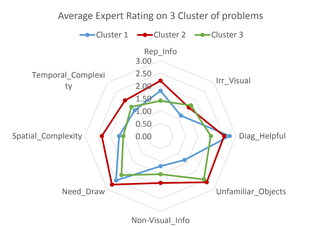
- Important information in the diagram
- Irrelevant information in the diagram
- Overall helpfulness of the diagram
- Type of objects involved in the problem
- Non-visual information in the problem
- Spatial Complexity of the Problem
- Temporal Complexity of the Problem
- Overall necessity to draw a diagram



A cluster analysis reveals that experts' ratings of the 12 problems form 3 clusters.

Problem	Cluster	Difficulty Sensitive	Time Sensitive	Draw Sensitive
P1	1	0	1	1
P2	1	0	0	0
P3	1	1	0	1
P11	1	0	0	1
P4	2	1	0	1
P8	2	1	0	1
P10	2	0	1	0
P5	3	0	0	1
P6	3	0	0	0
P7	3	0	0	0
P9	3	0	0	1
P12	3	0	0	0

Most of the problems that showed some sensitivity to the diagram condition fell in the first two clusters.



Cluster 1: Problems involving ideal physics objects such as blocks and pulleys.
Cluster 2: Problems that have high visual complexity and unfamiliar objects
Cluster 3: Problems involving real-world objects and visually simple.