CLASSROOM DEMONSTRATIONS: LEARNING TOOLS OR ENTERTAINMENT?

Catherine H. Crouch
Harvard University

Swarthmore College
19 April 2002

Goals of demonstrations

- **Educate**
- **Motivate**

Are these goals met?

Outline

- **Background**
- **Study: vary mode of presentation**
- **Results: impact on student understanding**
- **Conclusions**

Background

- **Psychology research: people remember what they expect to see**

- **Education research: students may not learn much from demonstrations**

Background

Research on learning from demonstrations:

- **Ability to predict outcome improves somewhat by seeing demonstration**
- **Understanding of concepts does not!**

P. Kraus, *Ph. D. thesis*, University of Washington, 1997

Background

Research on learning from demonstrations:

- **Demonstrations do not help students change incorrect ideas**

I. A. Halloun and D. Hestenes, *Am. J. Phys.* 53, 1056 (1985)

Background

Research shows value of engaging all students

- **think**
- **explain ideas**
- **discover misunderstandings**
- **ask questions**

Background

Research on learning from demonstrations:

- **Sequences of interactive demonstration-based activities produce learning gains**
- **Replaces one hour of lecture per week**

D. Sokoloff and R. Thornton, *Phys. Teach.* 35, 340 (1997)

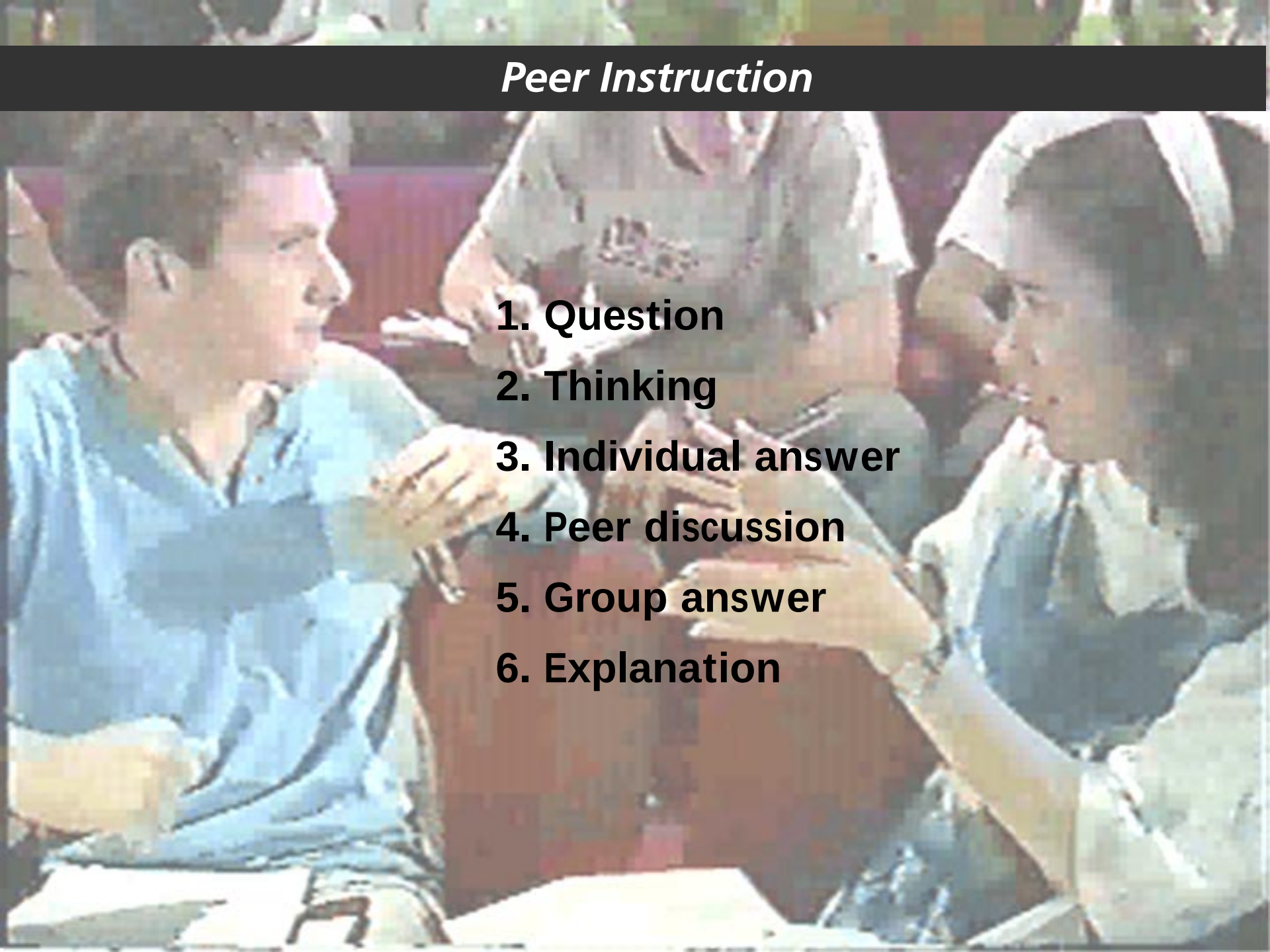
Can demonstrations be more educational?

How else can demonstions be improved?

Can demonstrations be more educational?

- **Peer Instruction: increase engagement by interspersing lectures with questions**

Peer Instruction



1. Question
2. Thinking
3. Individual answer
4. Peer discussion
5. Group answer
6. Explanation

Can demonstrations be more educational?

- **Peer Instruction: increase engagement by interspersing lectures with questions**

- **Demonstrated improvement in student understanding of lecture material**

Catherine H. Crouch and Eric Mazur, *Am. J. Phys.* 69, 970 (2001)

Can demonstrations be more educational?

- **Get students thinking:**

Can demonstrations be more educational?

- **Get students thinking: ask for predictions**

Can demonstrations be more educational?

- **Get students thinking: ask for predictions**
- **Create opportunities to explain and ask: students record and discuss predictions**

Can demonstrations be more educational?

- **Get students thinking: ask for predictions**
- **Create opportunities to explain and ask: students record and discuss predictions**
- **Confront and resolve: students rethink prediction after observation**

Research strategy

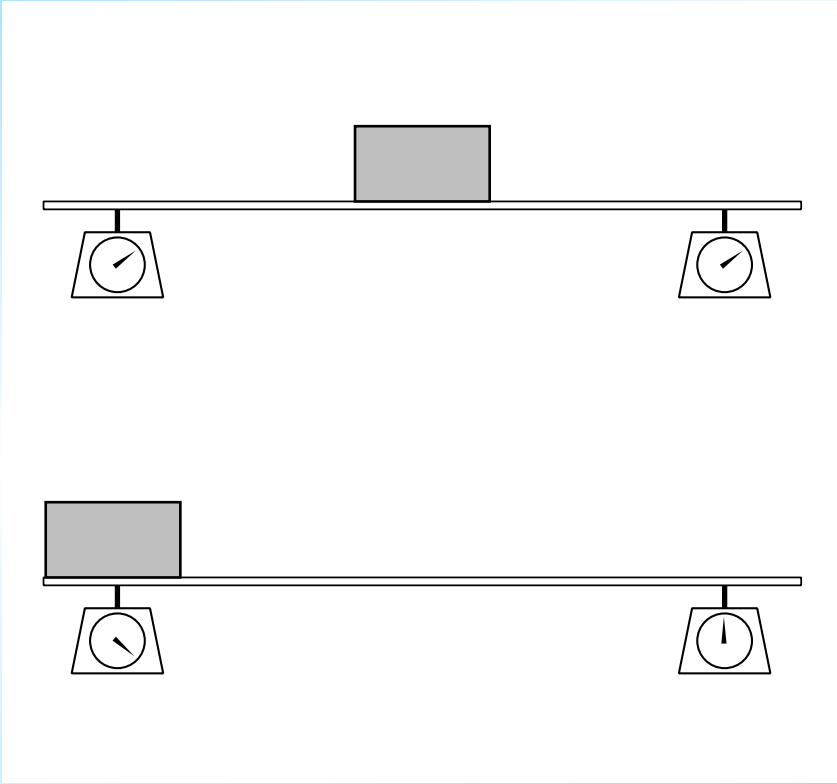
7 demonstrations presented to 7 sections ($N \approx 15$) of introductory physics class in one of 4 ‘modes’:

Research strategy

7 demonstrations presented to 7 sections ($N \approx 15$) of introductory physics class in one of 4 'modes':

- **demonstration not shown**
- **traditional presentation**
- **students predict before demonstration**
- **students predict, compare, and discuss**

Sample demonstration



Sample demonstration

A plank of negligible mass is supported at its two ends by platform scales. When a block of metal is placed at the center of the plank, halfway between the scales, the scales have the same reading x. If the metal block is now placed over the right-hand scale, the two scale readings are:

1. right scale = x, left scale = x
2. right scale = x, left scale = 0
3. right scale = 0, left scale = x
4. right scale = 2 x, left scale = 0
5. right scale = 0, left scale = 2 x
6. right scale = 1.5 x, left scale = 0.5 x
7. right scale = 0.5 x, left scale = 1.5 x
8. none of the above

Sample demonstration

A plank of negligible mass is supported at its two ends by platform scales. When a block of metal is placed at the center of the plank, halfway between the scales, the scales have the same reading x. The metal block is now placed over the right-hand scale.

---

1. What are the two scale readings now? Why?

---

2. Record your observation of the demonstration.

---

3. Compare your prediction (1) to your observation (2). Do they agree?

__ Completely __ Mostly __ Somewhat __ Not at all

---

4. After discussing your prediction and the demonstration with your neighbors, record why your prediction and the reasoning behind it were correct or incorrect (use the back of this sheet if you need more room).

Sample demonstration

A plank of negligible mass is supported at its two ends by platform scales. When a block of metal is placed at the center of the plank, halfway between the scales, the scales have the same reading x. The metal block is now placed over the right-hand scale.

---

1. What are the two scale readings now? Why?

PREDICTION

---

2. Record your observation of the demonstration.

---

3. Compare your prediction (1) to your observation (2). Do they agree?

__ Completely __ Mostly __ Somewhat __ Not at all

---

4. After discussing your prediction and the demonstration with your neighbors, record why your prediction and the reasoning behind it were correct or incorrect (use the back of this sheet if you need more room).

Sample demonstration

A plank of negligible mass is supported at its two ends by platform scales. When a block of metal is placed at the center of the plank, halfway between the scales, the scales have the same reading x. The metal block is now placed over the right-hand scale.

---

1. What are the two scale readings now? Why?

PREDICTION

---

2. Record your observation of the demonstration.

OBSERVATION

---

3. Compare your prediction (1) to your observation (2). Do they agree?

__ Completely __ Mostly __ Somewhat __ Not at all

---

4. After discussing your prediction and the demonstration with your neighbors, record why your prediction and the reasoning behind it were correct or incorrect (use the back of this sheet if you need more room).

Sample demonstration

A plank of negligible mass is supported at its two ends by platform scales. When a block of metal is placed at the center of the plank, halfway between the scales, the scales have the same reading x. The metal block is now placed over the right-hand scale.

---

1. What are the two scale readings now? Why?

PREDICTION

---

2. Record your observation of the demonstration.

OBSERVATION

---

3. Compare your prediction (1) to your observation (2). Do they agree?

__ Completely __ Mostly __ Somewhat __ Not at all

DISCUSSION

---

4. After discussing your prediction and the demonstration with your neighbors, record why your prediction and the reasoning behind it were correct or incorrect (use the back of this sheet if you need more room).

Testing

- **Web-based test**
  - **questions identical to worksheets**
  - **graded solely on effort**

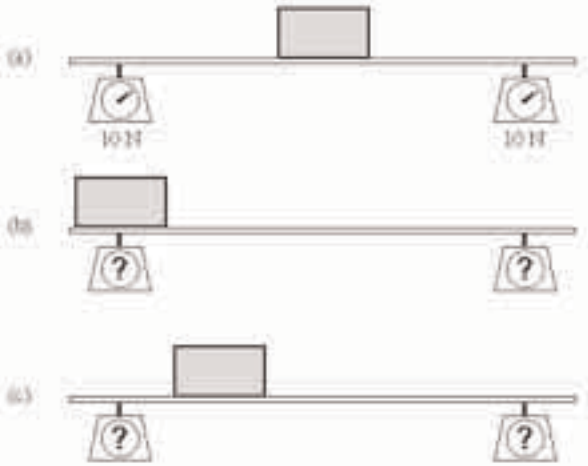
Testing

- **Web-based test**
  - **questions identical to worksheets**
  - **graded solely on effort**
- **Analyze responses for (N = 122, 7 questions):**
  - **demonstration outcome**
  - **physical understanding**

Testing

Physics 1 Third Computer Test

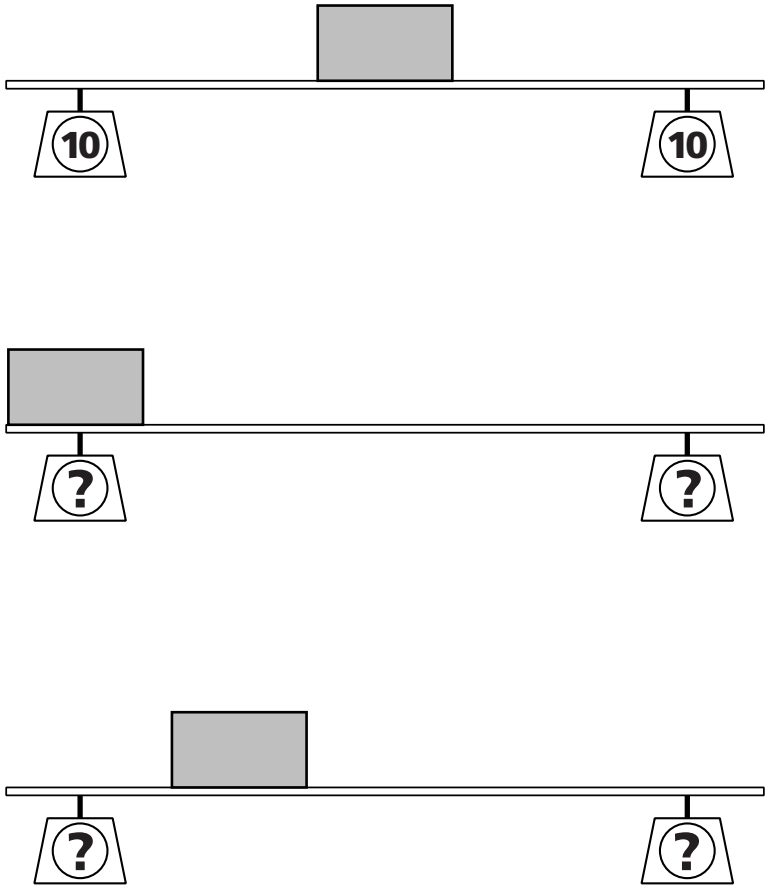
1 A plank of negligible mass is supported at its two ends by platform scales. When a block of metal is located at the center of the plank, halfway between the scales, the scales have the same reading of 10 N as shown in (a)



If the metal block is now placed over the left-hand scale, as in (b), what are the readings on the scales? Explain your answer briefly.

What are the readings when the block is placed halfway between the left-hand end and the center of the plank, as in part (c) of the diagram? Explain your answer briefly.

Testing



Results: Outcome of demonstrations

	correct outcome
no demo	
show	
predict	
reinforce	

Results: Outcome of demonstrations

	correct outcome
no demo	49%
show	
predict	
reinforce	

Results: Outcome of demonstrations

	correct outcome
no demo	49%
show	54%
predict	
reinforce	

Results: Outcome of demonstrations

	correct outcome	*P*-value
no demo	49%	–
show	54%	0.14
predict		
reinforce		

Results: Outcome of demonstrations

	correct outcome	*P*-value
no demo	49%	–
show	54%	0.14
predict	69%	< 0.001
reinforce		

Results: Outcome of demonstrations

	correct outcome	*P*-value
no demo	49%	–
show	54%	0.14
predict	69%	< 0.001
reinforce	69%	< 0.001

Results: Outcome of demonstrations

	correct outcome	*P*-value	*P*-value
no demo	49%	–	0.14
show	54%	0.14	–
predict	69%	< 0.001	0.001
reinforce	69%	< 0.001	0.001

Understanding affects 'memory'!

"As demonstrated in lecture, both scales will read 10N, regardless of where the center of mass is located. The platform and the metal block form one unit that is being measured, so the scales show two evenly distributed readings, no matter where the metal block is placed along the platform."

Understanding affects 'memory'!

- **Memory is a reconstruction at instant of recall, not like a video replay**
- **Fill in gaps in memory with information from schemas and scripts (mental models)**
- **Incorrect model can lead to inaccurate memory of scenario**

Results: Understanding

	fully correct	P-value	P-value
no demo	22%	–	0.32
show	24%	0.32	–
predict	30%	0.02	0.07
reinforce	32%	0.01	0.03

Results: Understanding

	fully correct	P-value	P-value
no demo	22%	–	0.32
show	24%	0.32	–
predict	30%	0.02	0.07
reinforce	32%	0.01	0.03

Results: Understanding

	fully correct	P-value	P-value
no demo	22%	–	0.32
show	24%	0.32	–
predict	30%	0.02	0.07
reinforce	32%	0.01	0.03

Results: Understanding

	concepts correct	P-value	P-value
no demo	24%	–	0.26
show	26%	0.26	–
predict	31%	0.04	0.14
reinforce	34%	0.01	0.07

Results: Cost vs. benefit

	time (min)	outcome gain	fully correct gain
show	11	5%	2%
predict	13	20%	8%
reinforce	21	20%	10%

Results: Cost vs. benefit

	time (min)	outcome gain	fully correct gain
show	11	5%	2%
predict	13	20%	8%
reinforce	21	20%	10%

Conclusions

- **Demonstrations without active engagement produce little gain in understanding**
- **Predicting outcome gives significant learning gains without costing time**
- **Reflection and discussion produce further improvement**

Collaborators: J. Paul Callan, Adam P. Fagen, Eric Mazur

Funding: National Science Foundation

Research: Students and staff of Physics 1
Demonstrations: Wolfgang Rueckner, Nils Sorensen
Discussion: Gay Stewart, Pamela Kraus, David Sokoloff

For a copy of this talk and
additional information:

http://mazur-www.harvard.edu

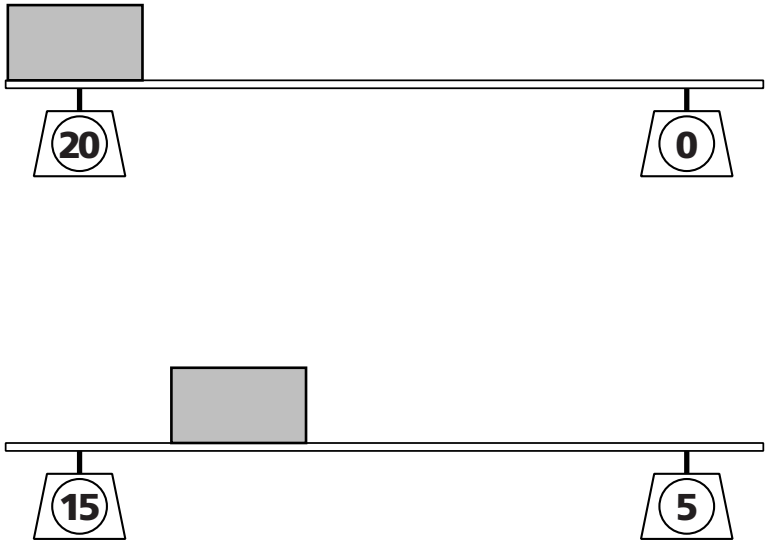
Background

- **Students don't necessarily know what the point is!**
- **Traditional demonstrations rarely engage students actively**
- **Demonstrations are unrelated to exams**

Roth *et al.*, *J. Res. Sci. Teach.* 34, 509 (1997)

Answers

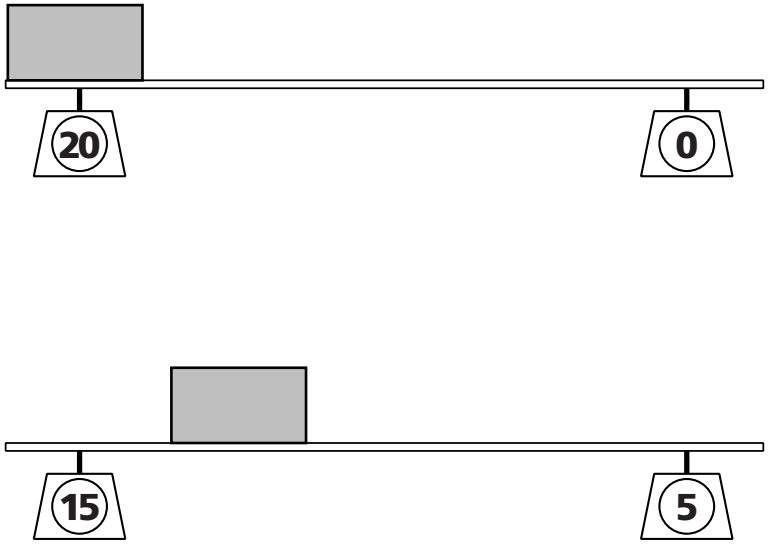
24% of students



correct (mentions torque)

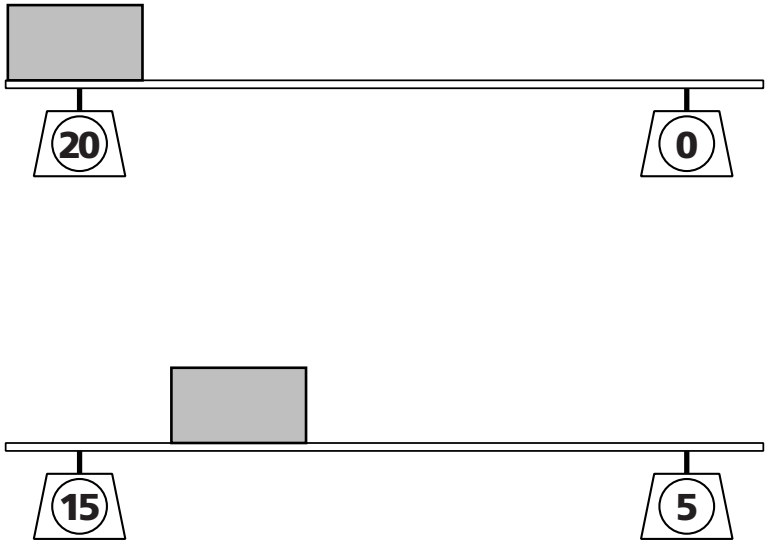
Answers

24% of students



correct (mentions torque)

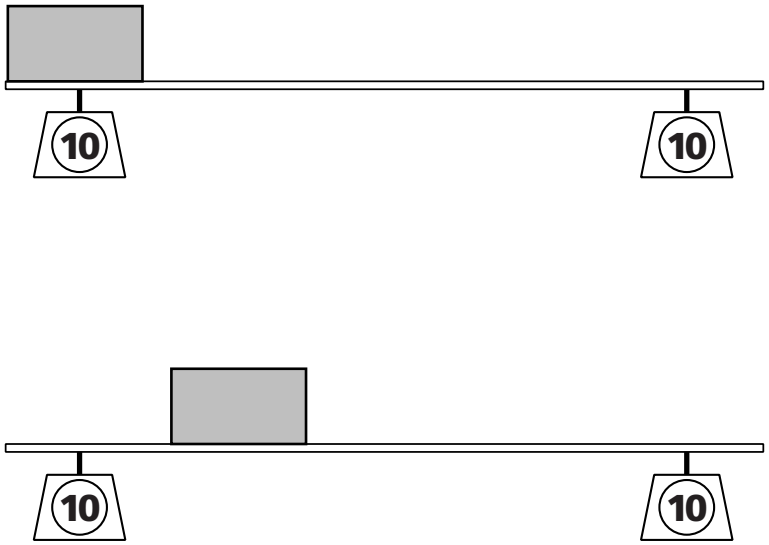
38% of students



proportional reasoning

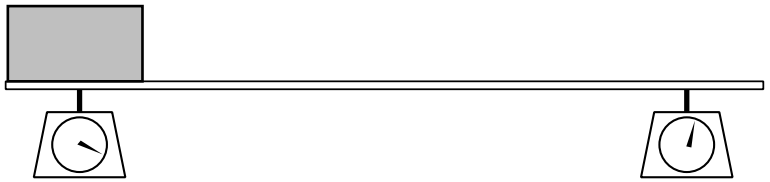
Answers

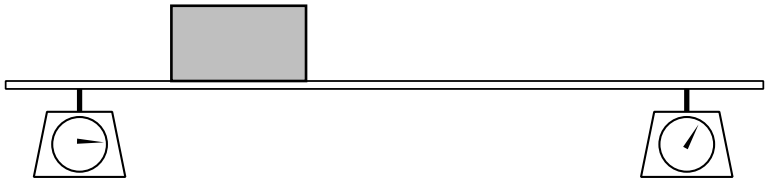
20% of students



independent of position

10% of students





qualitative reasoning

6% do not balance forces
2% give other incorrect answers