

# Using Models of Student Thinking to Predict Variability in Responses to Motion Questions



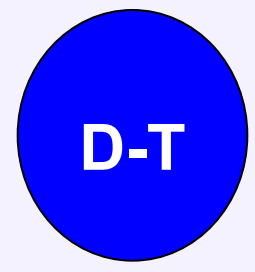
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## Model for Student Thinking about Motion

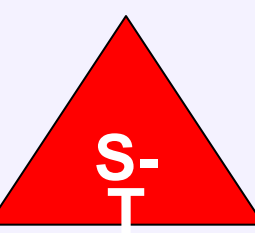
We adopt a simple resources-based model to characterize student thinking about motion. In contrast to asserting that students have fixed conceptions about the motion of objects, our resources-based model accounts for student reasoning in terms of fine-grained pieces of knowledge that students may or may not bring to bear on problems about motion.

### Three resources for making inferences about motion



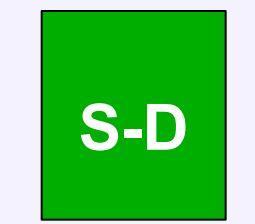
More distance implies more time

"I just know the farther you are away, the longer it takes to get there."



More speed implies less time

"If you do anything at a faster speed it will take less time to reach that destination."

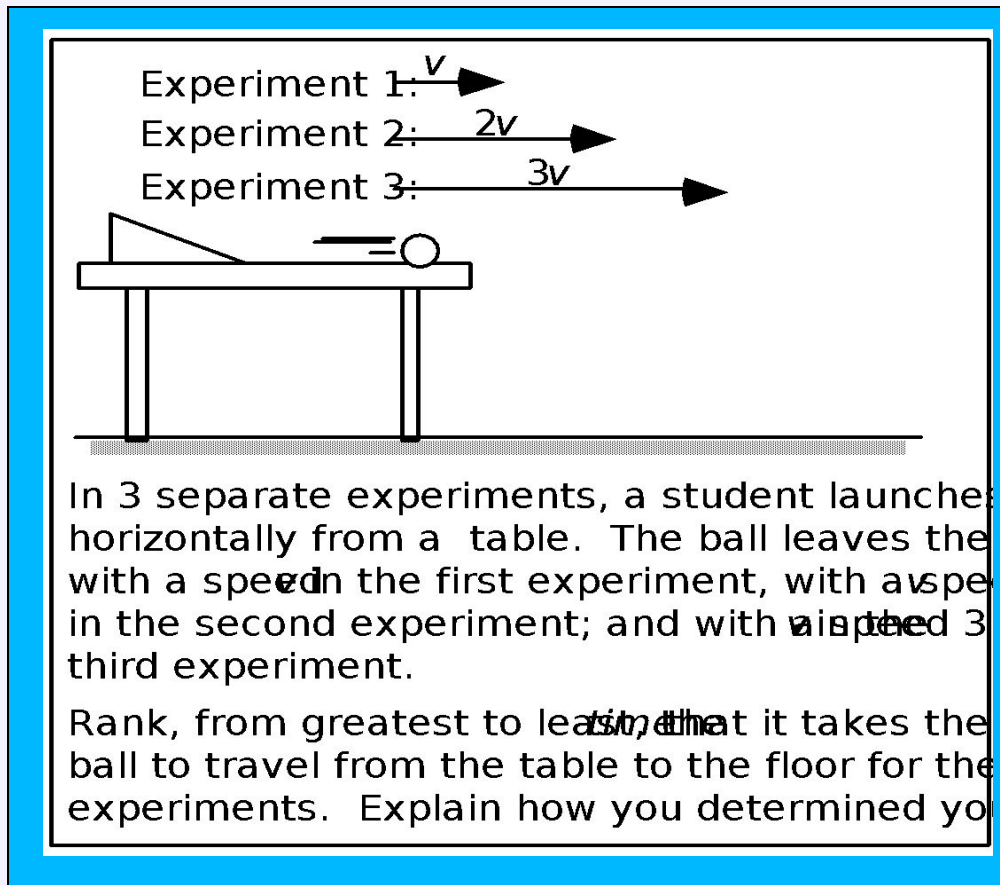


More speed implies more distance

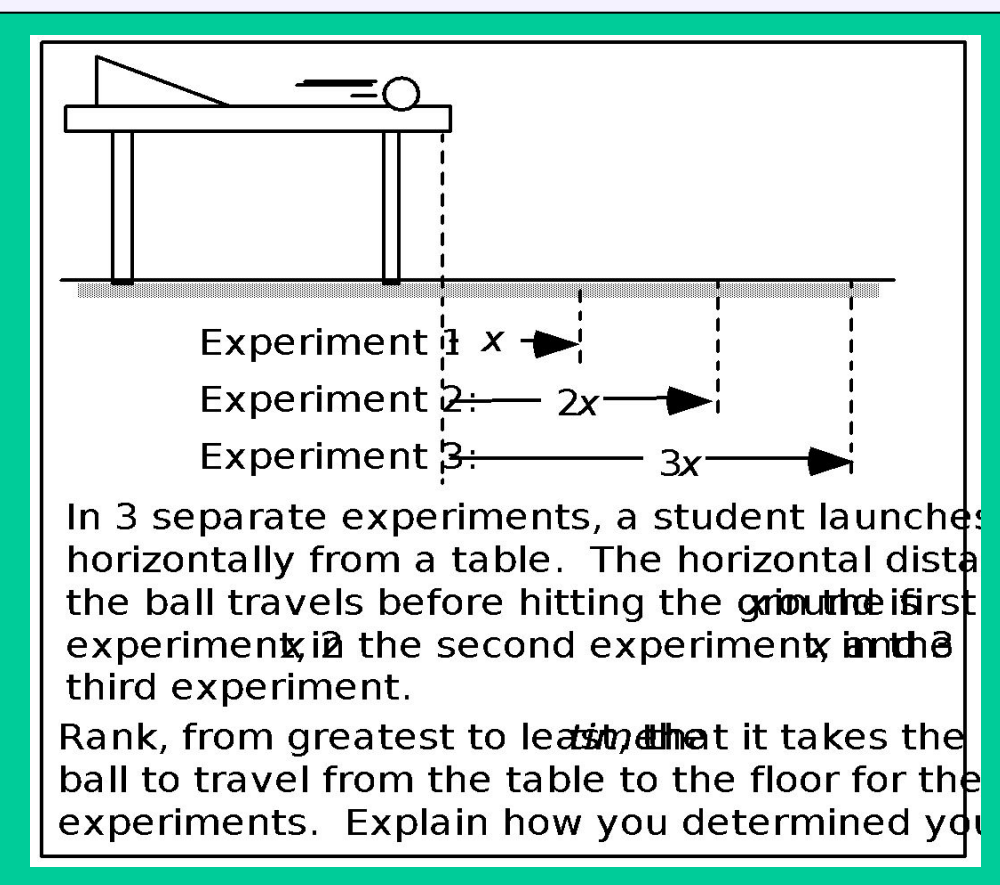
"The greater the distance traveled by the ball the greater the velocity"

## Experiment to Test Model-based Predictions

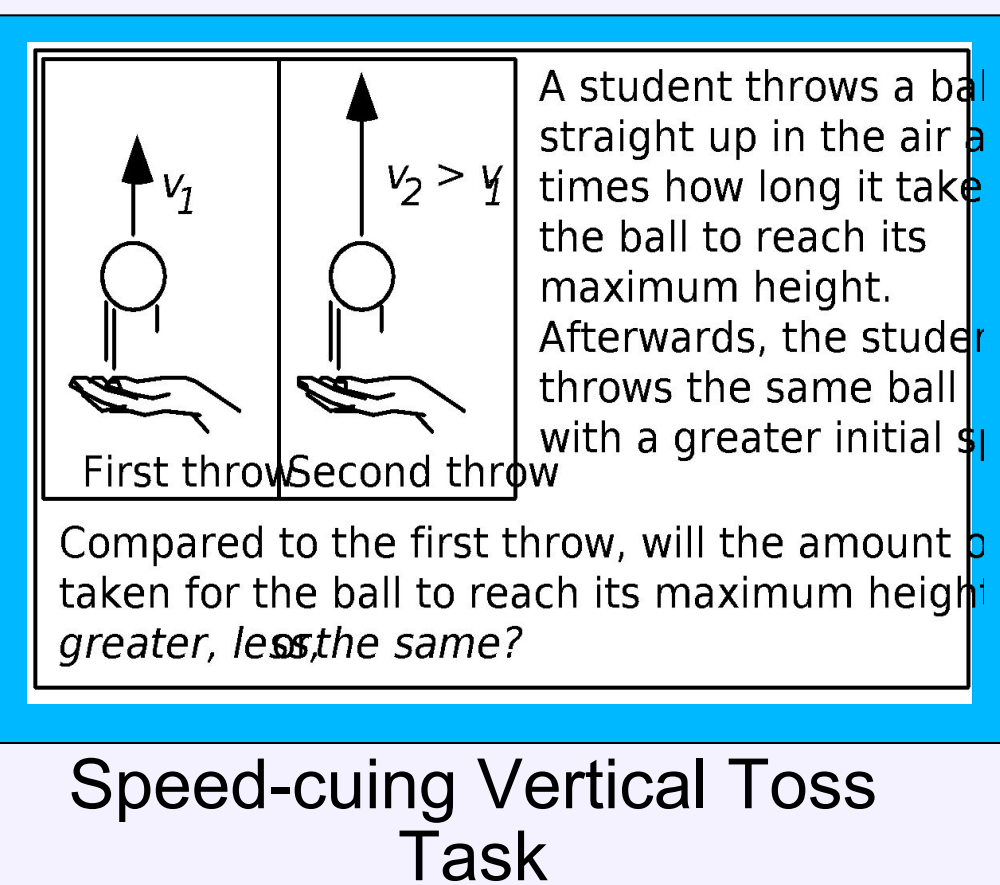
300 students enrolled in an algebra-based introductory physics course were given one of two variations on a survey about projectile motion - one that emphasized the object's **initial speed (blue)** and the other emphasized the **distance traveled (green)**



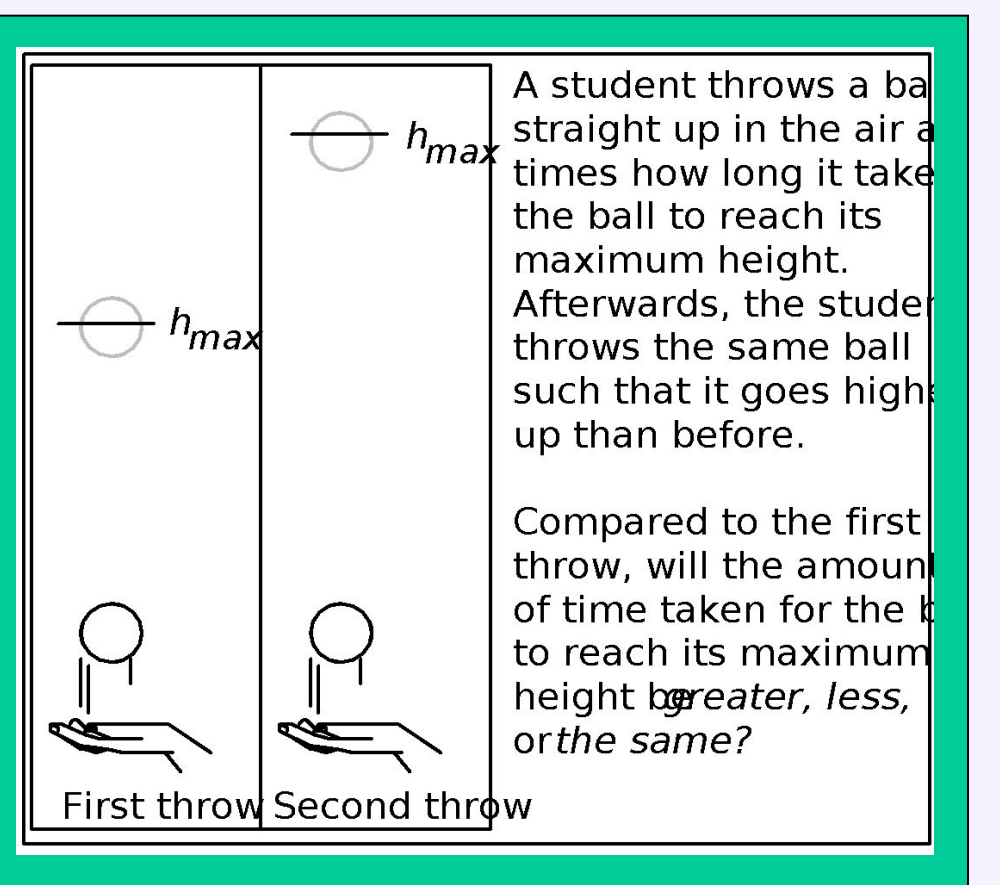
Speed-cuing Projectile Motion Task



Distance-cuing Projectile Motion Task



Speed-cuing Vertical Toss Task



Distance-cuing Vertical Toss Task



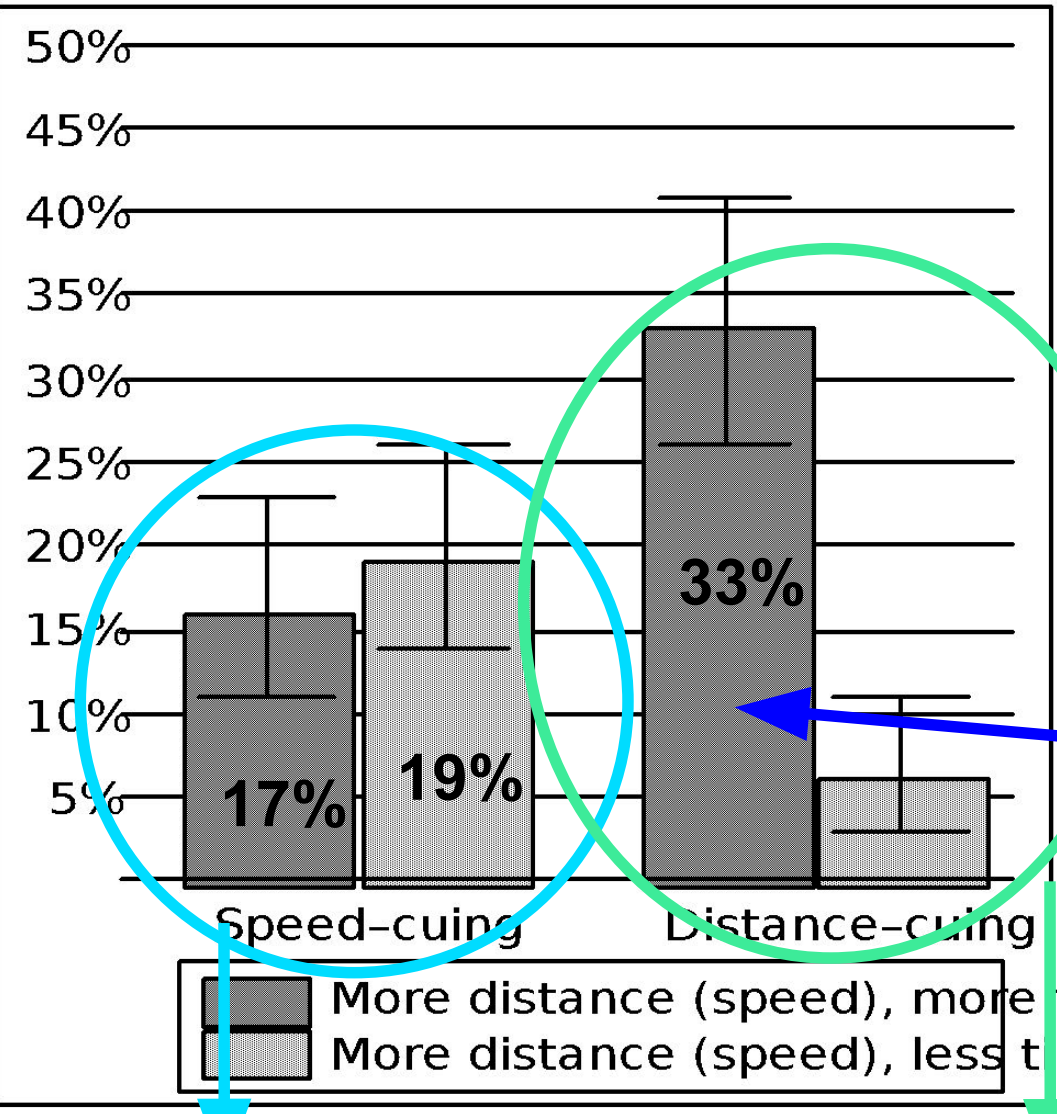
### Predictions:

Students given questions with the **distance cues** will be more likely to give answers and explanations consistent with **distance-time** resources. Those with **speed cues** will be more likely to answer consistent **speed-time** resources.

## Experimental Results: Cues affect student thinking in predictable ways

### Distributions of Students' Answers

#### Projectile Motion Questions



Students responded differently to the two variations of the problems.

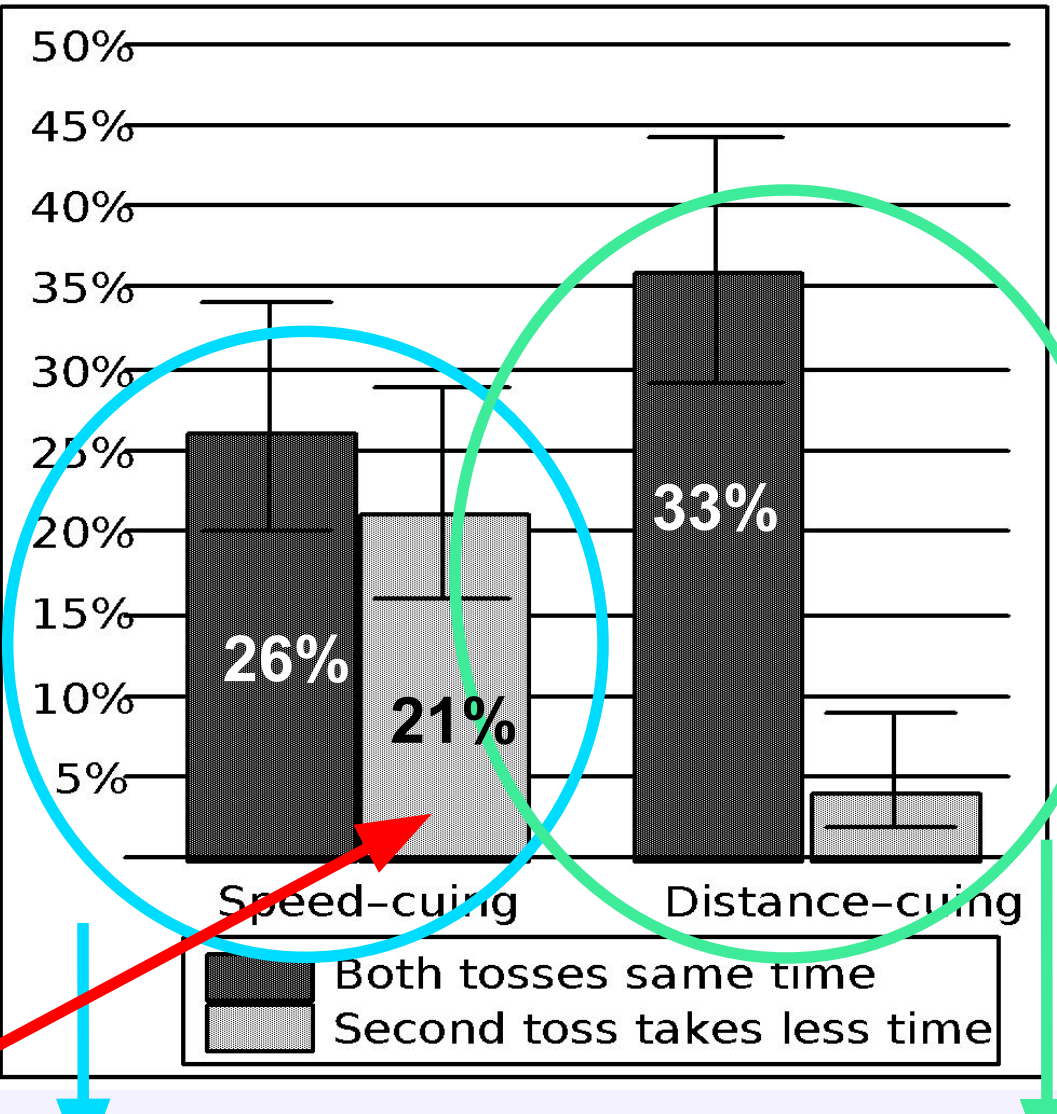
The different cues affected the **distribution of students' incorrect answers** only.

As predicted:

Distance cues increased number of students answering consistent with **distance-time** resources (33% vs 17% for speed cues) and nearly extinguished the other answer (6%)

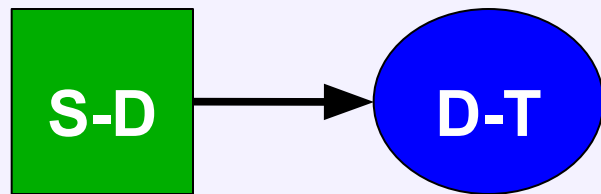
Speed cues increased the number of answers consistent with the **speed-time** resources (21% vs 4%)

#### Vertical Toss Questions

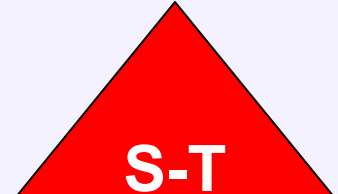


### Students' Written Explanations

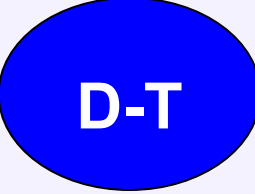
"Less speed means less distance traveled requiring less time."



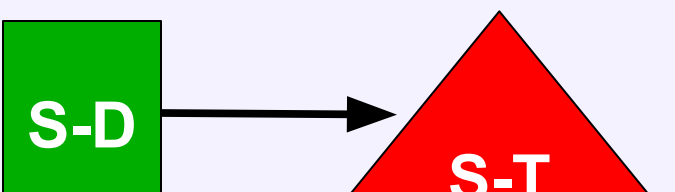
"Since the third ball is going the fastest it would take less time."



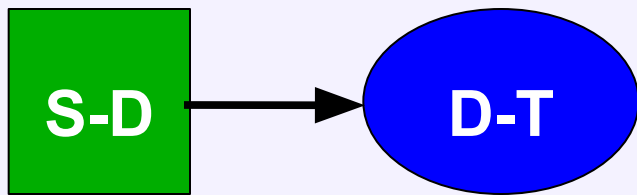
"Exp 3 has the greatest distance, so it will take the longest to get there."



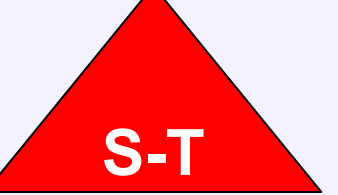
"The speed of the ball would have to be greater in order for it to go farther, so it will take less time for it go the farther distance."



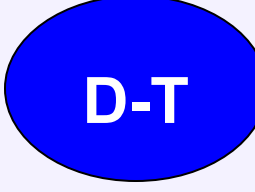
"It will take longer b/c w/ [sic] a faster initial speed, it will travel farther to a higher maximum height."



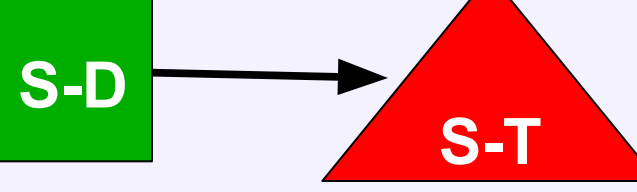
"I think it would take less time since the velocity is increased."



"Greater [time] because it travels a greater distance."



"The time for the ball to reach it will be less b/c it has a greater velocity so it will reach the higher distance faster."



## Alternative Student Explanations

### Vertical Toss Questions

"With more upwards vertical force applied to the ball, the 2<sup>nd</sup> throw will oppose gravity for a longer time."

"It will take longer for gravity to overcome the initial velocity"

Leads students to the right answer

### Projectile Motion Task

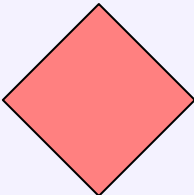
"The other two with higher velocity will take longer because they will fall more gradually."

"3v will take the longest because the [greater] velocity will carry it further and help resist gravity."

Leads to the wrong answer in the other task

An additional resource

"Going faster gives more staying power"



## Conclusions

The results of this experiment

- Highlight the context-dependent nature of student reasoning
- Demonstrate the potential for cognitive models to predict variability
- Suggest a need to develop improved research tools for characterizing context and measuring variability in student thinking.