Resources for Learning Robots

Facilitating the Incorporation of Mathematical Models in Students' Engineering Design Strategies

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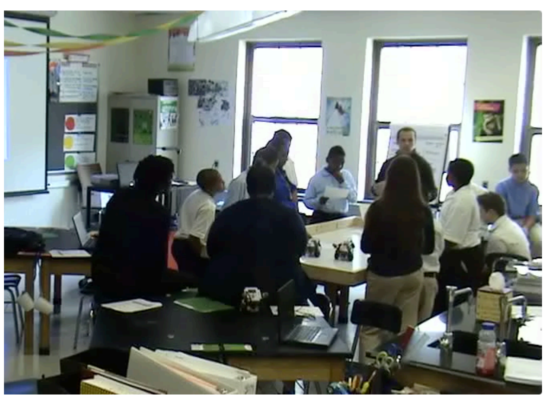
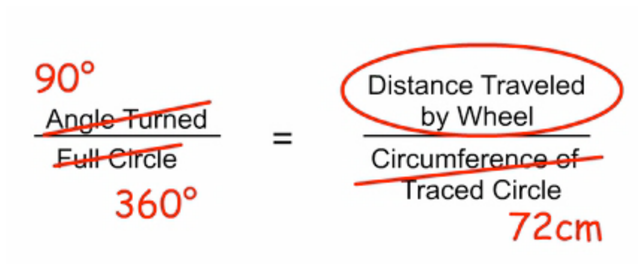
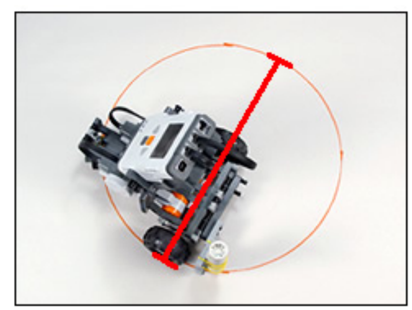




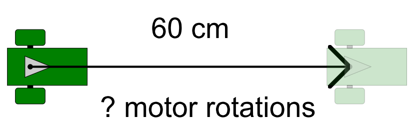


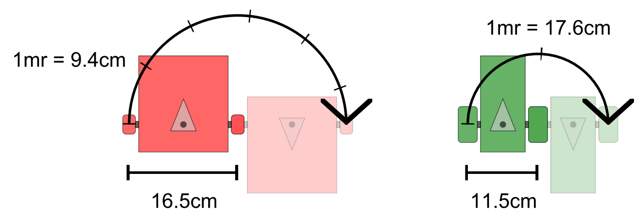
Why robotics? And what do I mean by “Learn Robots”?

Controlling Robot Movements

- **Patterns/relationships** are inspectable, manipulable, & reliable
  - So good for learning how students incorporate math as a resource (Schwartz et al., 2005)
  - Robot Movements ↔ Program Features ↔ Physical Features

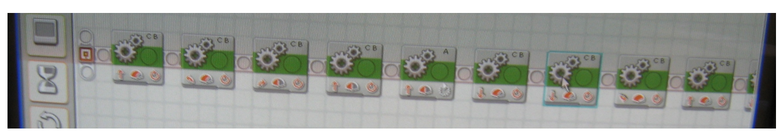
Distance = Motor Rotations × Wheel Circumference

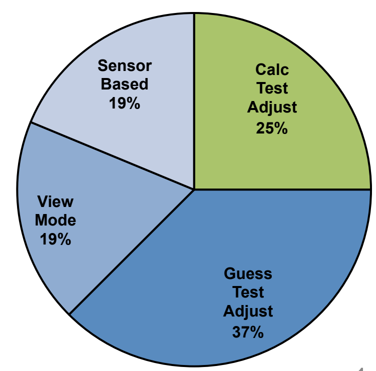




- Engaging BUT lends itself to **playing around** (guessing) (Silk et al., 2011)

Competitions encourage informal solutions, but most are **non-math-based**

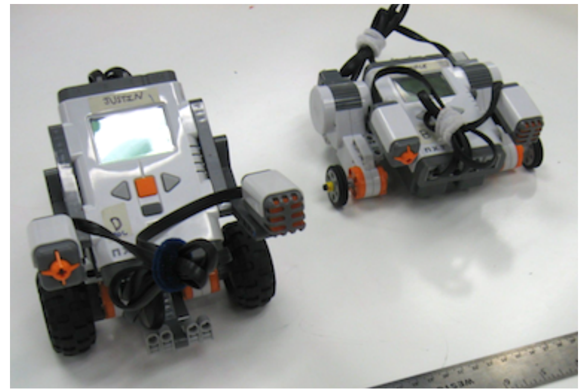


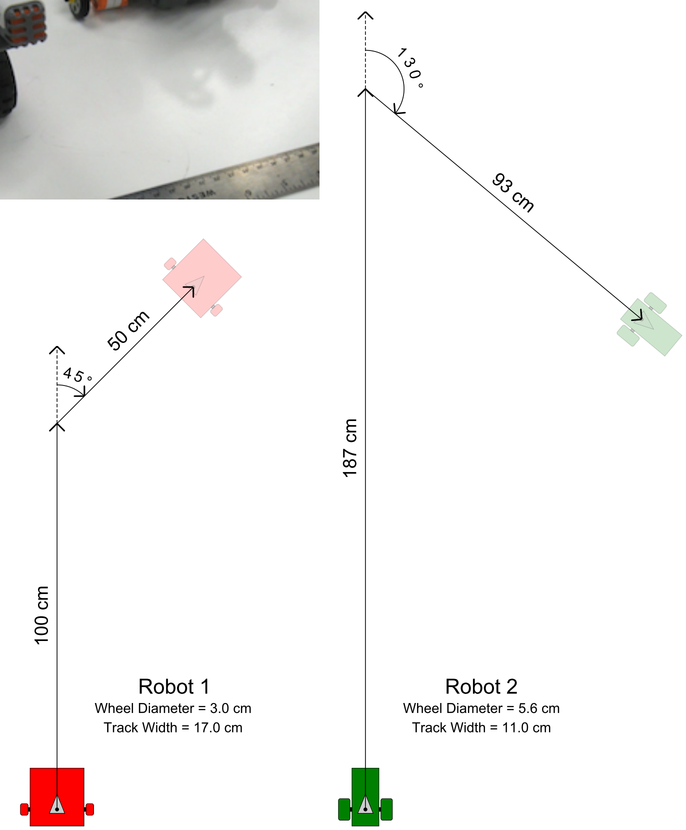


Study 1 – MEA Robot Instruction

Does facilitating use of mathematical resources improve understanding?

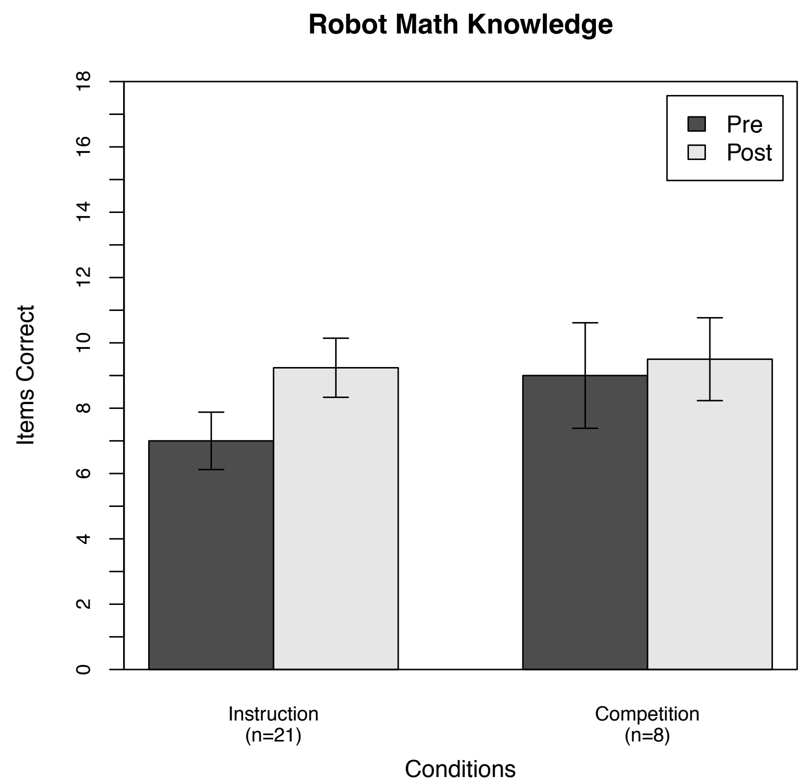
- Robot Synchronized Dancing
  - Develop a "toolkit" for a dance team captain
  - Model-Eliciting Activity (MEA) (Lesh et al., 2000)
- Urban STEM-focused middle school
  - 6th-9th grade, Met during elective period
- Participants
  - Students self-selected into groups
  - Instruction Group (n=21; 2 sections)
  - Competition Group (n=8; 1 section)
- Pre/Post Assessment (18-items)
  - A robot completes a move with 12 motor rotations and moves forward 14 centimeters. You modify the program to be 30 motor rotations. How far forward will it move now?



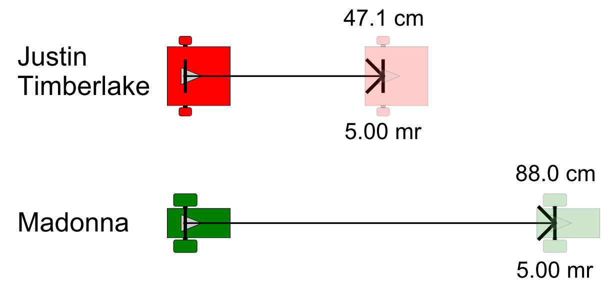


Study 1 – Pre-Post Test Results

- Repeated Measures ANOVA suggest significant effect of time and marginally significant interaction
  - Pre vs Post
    - $F(1,27) = 6.60$, $p = .01$
  - Interaction
    - $F(1,27) = 2.66$, $p = .11$
- Follow-up tests suggest that the ***Instruction*** Group is the only one that improves Pre-Post

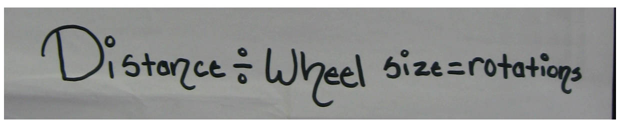


Study 1 – Contrasting Cases

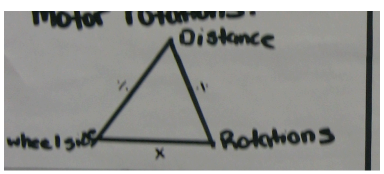


Team B1

- Scale Factor - Wheel Size Ratio
  – “Bigger wheels go farther because one rotation is larger”



- Unit Rate - Wheel Size
  – “would rather use the wheel size because distance doesn’t apply in turns and can be affected by outside factors”



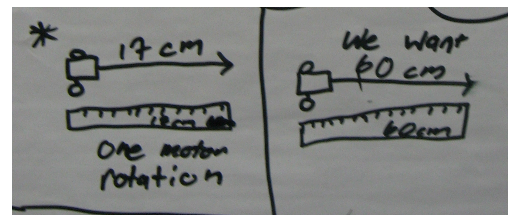
Initial Ideas

Revised Ideas

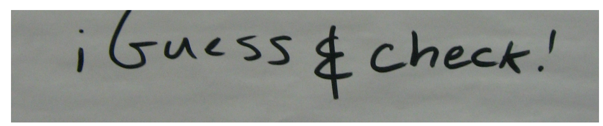
Final Ideas

Team A2

- Scale Factor - Distance Ratio
  – No robot physical parameters, just numerical steps



- Unit Rate - Distance in 1 Rotation
  – “We did 60 / 17 and got 3.52. We tested it and it was a little over. So we tried 3.48 and got 60 cm.”
  – Fine-tune beyond the math calculation



MECHANISTIC

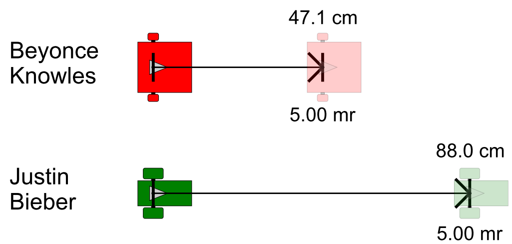
(Kaplan & Black, 2003; Russ et al., 2008)

CALCULATIONAL

(Thompson et al., 1994)

Study 2 – Framing Instruction

Do different framings of the use of mathematical resources improve understanding differently?



- Research setting 1-week in summer

- Participants
  - *Instruction* Groups (2 sections)
    - Students assigned based on time availability, but groups randomly assigned to condition
    - 5^{th}-7^{th} grades (16/18 in 5^{th} or 6^{th})
    - *Mechanistic* (n=10)
    - *Calculational* (n=8)
  - *Competition* Group (n=19; 2 teams)
    - 2 teams from local robot competition; 6^{th}-8^{th} grades (17/19 in 7^{th} or 8^{th})

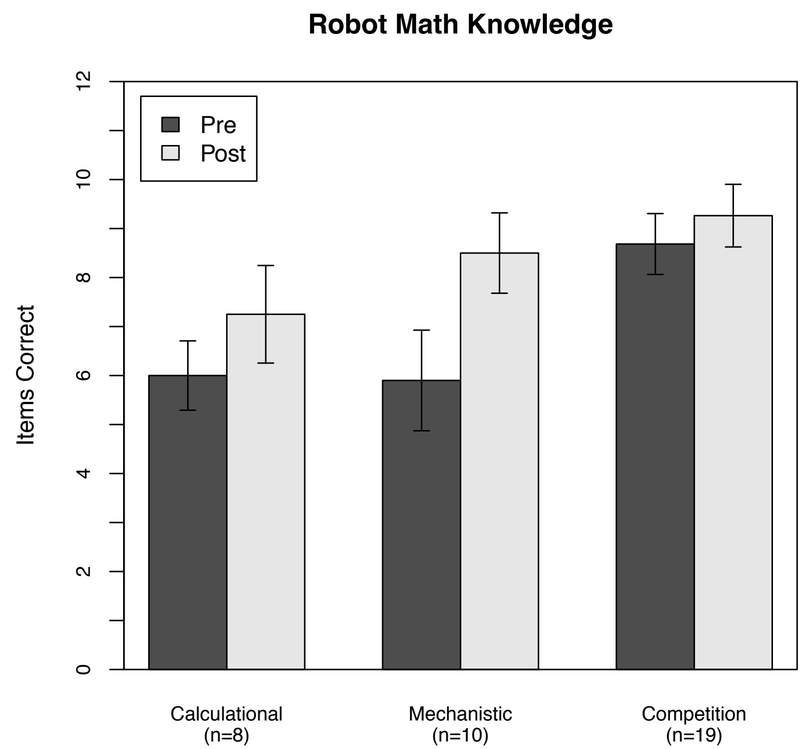
- Pre/Post Assessment (12-items)
- Post-Instruction Competition Task

- Mechanistic vs Calculational (Contrasting Instructional Resources and Framings)
  - Design Task Setup
    - Modeling intuitions (mechanistic) versus input-output focus (calculational)
  - Teacher Cases
    - Explanations of mechanisms (mechanistic) versus of empirical patterns (calculational)
  - Instructional Support
    - Focus on explaining what quantities means (mechanistic) versus on seeing patterns in data (calculational)

Study 2 – Pre-Post Test Results

- Repeated Measures ANOVA suggest significant effect of time and marginally significant interaction
  - Pre vs Post
    - $F(1,34) = 17.09$, $p < .001$
  - Interaction
    - $F(2,34) = 3.24$, $p = .052$

- Follow-up tests suggest that the ***Mechanistic*** Group is the only one that improves Pre-Post



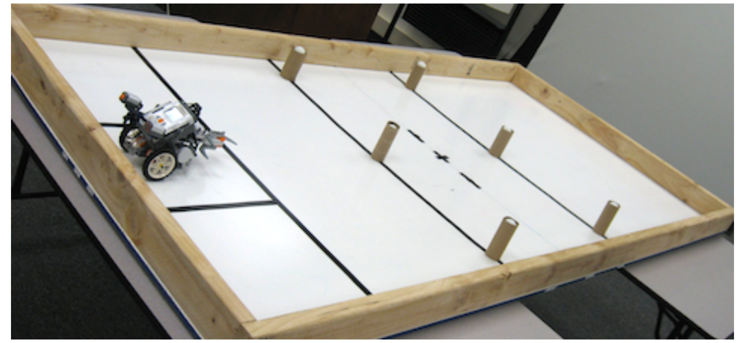
Study 2 – Whole Class Discussions

- Do *Calculational* group teams just do low-level procedural stuff? (tinkering or focused on completion?)
  - Connect procedures to situation
    - "We divide by 2 because Justin goes about twice as far"
  - Connect to each other's ideas
    - "It's showing the, um, like how, sort of like how the Green team had, divided by two, but we wanted it more exact number ... the more exact number of how much the time, of how much the speed is. It's a bit less than half the time."
  - Recognize when they don't have a solution or explanation
    - the "Feeling" strategy & "that's too smart"
  - **Limited by resources provided and affordances of task framing**
    - Don't use robot physical features or mental animations/images

NO!!

Study 2 – Competition Task

Did you use any of the strategies from this week?



Mechanistic (4/4 teams)

- Red Team
  - S1: We sort of first wanted to find the distance of where it really had to go.
  - S2: So we measured them and divided it and we got the distance.
  - S1: The wheel rotations.
  - S2: Yeah, the wheel rotations.
  - S1: Of how far it was supposed to go.
  - …
  - S3: Oh when we got the circumference of the wheel, I thought it would be easier just to measure the thing in centimeters. But everything else was in inches. So I just got the centimeters and divided by 2.5 cause there's 2.5 centimeters in an inch. And that's how we got 10.4 as a circumference.
- Purple Team
  - S1: We used the, the strategies that we learned all throughout the week. Um, we, like, for the straights, we, um, used the circumference of the wheel as the rotations and measured it, measured the area.
  - I: What do you mean by measured the area?
  - S2: Like how far it was from here to here. And then we like said, I think the wheel was 26 cm, so we said one rotation would be 26 cm, two would be whatever that is times two.

Calculational (1/4 teams)

- Red Team
  - S: "Not really. No. Cause there isn't any, like, it isn't like we are comparing two different robots to do the same thing. All robots are the same in this. We're not using two different robots to do the same thing. So there really is no need for any strategies like that."
- Purple Team
  - S1: "Cause it's a different robot. It has bigger wheels."
  - S2: "Well, we don't know like, I don't really know why we didn't use one of our strategies. We just decided to use one and didn't really think about the others."
  - S1: "We're still in the lead."
  - I: "So it's working for you?"
  - S1, S2: "Yeah"

Study 2 - Summary

- The two groups approached the task in substantively different ways
  - Representing images/animations versus capturing numerical patterns
  - But both engaged in productive mathematics and sense-making

- The Mechanistic group learned more and more likely to use those strategies in a transfer competition task

Potential Significance

- Better understanding of effective instruction this domain – robots in middle school
  - How to move students toward more systematic design practices and explicit understandings through use of mathematical resources (technology/engineering)
  - Begin to see robots as “hard fun”

- Math as tool for situational understanding
  - A lot is gained by just making the resources **accessible** (available and salient)
  - Also about **framing** the use of those resources
    - Quasi-experimental manipulation of frames/orientations

Thank You

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