The Use of Robotics to Teach Mathematics

Eli M. Silk & Christian D. Schunn
Learning Research & Development Center, University of Pittsburgh

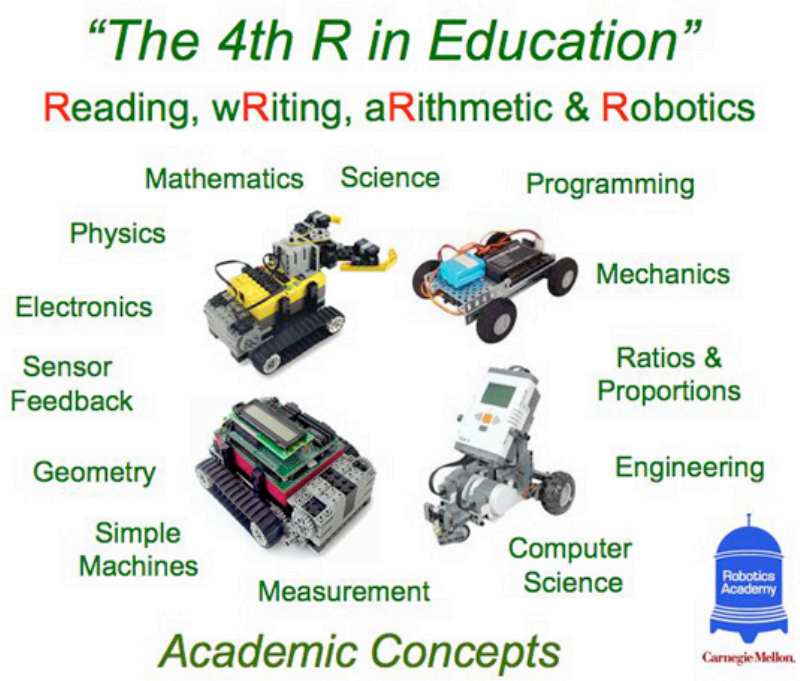
Ross Higashi & Robin Shoop
Robotics Academy, NREC

Al Dietrich & Ron Reed
Shaler School District and Pittsburgh Public Schools

Robotics Educators Conference
Butler County Community College, Butler, PA

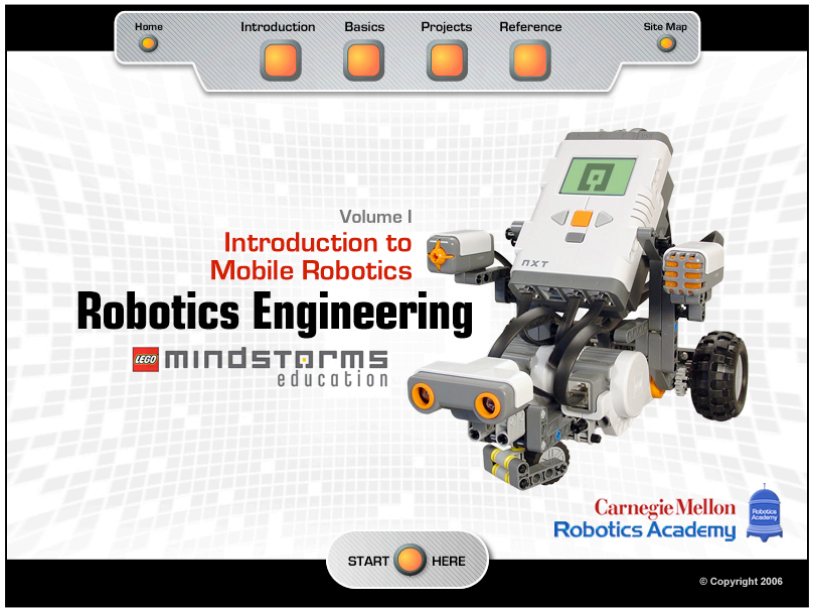
The Argument for Robotics

- Robotics should:
  - Motivate and engage
  - Integrate STEM concepts and skills
- But does it?
  - Let's just focus on Mathematics



How can we know if Robotics is an “Integrator” for Math?

- Curriculum Design
  - Content analysis of curriculum tasks
- Curriculum In-Action
  - Observations of the curriculum being taught in a high-needs setting
- Moving Forward
  - Possible improvements and further research



Curriculum Design

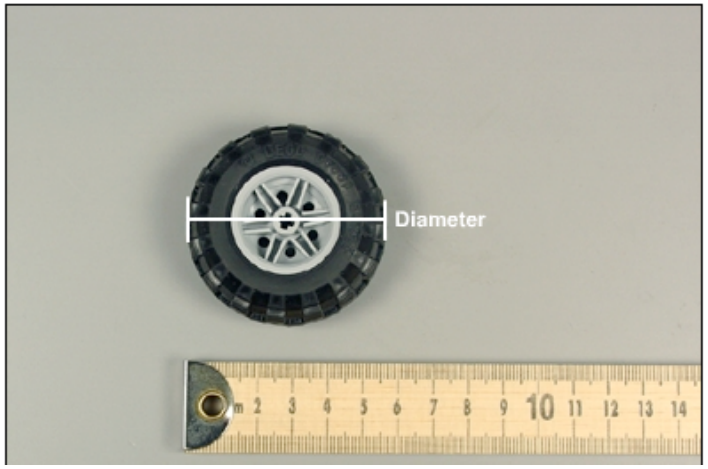
Content analysis of curriculum tasks

Curriculum Design

- Surveys of Enacted Curriculum (SEC)
  - Used an independent source of mathematics *topics* and method
  - 215 Topics
    - (time/temperature, exponents, etc.)
  - 17 Topic Areas
    - (Algebra, Geometry, etc.)
- Coded the REV1 Investigation tasks
  - 6 Investigations
    - 33 Tasks/Invest.
    - 198 Tasks
  - 3 Weeks
  - Proportion of time = Proportion of tasks

Example REV1 Tasks

Standard Wheels Calculate Distances



1. Measure Diameter

Measure the diameter of the wheels on your Personal Assistant robot.

Record your measurements in the data table on your worksheet.

> Next Slide

Example 1

- Use of measuring instruments
- Length
- Circles

15. What is the average distance that the robot ran with these wheels? Is the average a good representation of the data you gathered in this Condition, or does the data look nothing like the average?

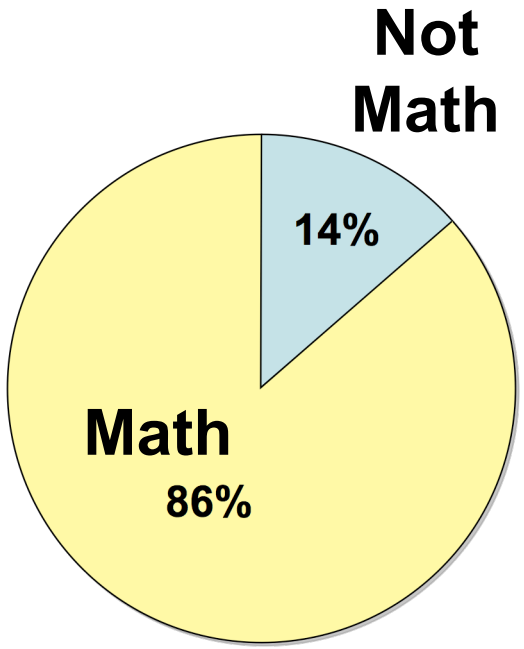
$$\text{average distance (for 3 trials)} = \frac{\text{distance 1} + \text{distance 2} + \text{distance 3}}{3}$$

Example 2

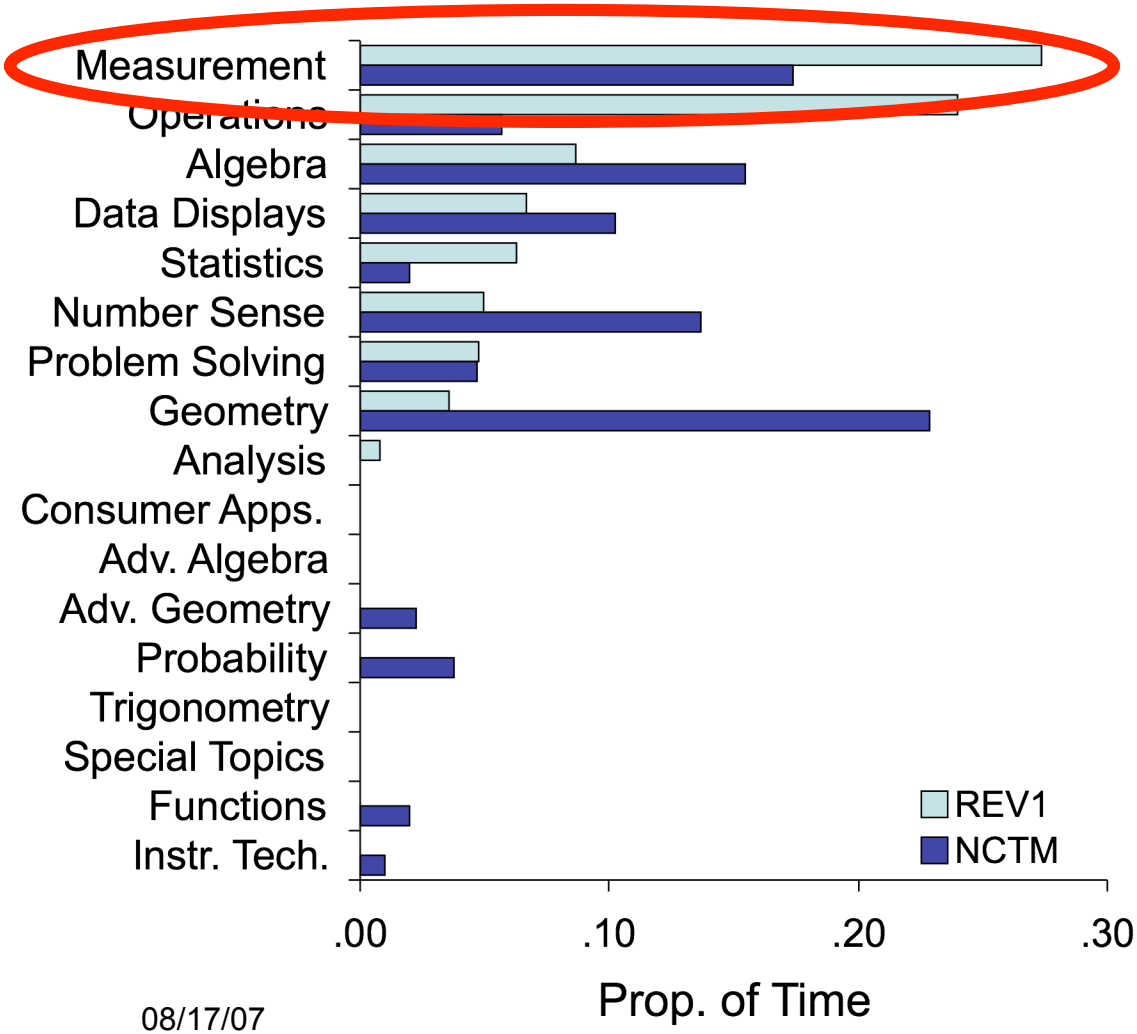
- Mean

Do the REV1 Tasks Involve Mathematics?

- YES!
  - The unit was clearly designed to incorporate mathematics

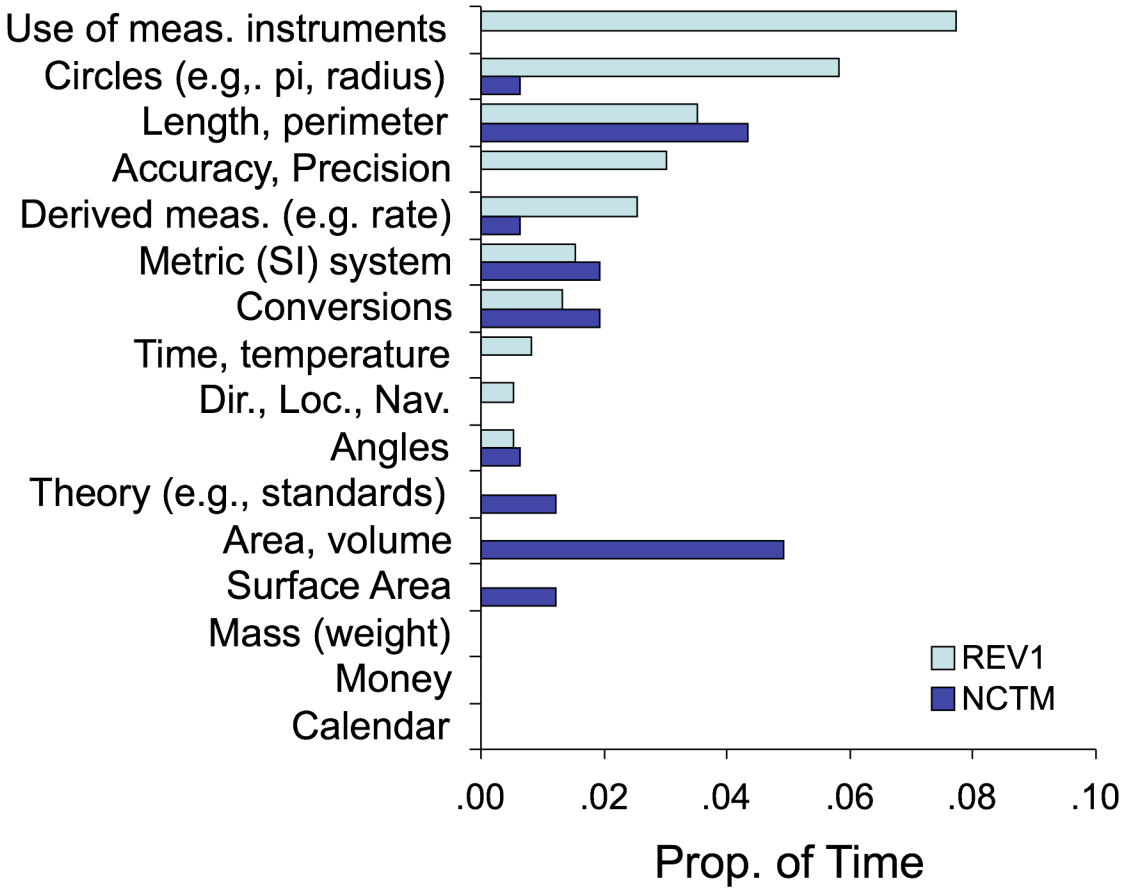


What Kinds of Mathematics are Being Covered in REV1?



- REV1 ***covers*** a range of topics
  - INTEGRATOR!
- Alignment = .5
- Measurement (27%)
  - Day-to-day Grain Size?

What Does it Mean to Cover "Measurement"?



- At ***finer*** grain size still covers a range of topics
- But some topics aren't covered!
  - Area, volume, surface area, money
- Alignment = -.06

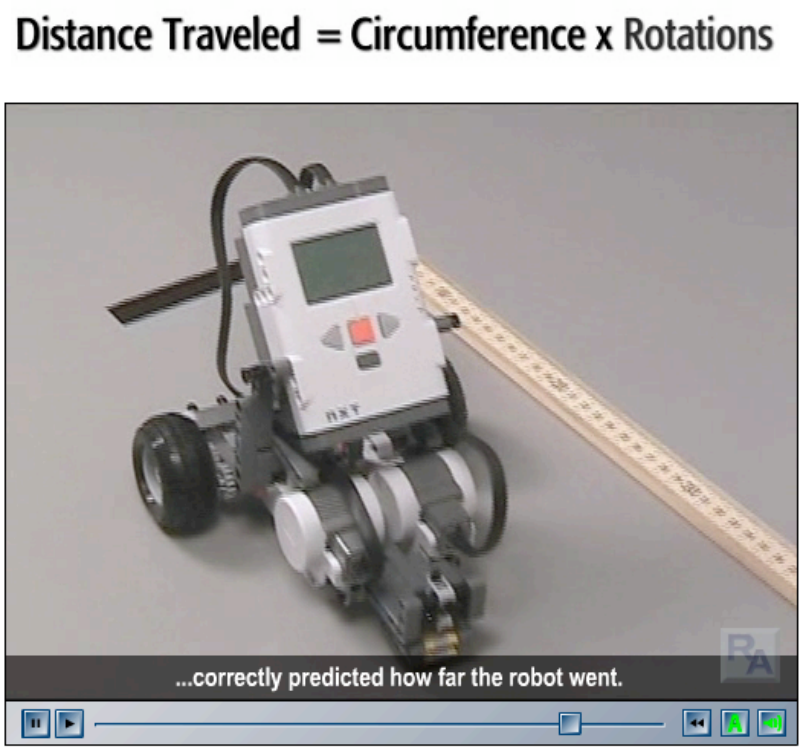
Curriculum Design

- REV1 is an Integrator
  - Tasks cover a wide range of math topics
  - Well-aligned with topic areas in the national standards (the coarse grain size)
- But a caution…
  - Not as well-aligned at the fine grain size
    - The grain size that may make a difference for increasing standardized test scores?
    - The grain size at which students and teachers think on a day-to-day basis?

Curriculum In-Action

Observations of the REV1 being taught in a high-needs setting

One Day Observing



- The Context
  - All students (S) had gotten their robot to go 1m (100cm) with the standard wheels
  - “Every robot was a little different, but around 2000” (T)
  - Teacher asked students to solve the problem for half (50cm)

One Day Observing (Part 1)

- In whole class discussion, Teacher asked everyone to share results on the board
  - The recorder wrote two columns (“Distance” and “Rotations”), but everyone used degrees as the parameter

- “Are they the same? Which is the right one? What can make them different?” (T)
    - “Machines get ‘tired’” (S)
    - “They don’t get tired, but they wear” (T)

Distance	Degrees
50cm	1000
100cm	2018
100cm	2050
50cm	1000
100cm	2004
50cm	1002
50cm	1005
100cm	2025

One Day Observing (Part 2)

- "We need to work with one number, not five. Anyone know a fair way to combine them?" (T)
  - "Just use mine" (S)
  - "Could align your wheels different" (S)
  - "Would it be the same every time?" (T)
- "Use the median, the middle number" (S)
  - "How do you find the middle number? … Put them in order and take the middle number. But we have an even number of values." (T)

Distance	Degrees
50cm	1000
100cm	2018
100cm	2050
50cm	1000
100cm	2004
50cm	1002
50cm	1005
100cm	2025

One Day Observing (Part 3)

- “Another fair way? They are normally together.” (T)
  - “Mean, mode” (S)
  - “You said it right before mode” (T)
- “Find the mean, because we need a fair number for what the average robot will do.” (T)

Distance	Degrees
50cm	1000
100cm	2018
100cm	2050
50cm	1000
100cm	2004
50cm	1002
50cm	1005
100cm	2025

One Day Observing (Part 4)

- "How do we do it?" (T)
  - "Add them up and divide" (S)
- Multicolumn addition
  - "I am getting nervous, somebody come up here" (S)
- Division with remainders
  - "Why is it 4?" (S)
  - "Because that's how many numbers we have." (T)
- 2024 degrees to go 100cm

Distance	Degrees
50cm	1000
100cm	2018
100cm	2050
50cm	1000
100cm	2004
50cm	1002
50cm	1005
100cm	2025

```
  2018
  2050
  2004
+ 2025
--------
  8097
```

```
  2024
 -------
4 | 8097
    8
    ---
    009
      8
      --
      17
      16
      ----
       1
```

One Day Observing (Part 5)

- 2024 degrees for 100cm
- “Let’s do it for 50cm” (T)
  - 1001 degrees for 50cm

$$\frac{2024}{2} = 1012$$

- “Would you say that is half? How do you find out? How far apart is 1001 with 1012?” (T)

Distance	Degrees
50cm	1000
100cm	2018
100cm	2050
50cm	1000
100cm	2004
50cm	1002
50cm	1005
100cm	2025

```
  1000
  1000
  1002
+ 1005
---------
  4007
```

```
    1001
  ------
4 | 4007
    4
    ---
    0007
       4
       ---
       3
```

One Day Observing (Part 6)

- "How far apart is 1001 with 1012? Is it significant? How many of these go in here? Is 11 big compared to 1012?" (T)
  - "I think we need a way to describe this. It depends on the number we started with." (T)

$$1012 - 1001 = 11$$

- "Divide it" (S)
  - "92 of these go in here. If you are off by 1 of 92, then it is okay?" (T)

$$\frac{1012}{11} = 92$$

- "Flip this over, we get a percent" (T)
  - "What is the percent of wrongness? The percent of error?" (T)

$$\frac{1}{92} = 1.1\%$$

One Day Observing (Part 7)

- “If you go half as much, can you reasonably expect to go half as far?” (T)
- “There’s obviously a pattern. What would it take to go twice as far? Put into your robot twice that and we’ll see how far it goes.” (T)
- “You found half, you found double, what is 3/4?” (T)

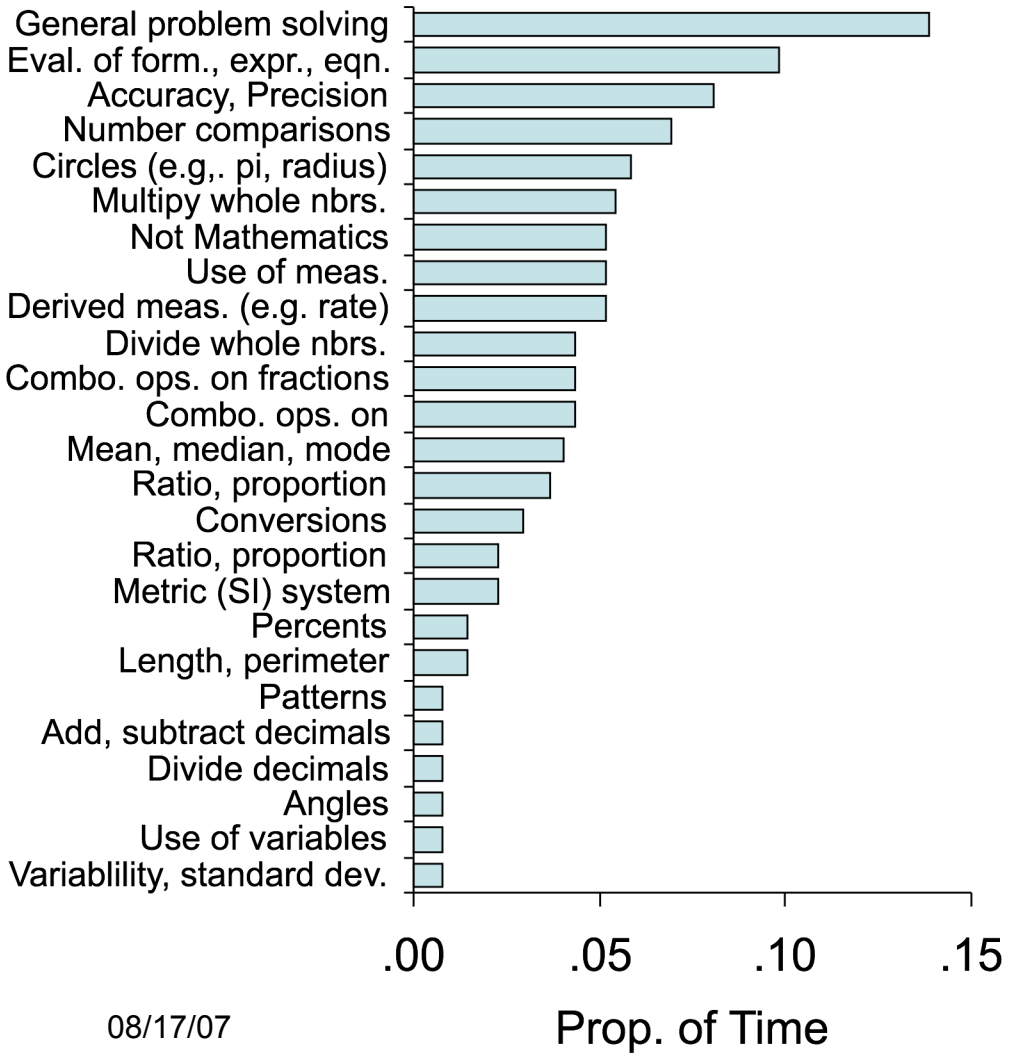
One Day Observing (Recap)

- Topics Covered
  - Data tables
  - Conversion of units
  - Experimental error
  - Central tendency
  - Multicolumn addition, Division
  - Number comparisons
  - Percents
  - Percent error
  - Proportionality
  - Patterns
  - Extrapolation
  - Fractions

- Integrator
  - Many different topics naturally are ***connected*** to solve the problem

- Teacher has to be prepared to address many different ideas

Coding of Investigation 1



- Coding predicts that many of these topics will be covered
- Are these topics all supposed to be taught explicitly or already known?
- Major challenge for teachers

Curriculum In-Action

- REV1 is an Integrator
  - Tasks ***connect*** a wide range of math topics while solving robotics problems
  - Students bring their math knowledge to the discussion (when prompted)
- But a caution…
  - Many topics are covered in a short period of time
    - Are all of those topics supposed to be taught explicitly?
    - What kind of content knowledge and preparation demands does that place on the teacher?

Moving Forward

Possible improvements and further research

Teacher Resources

- 2 teachers (math/science) analyzed materials
  - What would be necessary for teachers to use the curriculum and teach the math at a deep level of understanding?

- Their Conclusions…
  - Content Knowledge is important, but…
  - **Pedagogical Content Knowledge** (PCK) is also important
    - Variety of possible student solutions
    - Variety of common student errors
    - Questions to assess and advance

Possible Student Solutions & Teacher Questions

19. Configure your robot using what you feel are the best all-purpose wheels for your classroom. Measure the wheels on your robot.

i How many cm does your wheel turn per 360 degree rotation?

ii In order to travel 10cm, how many degrees does the wheel need to turn? Show your work.

6 Solutions with assessing/advancing questions for each

- Part-Whole Ratio
- Per-Unit Rate
- Proportion using Unit Ratio
- Proportion using Equivalent Fractions
- Ratio Method
- Algebra Method

Improving Alignment with Standards

- Attempt to "***focus***" instruction
  - Emphasize the concepts that are most aligned (e.g., length, unit conversions)
  - Emphasize bigger ideas (e.g., proportionality)

- Provide "***bridging***" activities
  - Help students transfer from the robotics context to a general math idea

Research on Student Learning

- Need to connect the last link in the chain
  - Once we align the design of the curriculum with what we want to teach, AND
  - Provide teachers with what we think they need to teach it, THEN

- We need to collect data on ***student learning*** to see if they actually learn what we thought they would learn

Robotics as an Integrator to Teach Mathematics

- Curriculum Design
  - There is definitely math designed into REV1 tasks
  - Cover a broad range of topics
  - Grain size of analysis matters for alignment

- Curriculum In-Action
  - Math topics are relevant for the tasks and connected
  - Demanding on teachers to go from topic to topic

- Next Steps
  - Support teachers by providing PCK resources
  - Emphasize the fine-grain-size ideas that are aligned with standards
  - Collect data on student learning of the math ideas

Thank You

Eli M. Silk
esilk@pitt.edu