Using Robotics to Teach Mathematics

Analysis of a Curriculum Designed and Implemented

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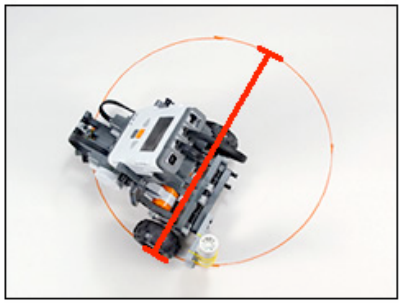
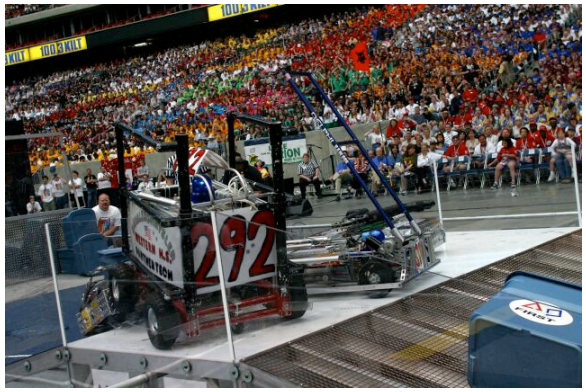


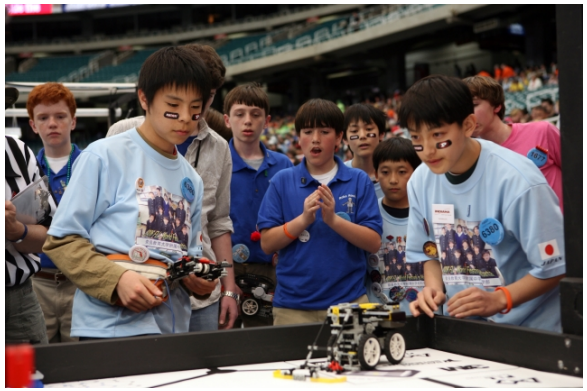
$$\frac{90^\circ}{360^\circ} = \frac{\text{Distance Traveled by Wheel}}{72\text{cm}}$$

Why use Robotics to Teach Math?

- Math in US – “mile wide and an inch deep”
  - Superficial coverage
  - View of math as procedures
  - Inert knowledge



- Engineering as an alternative
  - **Integrates** STEM concepts and skills
    - Concepts are **brought in as needed** to solve the problem and enhance the design
    - Mathematics is **used as a tool** to facilitate that process – problem solving in context
  - **Robotics**
    - Highly motivating and engaging



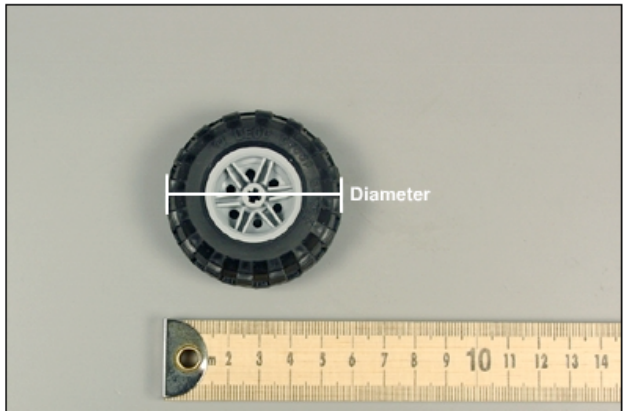
- But does it work?
  - Under what conditions?
  - What design principles should we use?

Robotics Engineering Curriculum (REC)

- Targets “technological literacy and mathematical competency using robotics as the organizer”
- LEGO MINDSTORMS NXT platform
- Pre-algebra students
- 6 Investigations
  - Control robot using mathematical relationships
  - e.g., Relationship btwn wheel size and distance traveled

Example REC 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

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?

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

Methods

Content Analysis (Designed Curriculum)

- In what ways and to what extent is the math present in the **design** of the curriculum?
  - Surveys of Enacted Curricula
    - 217 math concepts grouped in 17 topic areas
  - Coded
    - REC tasks (n=198)
    - NCTM Standards Grade 6-8

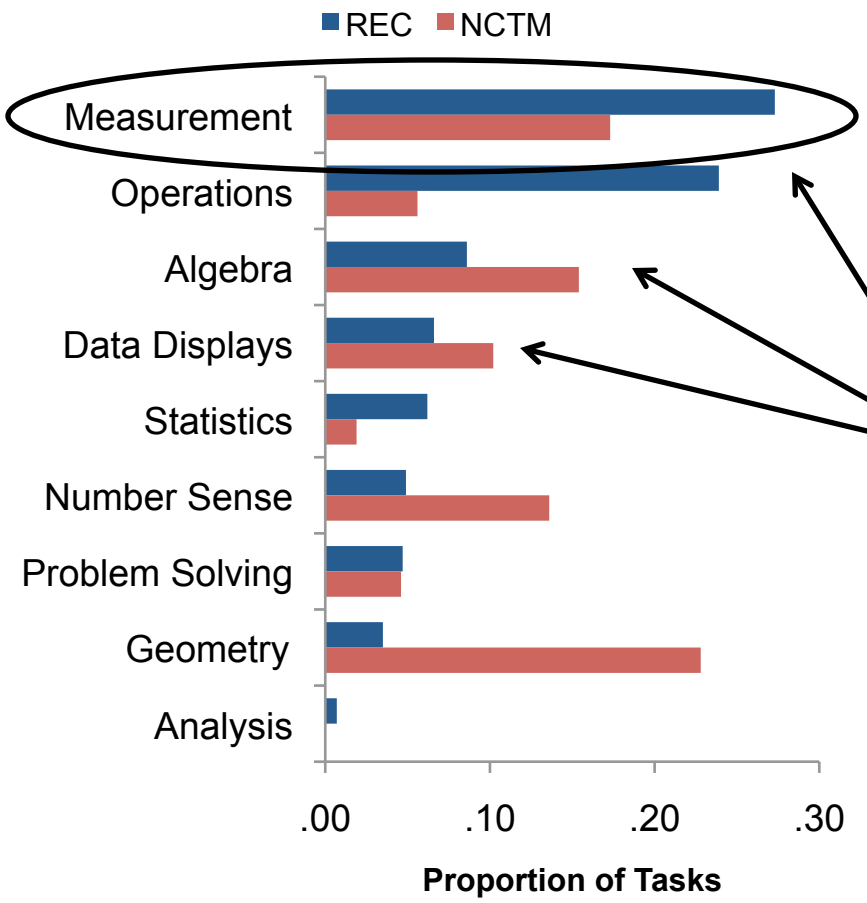
Case Study Analysis (Curriculum-in-Action)

- In what ways and to what extent is the math present in the **implementation** of the curriculum?
  - Knowledgeable instructor
  - High-needs setting
    - 99% minority, 94% low-SES
    - 8th grade remedial math
  - Data sources
    - Classroom observations
    - Pre/post test

Content Analysis

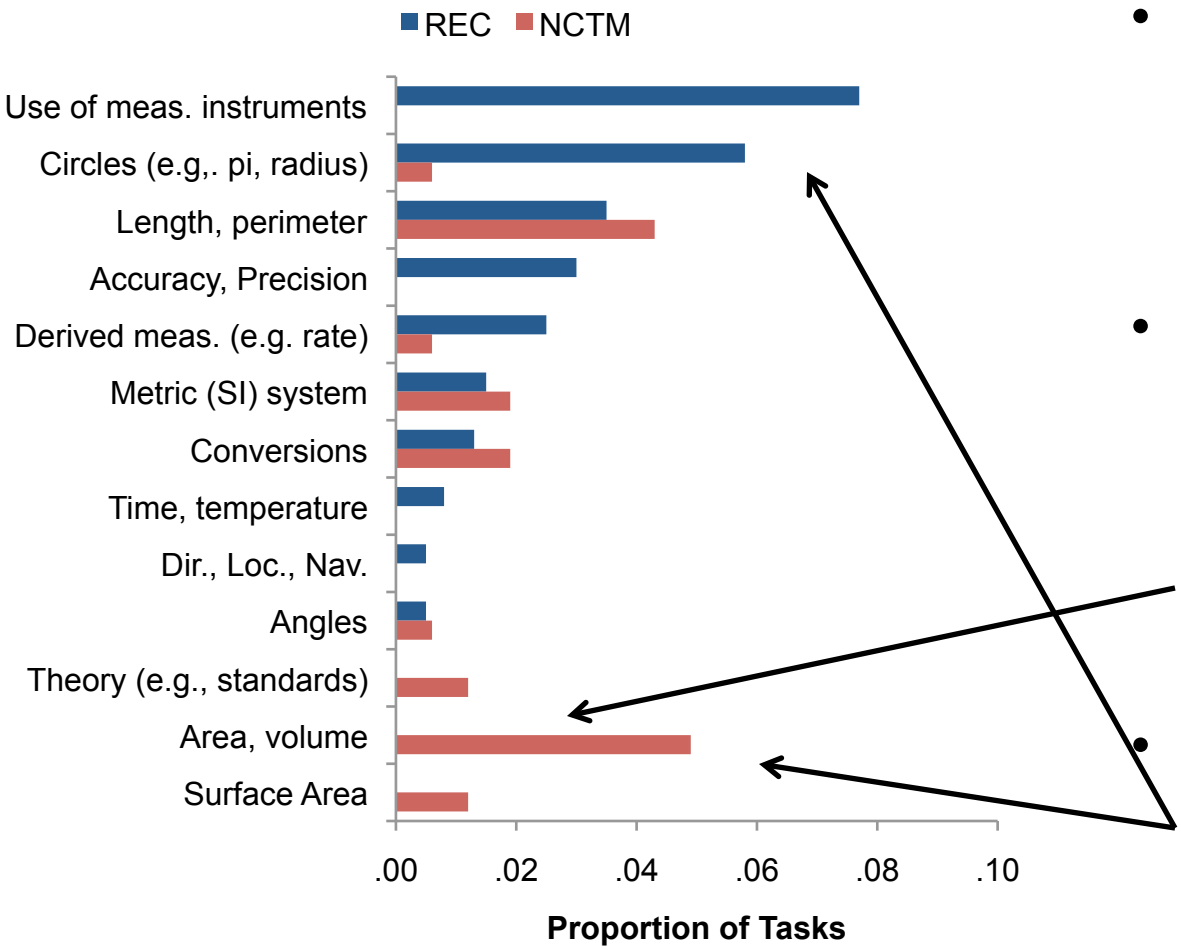
Coding of REC tasks relative to mathematical topics

Math Topic Areas Relevant in REC



- REC ***brings together*** a wide range of relevant topic areas
- Alignment = .5
  - Emphasizing some of the same topic areas
- Measurement (27%)
  - What math concepts are relevant (a finer grain size)?

Mathematics Concepts within "Measurement"



- At ***finer*** grain size, a rich set of concepts are relevant
- Not an equal distribution (some concepts not covered at all)
  - Area/volume, Surface area
- Alignment = -.06
  - Emphasizing different concepts

Content Analysis Lessons Learned

- REC brings together many math concepts
  - 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 distributed equally among concepts within a topic area
    - Students may not have a general understanding of the whole topic area (e.g., “Measurement”)
  - Not as well-aligned at the fine grain size
    - The grain size that may make a difference for increasing standardized test scores or addressing the most fundamental math ideas?
    - May underestimate the effect of the curriculum

Case Study Analysis

Observations of REC being taught
in a high-needs setting

A Typical REC Discussion

Variability, Average (mean), Experimental Error

- Teacher: “We need to work with one number, not four. Anyone know a fair way to combine them?”
- Student 1: “Just use mine”
- Student 2: “Align the wheels better”
- Student 3: “The median… the middle number”
- Teacher: “We need a fair number for what the average robot will do.”

Accuracy, Precision, Percent Error

- Teacher: “Would you say that is half? …
- Teacher: “How far apart are these two numbers here? Is 11 big compared to 1012?”

Patterns, Proportionality, Extrapolation

- Teacher: “If you go half as much, can you reasonably expect to go half as far? …
- Teacher: “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. …
- Teacher: “You found half [of 1 meter], you found double, what is 3/4?”

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

100cm Mean = 2024

50cm Mean = 1001

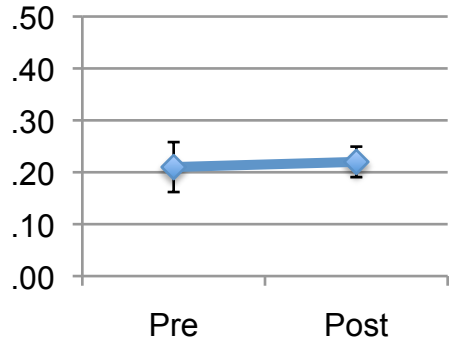
$$\frac{2024}{2} = 1012$$

Connecting Many Math Concepts

- Rich set of relevant math concepts for solving the problem
  - Data tables
  - Conversion of units
  - Experimental error
  - Central tendency
  - Multicolumn addition, Division
  - Number comparisons
  - Percents
  - Percent error
  - Proportionality
  - Patterns
  - Extrapolation
  - Fractions

- Strong Math Connections
  - Many different concepts are ***connected*** in authentic ways in service of solving the problem
  - Students bring in math ideas to contribute to the discussion

- But are students achieving **fluency** in those concepts?
  - Pre/post tests indicate that they are not (even in robotics contexts)



Case Study Lessons Learned

- REC brings together many math concepts
  - Tasks ***connect*** a wide range of math concepts in authentic ways while solving robotics problems
  - Students bring their math knowledge to the discussion (when prompted), providing an opportunity to engage with those concepts

- But a caution…
  - Many topics are covered in a short period of time
  - Although added problem-solving context, still easy to fall into the trap of curriculum covering a diffuse set of loosely-related concepts without sufficient depth
    - Are all of those concepts supposed to be taught explicitly?
    - What opportunities do students have to explore each of those concepts in depth and to consider them in multiple contexts?

Implications

- Under what conditions?
  - Many math concepts are relevant and students seem to recognize that they are
  - Too many integrated math concepts may minimize opportunity to learn any one of them
- What design principles should be used?
  - Target instruction at the fine-grain level of math concepts
  - Focus on a small set of concepts
    - Those core to the topic area, challenging for students to understand by traditional methods, and those best exemplified in robotics problems
  - Provide students with multiple opportunities to consider them in depth and become familiar with them

Thank You

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