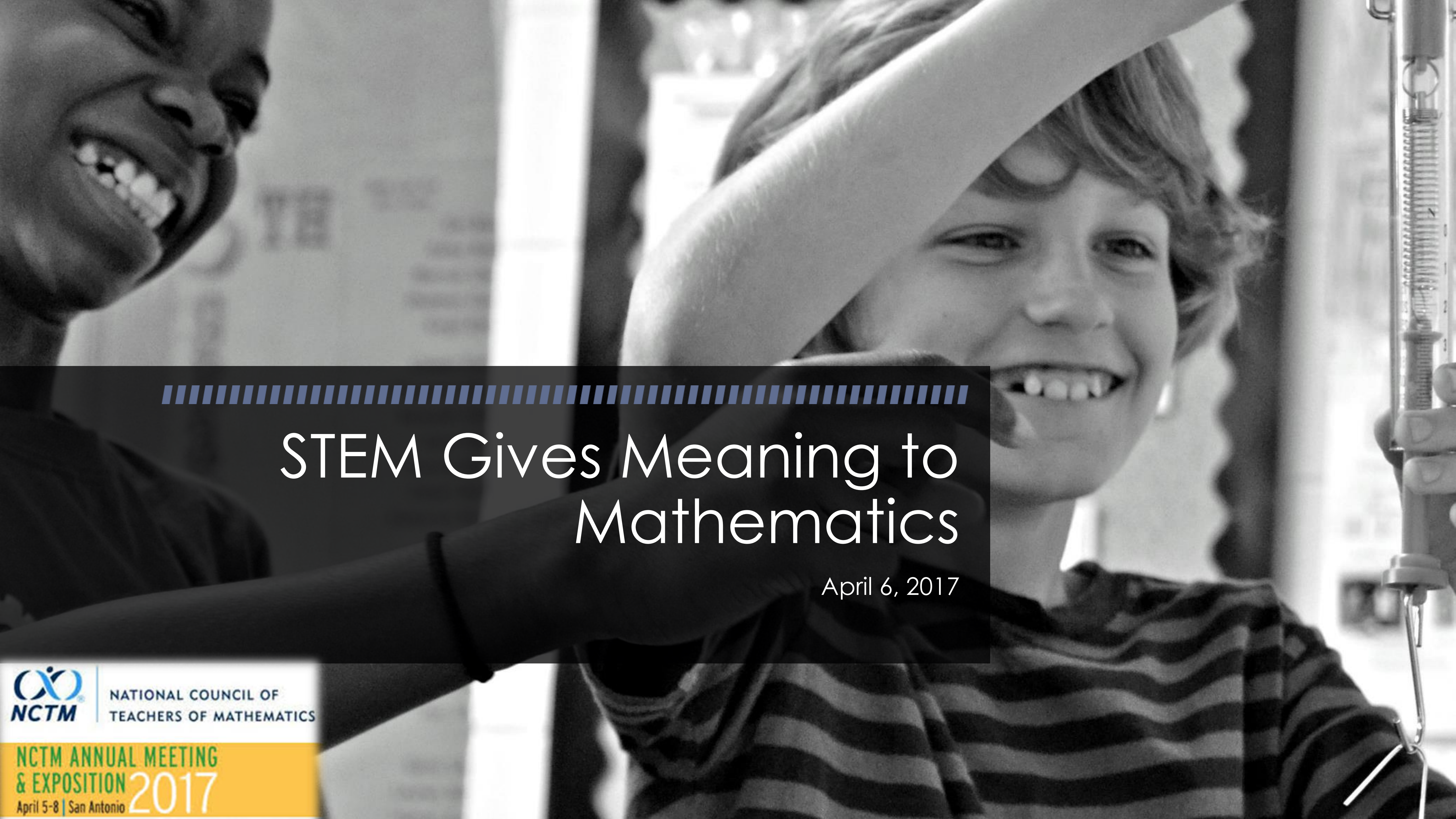

STEM Gives Meaning to Mathematics

April 6, 2017

NCTM
NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS
NCTM ANNUAL MEETING & EXPOSITION 2017
April 5-8 | San Antonio

Presented By

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Engineering Innovative Thinkers for Global Success!

Objectives

Participants will…

- Experience engineering design activities that develop communication skills and perseverance alongside science and mathematics content.
- Make connections between the *Next Generation Science Standards* "Science & Engineering Practices" and the *Common Core* "Standards for Mathematical Practice."
- Analyze the potential long-term science and mathematics outcomes of K-5 engineering units of study.
- *Receive adaptable K-5 lesson plans and units of study*.

Douglas Jamerson Elementary

100% application school with no entrance criteria

Teacher-created engineering curriculum

575 students with a full range of programs including ESE

47% Caucasian

39% Black/African American

7% Hispanic

5% Multiracial

2% Asian

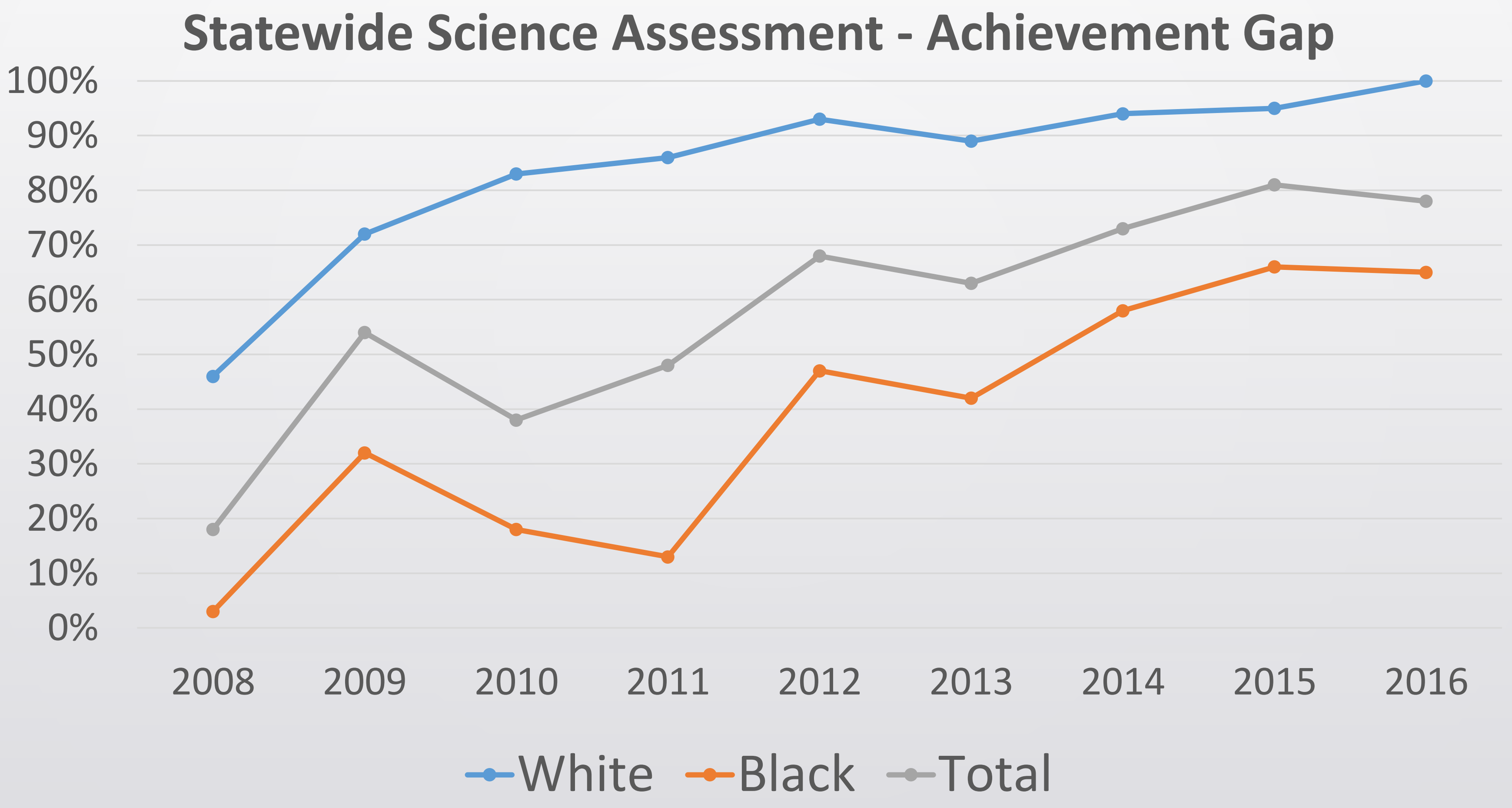
57% Low SES

Evidence from Douglas Jamerson Elementary

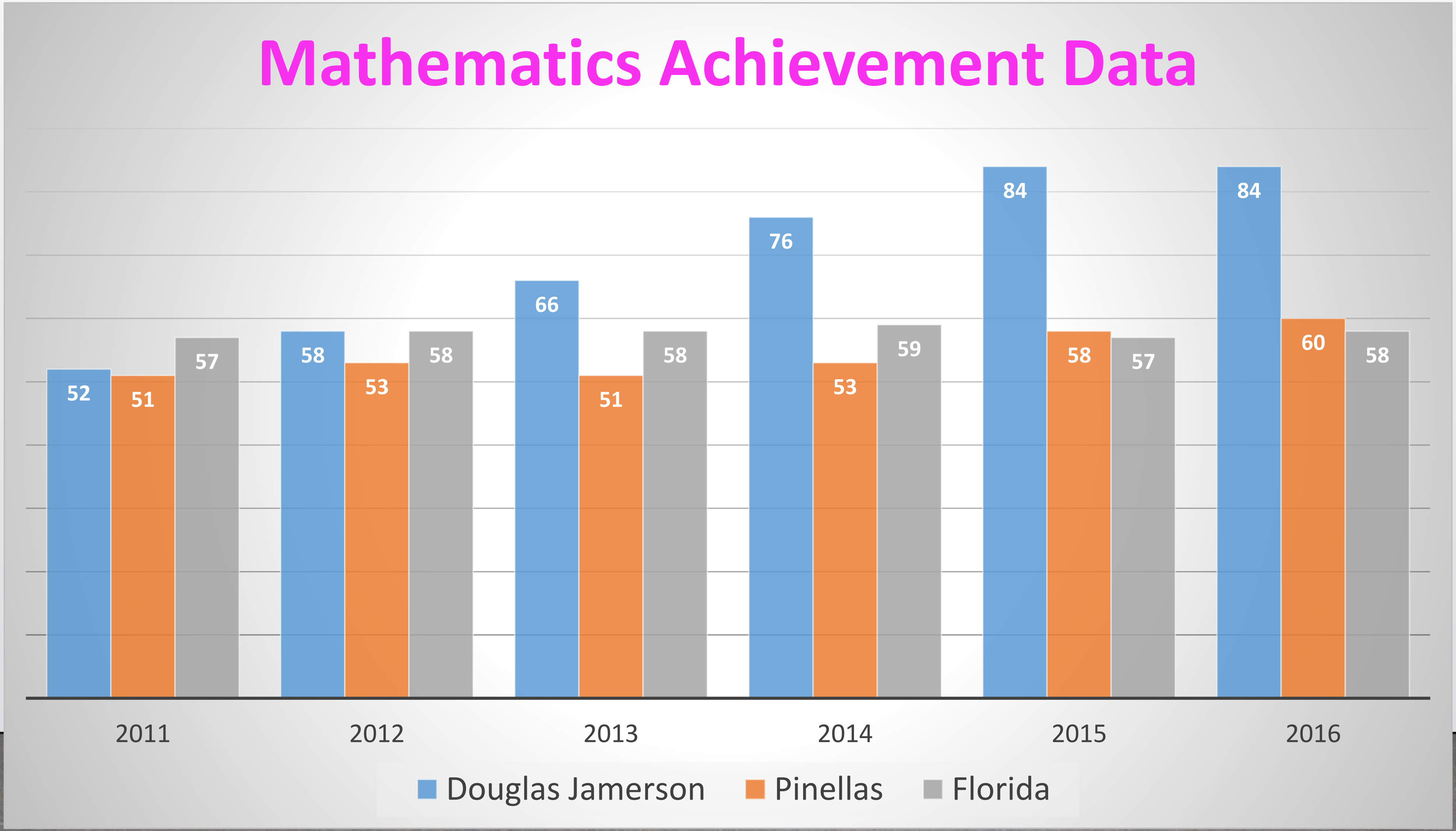
State Science Assessment	2010	2011	2012	2013	2014	2015	2016
Douglas Jamerson	39%	48%	68%	63%	74%	81%	78%
District	49%	50%	51%	49%	55%	54%	55%
State	50%	50%	51%	53%	54%	53%	54%

Highest percentage of students exceeding expectations in science in the district!

Evidence from Douglas Jamerson Elementary



Evidence from Douglas Jamerson Elementary



Engineering Design Challenges

	Nature of Science & Engineering	Physical Science	Earth Science	Life Science
K	What is an Engineer? Create a Picture Frame	Goldilocks Just Right Chairs Humpty Dumpty	Construct a Home to Withstand Wind Force Materials for Bridge Design	Visual Life Cycle Models
1	What is an Engineer? Design Hats	Light and Sound Waves Design a Drum to Communicate	Build a Dam Explore Telescopes	Design a Garden Habitat Diorama
2	Engineering for Animals Design an Elephant Trunk	Design a Lego Tower/Bridge Scale Drawing	Weather Tracking Design the Ideal Garden (Soil)	Life Cycle of Butterflies Design a Butterfly Habitat
3	Creating Models Boom Town Communities	Measuring Light Laser Light Maze Design	Telescope Design Solar Cooker Design	Animal Classification Design an Animal
4	Scientists & Engineers Design a Totem Pole	K'Nex Car Testing & Design	Build a Dugout Design and Test a Boat	Garden Design (Hydroponics) Design a Water Filter
5	Fields of Engineering Catapult Investigations	Bridge Testing & Design Design a Home Lighting System	Hurricane Preparedness Plan Design a Lunar Mission	Medical Engineering for the Body Design a Lunar Habitat

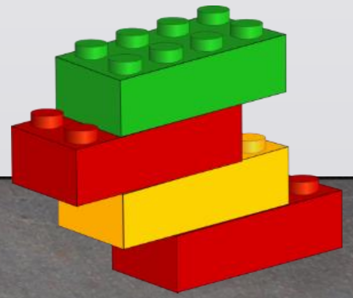
Example 1: Nature of Science

Activity 1

Engineers communicate using precise language.

1. Sit in a chair, back-to-back with your partner. Partner 1 is on the left, Partner 2 on the right.
2. You each have identical Legos in a bag. Partner 1 will arrange his/her Legos on the baseplate.
3. Partner 1 will use precise language to describe the Legos and their placement, while Partner 2 attempts to build an exact match.
4. Partner 2 may not speak!
5. Once you are ready, check to see how you did and switch roles.

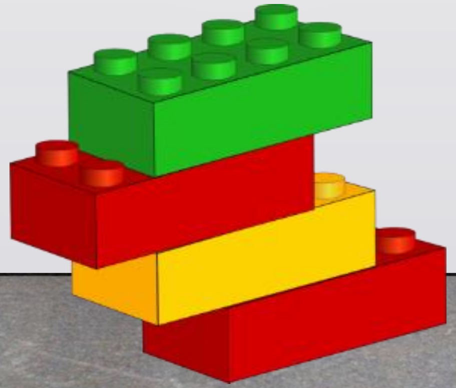
*If you have a group of three, the third person will observe and take notes, then rotate in.



Activity 1

Engineers communicate using precise language.

- What is difficult about this activity?
- Would it be helpful if Partner 2 could ask clarifying questions?
- What types of descriptors did you use that were most helpful?

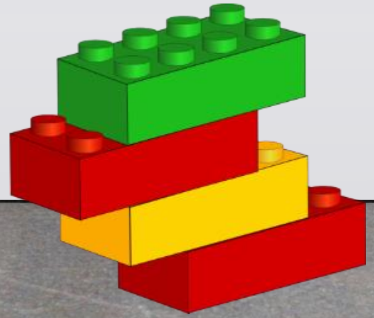


Activity 1

Engineers communicate using precise language.

- Is there a difference between 2x4 and 4x2?
- Which mathematical practices could we emphasize? Why?

Where's the math?



Activity 1

Engineers communicate using precise language.

- We use this and similar activities in the context of a six-week Nature of Science & Engineering unit of study at the beginning of every year, in every grade.
- The unit focuses on development of communication, growth mindset, SMPs, and Science & Engineering Practices.
- Every unit culminates in a team-based engineering design challenge…

Example 2: Nature of Science

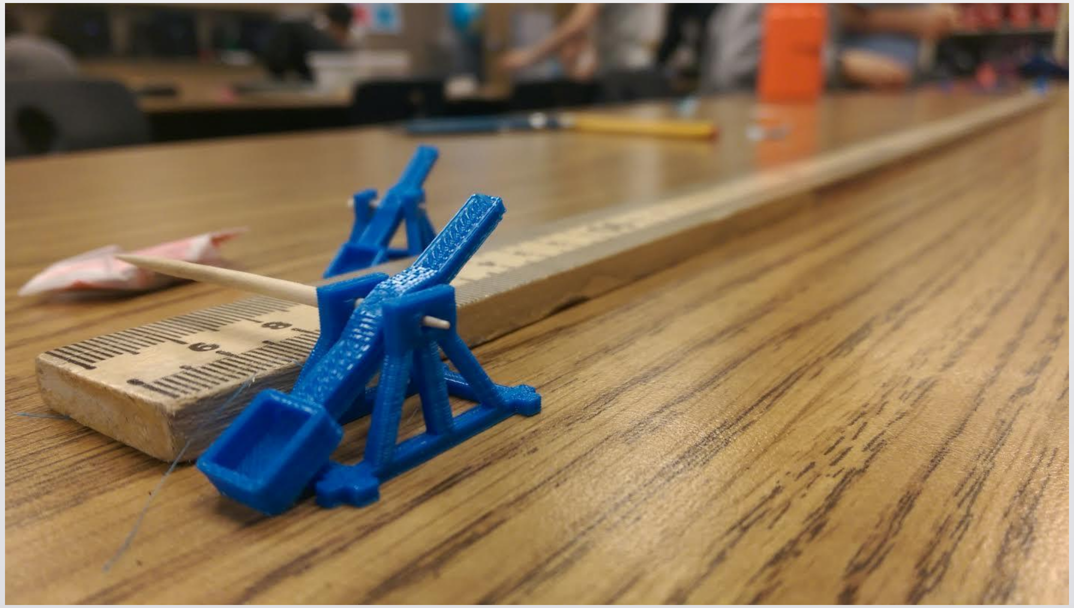
3D Printed Catapults

Explore

3D Printed Catapults

The catapult is a ***system model***.

Engineers use models to analyze a system.



Which aspects of the model could we test?

Which aspects need to be held constant in order to collect reliable data?

3D Printed Catapults

Investigate

How does the mass of a projectile affect the distance it travels in the air?

What needs to be held constant to ensure a fair trial?

What is challenging about this investigation or the materials?

What conclusions can I draw from the data?

What are the prerequisite math skills for this investigation?

Catapult Design Challenge

Construct a catapult that…

- *Is a working prototype.*
- *Launches a projectile to consistently hit a target 50 cm away.*
- *Uses simple materials found in the classroom, science lab, or around the house.*

This leads into similar engineering design units throughout the year.

Lesson	Duration	Essential Question(s)	Lesson Overview
1	4 days	How and why do scientists observe and record? How do engineers use the design process?	1. Unit Pretest and Formative Assessment Probe *Doing Scienc* 2. Compare scientists and engineers 3. Introduce, setup, and explore Science Notebooks 4. Fusion Textbook – Unit 1, Lesson 1 "What is Science?" 5. Review the Jamerson Design Process – *Skyscraper Design Challenge* 6. ELA – DaVinci Names 7. HOMEFUN – Photo Autobiography
Example 1 2	3 days	What are the qualities of effective teams? How do scientists and engineers communicate?	1. *Communicate Like an Engineer* – Activity 1, "Engineers Use Precise Language" 2. *Communicate Like an Engineer* – Activity 2, "Engineers Communicate With Teammates" (Widgets) 3. *Traveling Circuits* – Hour of Code
3	3 days	How do scientists design investigations?	1. Everyday Science Mysteries – "Grandfather's Clock" 2. Pendulum Investigation – How does arm length affect period' 3. Fusion Textbook: Unit 1, Lesson 3 "What are some types of investigations? 4. Fusion Textbook: Unit 1, Lesson 5 "What are some science tools?"
Example 2 4	9 days	How do scientists design investigations? How do engineers develop solutions?	1. Introduce Tinkercad and 3D Printing. 2. 3D Printed Catapults – Explore and discuss 3. 3D Printed Catapults – How does mass of the projectile affec distance? 4. Catapult Design Challenge 5. Investigations with the 4 Foot Catapult
5	7 days	Which (STEM) careers match my strengths and interests?	1. Learning Styles and Multiple Intelligences Quizzes 2. Explore STEM Careers – Webquest, Interest Survey 3. Webquest – DiscoverE 4. Engineer Wall/Learning Signs Scavenger Hunt 5. Connect Fields of Engineering to Enterprise Village 6. Nature of Science POSTTEST 7. HOMEFUN: Engineering Throughout the Day

Practices in Mathematics, Science, and English Language Arts*

Mathematics	Science	English Language Arts
M1. Make sense of problems and persevere in solving them. **M2.** Reason abstractly and quantitatively. **M3.** Construct viable arguments and critique the reasoning of others. **M4.** Model with mathematics. **M5.** Use appropriate tools strategically. **M6.** Attend to precision. **M7.** Look for and make use of structure. **M8.** Look for and express regularity in repeated reasoning.	**S1.** Asking questions (for science) and defining problems (for engineering). **S2.** Developing and using models. **S3.** Planning and carrying out investigations. **S4.** Analyzing and interpreting data. **S5.** Using mathematics and computational thinking. **S6.** Constructing explanations (for science) and designing solutions (for engineering). **S7.** Engaging in argument from evidence. **S8.** Obtaining, evaluating, and communicating information.	**E1.** They demonstrate independence. **E2.** They build strong content knowledge. **E3.** They respond to the varying demands of audience, task, purpose, and discipline. **E4.** They comprehend as well as critique. **E5.** They value evidence. **E6.** They use technology and digital media strategically and capably. **E7.** They come to understand other perspectives and cultures.

Example3 : Force & Motion (Intermediate)

K'Nex Vehicles Unit Overview

Lesson	Description
1	K'Nex Materials Inventory *Mini Design Challenge*: Construct a K'Nex vehicle that travels at least 100 cm
2	Introduction to Technical Drawings and Blueprints Construct the standard K'Nex vehicle from a blueprint
3	Energy and Motion Concepts How does the number of wraps of the rubber band affect distance?
4	How does the surface texture (friction) affect distance?
5	How does load/mass affect distance? Introduction to speed (s = d/t)
6	*K'Nex Vehicle Design Challenge (Performance Assessment)*

K'Nex Vehicle Design Challenge

Modify the standard vehicle to travel *exactly* 400 cm at the fastest speed.

Variables to Consider

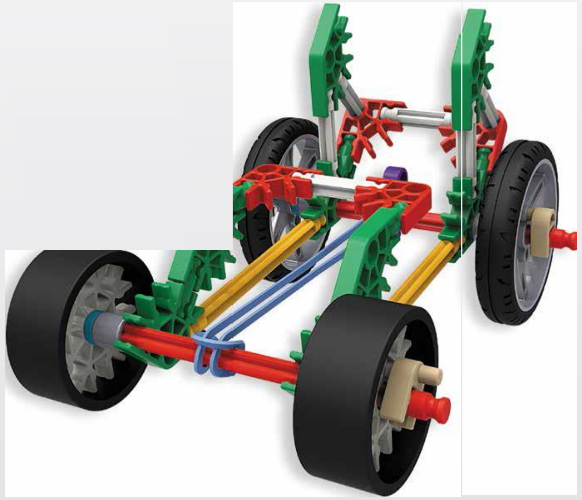
Number of Wraps (Tension)

Load

Surface Texture

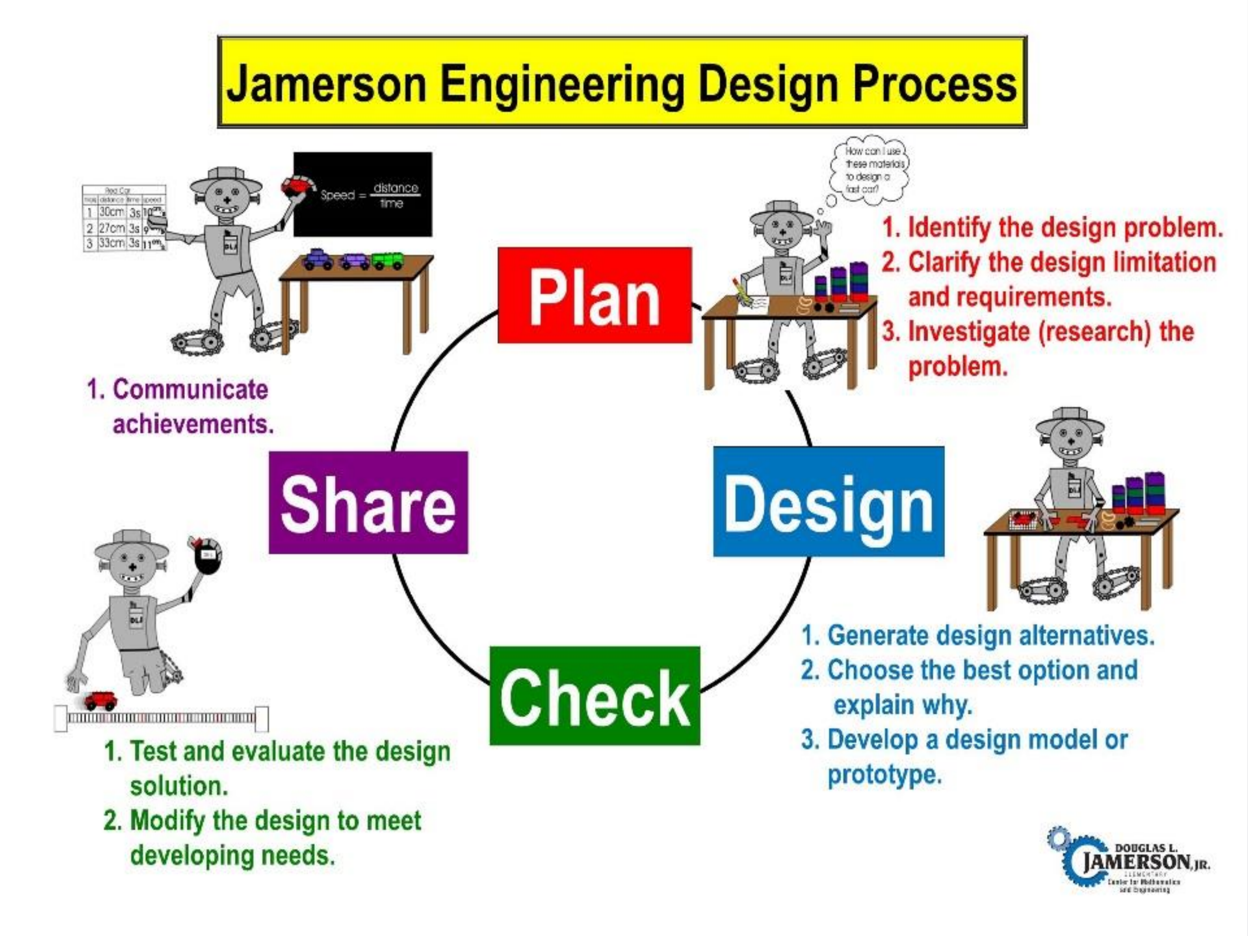
Aesthetics

Cost

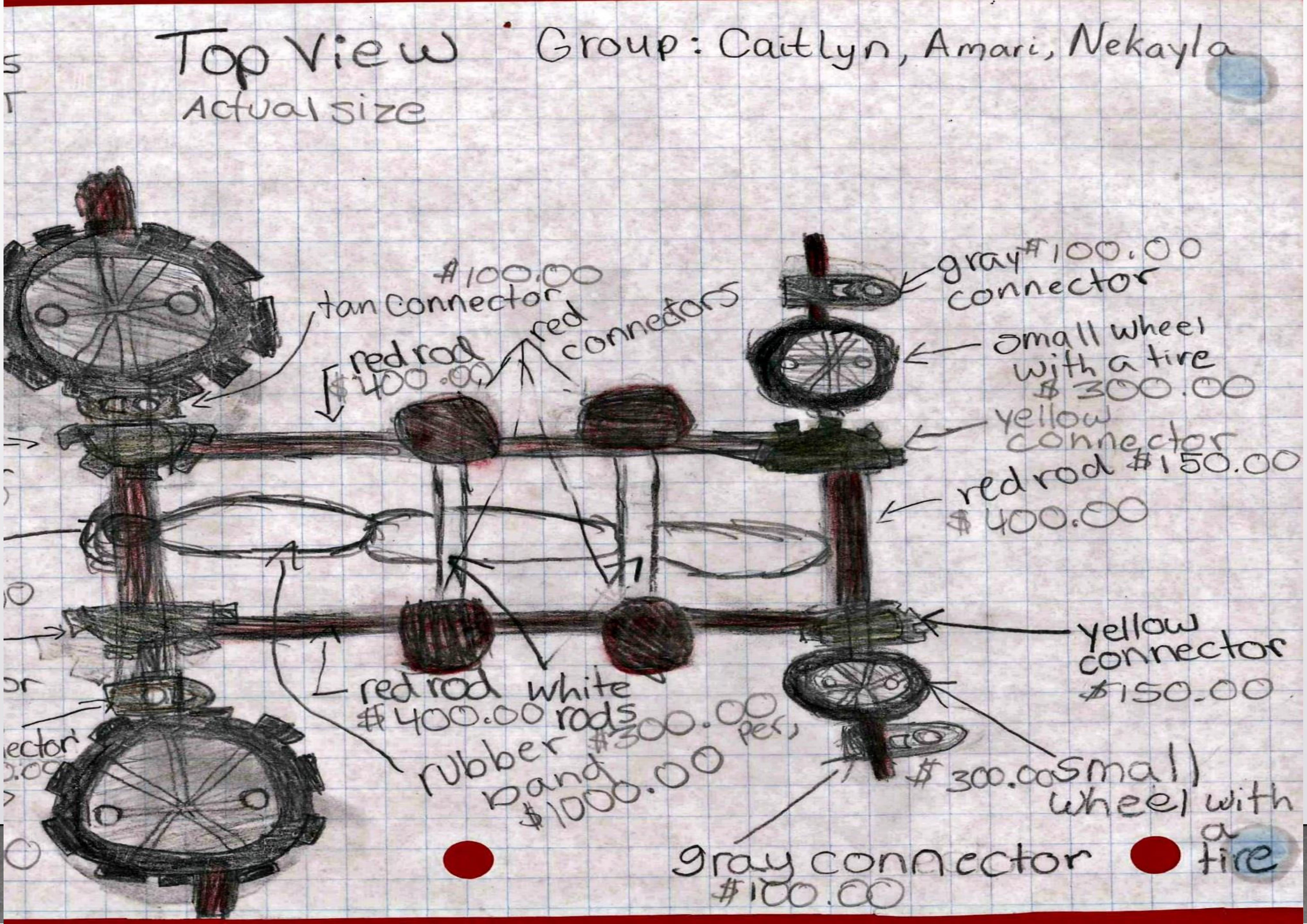


The design challenge is an opportunity for the students to apply what they have learned in a real world context. The challenge leaves room for creativity within the constraints. In this case the best car is not the fastest but the most *efficient*.

K'Nex Design Challenge



Students repeatedly design, check, and redesign their vehicles. The engineering design process is used to develop perseverance, or an understanding that failure is an opportunity to redesign.


Top View
Actual size
Group: Caitlyn, Amari, Nekayla
$100.00
tan connector
red rod
$400.00
red
connectors
gray $100.00
connector
small wheel
with a tire
$300.00
yellow
connector
red rod $150.00
red rod
$400.00
yellow
connector
$150.00
red rod
$400.00
white
rods
$300.00
per,
rubber
band
$1000.00
$300.00
small
wheel with
a
tire
gray connector
$100.00

Could you reduce your vehicle cost to $5000 without losing efficiency?

Evaluating the Cost of Our Design

Building Piece	Cost Per Piece		Number of Pieces Used		Total Cost	
Propeller	$500	x	1	=	500	✓
Rods						
Gray	$450	x	2	=	900	✓
Red	$400	x	2	=	600	✓
Yellow	$350	x	0	=	0	✓
White	$300	x	0	=	0	✓
Blue	$250	x	2	=	500	✓
Green	$100	x	0	=	0	✓
Connectors						
White	$250	x	0	=	0	✓
Yellow	$150	x	4	=	600	✓
Green	$150	x		=		
Red	$100	x	4	=	400	✓
Orange	$100	x		=		
Dark gray	$100	x		=		
Brown	$100	x	4	=	400	✓
Wheels						
Small	$200	x	2	=	400	✓
Large	$400	x	2	=	800	✓
Tires						
Small	$100	x	2	=	ok	X
Large	$200	x	2	=	400	✓
				TOTAL	6,700 $	✓

K'Nex Vehicle Unit

Where's the Math?

- *Measurement and Data*
  - Length and time
  - Median and mean
  - Data collection and analysis
- Speed calculations
- Students use blueprints to construct vehicles and draw blueprints from constructed vehicles.
- Scale
- Budgeting and Cost Analysis

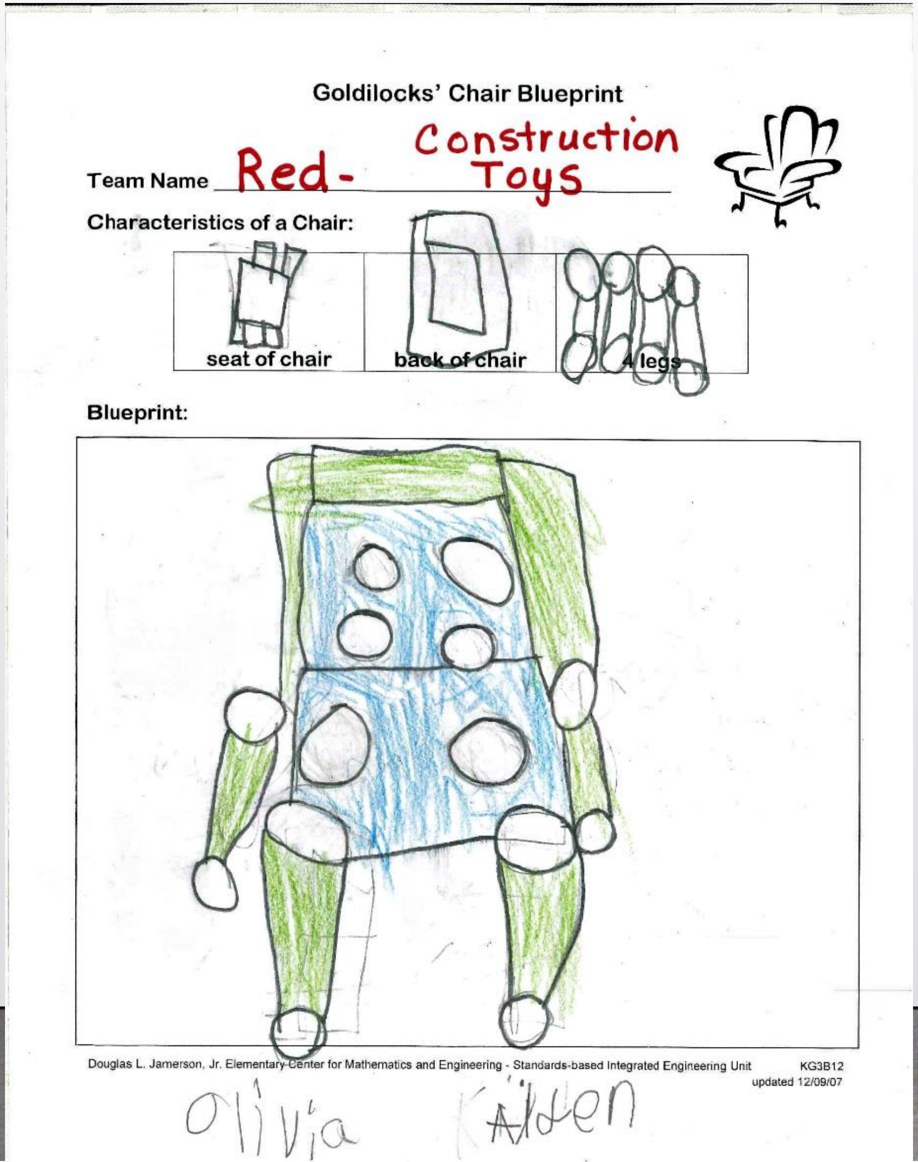
Example 4: Kindergarten

Design a *Just Right* Chair for Goldilocks

1. Work on an engineering team to design a chair with a seat, back, and four legs.
2. The chair should balance when different forces are applied.
3. Select from a variety of materials (i.e., Legos, Blocks, Lincoln Logs, Tinker Toys).
4. Plan and draw a diagram of the chair prior to building.
5. Test the chair using the *Less Mass* and *More Mass* Goldilocks dolls.
6. Revise the design and test again as needed.

Example 4: Kindergarten

Design a *Just Right* Chair for Goldilocks


Goldilocks' Chair Blueprint

Team Name Red- Construction Toys

Characteristics of a Chair:

seat of chair | back of chair | 4 legs

Blueprint:

Douglas L. Jamerson, Jr. Elementary Center for Mathematics and Engineering - Standards-based Integrated Engineering Unit KG3B12 updated 12/09/07

Olivia Kaiden

Properties of Materials

More Mass, Less Mass

Forces: Push and Pull

Structural Design

Blueprints

Example 5: Primary
Design a Lego Tower

Work on an engineering team to design a Lego Tower that…

- Is 30-50 cm tall
- Has a describable color pattern
- Won't fall down in the "wind"

Example 5: Primary

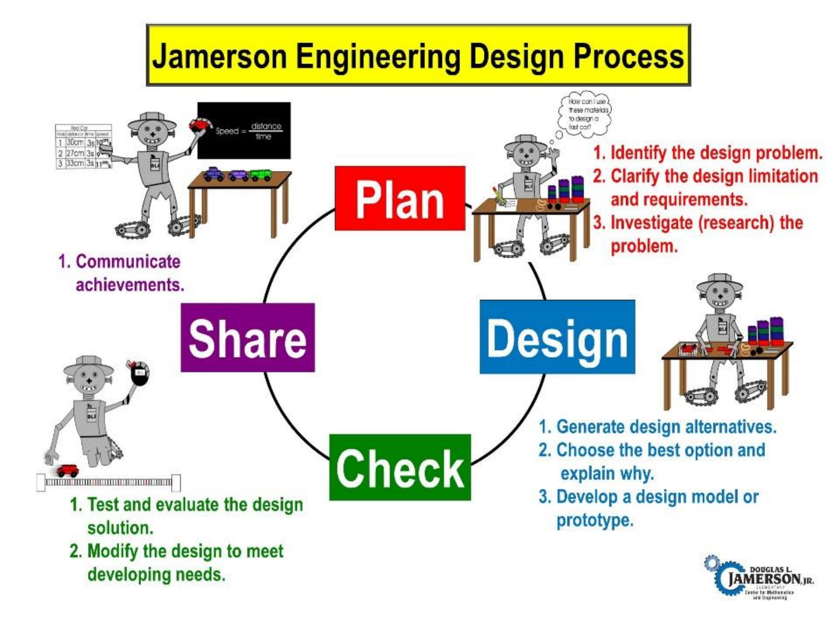
Design a Lego Tower

PLAN – Practice building a tower without constraints; draw a diagram.

DESIGN – Construct a tower based on the diagram.

CHECK – Make sure the tower meets the design constraints.

SHARE – Tell others how the tower meets all constraints; collect data.



Example 6: Intermediate

Investigating Bridge Design

Lesson	Description
1	Introduction to bridges
2	Arch bridges
3	Investigation: Beam vs. Suspension
4	Truss Supports
5	Calculating Load and Equilibrium
6	Design Challenge

The lessons leading up to the design challenge incorporate language arts, math, science, and social studies concepts. They serve to build background knowledge that levels the playing field, giving all students an entry point into the design challenge.

Example 6: Intermediate

Investigating Bridge Design

Your team is part of a civil engineering company that specializes in building bridges. The Department of Transportation wants you to design a bridge that meets the following constraints while keeping the cost as low as possible.

Design Constraints – The model bridge must…

- Span at least 20 cm
- Maintain its shape with 5 Newtons of force
- Have a least two supports
- Be visually appealing
- Stay within the $5000 budget

Material	Cost	Quantity	Item Cost
1 straw	$300	3+1+2+2	2400
10 cm of tape--masking or electric	$100	2+1+2+3+2+2	1200
10 cm of string	$200	8+2+4+3	1800
Total cost	X	X	5400

300
4
1200

Plan:

Discuss possible types and designs for your bridge with your team. Choose the best design and determine the materials needed. Determine the total cost of the design using the table above.

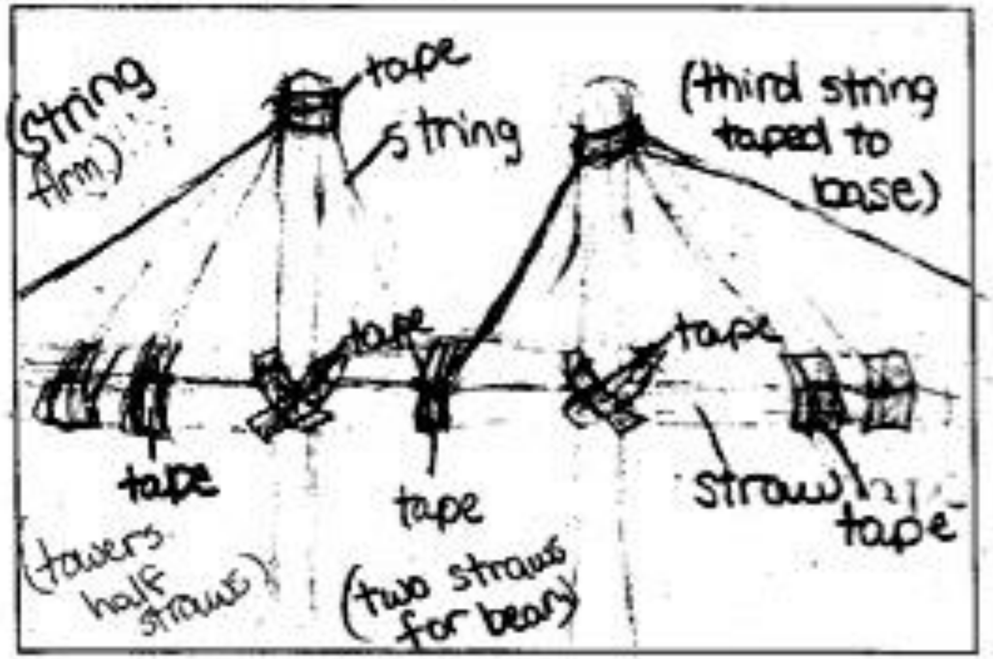
Include a sketch of your bridge below.

3

600
400
200
1700

300
3

100
20
200



Example 6: Intermediate

Investigating Bridge Design

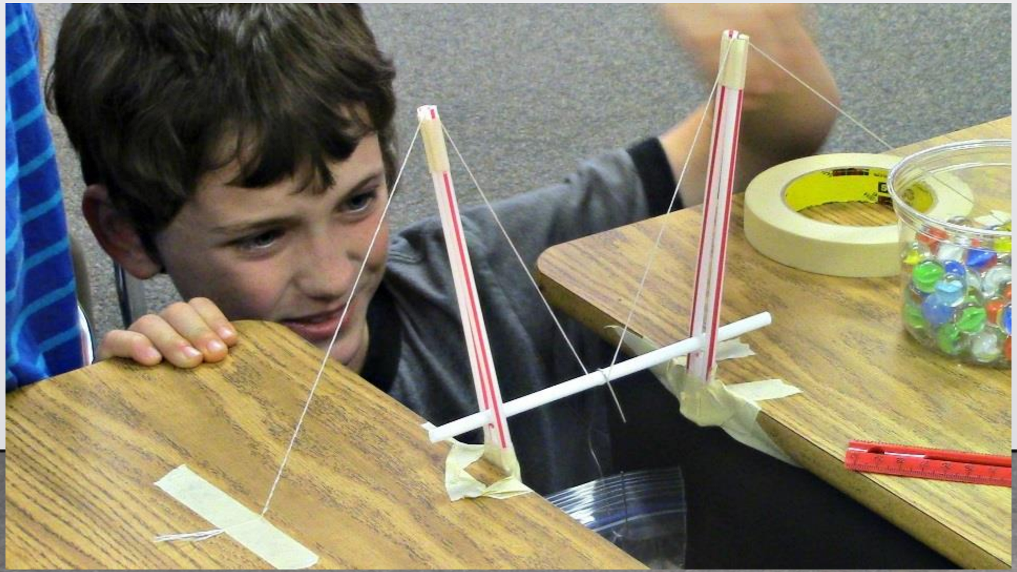
Data collection, analysis, and graphing

Length measurement

Force measurements: using formulas, spring scales and force plates

Load and equilibrium calculations

Budgeting and cost analysis



Tips for Getting Started

1. Develop a *Nature of Science & Engineering Unit* to span the first four weeks of school.
2. Start with your standards and existing science units of study.
3. Develop a culminating engineering design challenge to align with one of your units.
4. Determine the mathematics skills/standards necessary for success with the design challenge.
5. Connect the unit with language arts, social studies, and research whenever possible.
6. Collaborate with other willing teachers.

Resources

Questions, Comments, and Curriculum

heftyl@pcsb.org

@LukasHefty

Videos, Photos, and Articles

http://www.pcsb.org/domain/1829

Hefty, L. (Mar 2015). "STEM Gives Meaning to Mathematics." *Teaching Children Mathematics*, Vol. 21, No. 7.

Hefty, L. (Nov 2015). "Investigating Bridge Design." *Teaching Children Mathematics. Vol. 22, No. 4.*

Hefty, L. (Feb 2016). "Goldilocks, an Engineer?" *Teaching Children Mathematics.* Vol. 22, No. 6.

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