Engineering in the Elementary and Middle School Classroom: Opportunities for Integrating Across Your Curriculum

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11:30 am-1:00pm

A Framework for K-12 Science Education:

Practices, Crosscutting Concepts, and Core Ideas

BOX ES.1
The Three Dimensions of the Framework

1. Scientific and Engineering Practices	3. Disciplinary Core Ideas
1. Asking questions (for science) and defining problems (for engineering) 2. Developing and using models 3. Planning and carrying out investigations 4. Analyzing and interpreting data 5. Using mathematics and computational thinking 6. Constructing explanations (for science) and designing solutions (for engineering) 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information **2. Crosscutting Concepts** 1. Patterns 2. Cause and effect: Mechanism and explanation 3. Scale, proportion, and quantity 4. Systems and system models 5. Energy and matter: Flows, cycles, and conservation 6. Structure and function 7. Stability and change	<u>Physical Sciences</u> PS 1: Matter and its interactions PS 2: Motion and stability: Forces and interactions PS 3: Energy PS 4: Waves and their applications in technologies for information transfer <u>Life Sciences</u> LS 1: From molecules to organisms: Structures and processes LS 2: Ecosystems: Interactions, energy, and dynamics LS 3: Heredity: Inheritance and variation of traits LS 4: Biological evolution: Unity and diversity <u>Earth and Space Sciences</u> ESS 1: Earth's place in the universe ESS 2: Earth's systems ESS 3: Earth and human activity <u>Engineering, Technology, and the Applications of Science</u> ETS 1: Engineering design ETS 2: Links among engineering, technology, science, and society

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BOX 8-1

Definitions of Technology, Engineering, and Applications of Science

Technology is any modification of the natural world made to fulfill human needs or desires [2].

Engineering is a systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants [2].

An application of science is any use of scientific knowledge for a specific purpose, whether to do more science; to design a product, process, or medical treatment; to develop a new technology; or to predict the impacts of human actions.

BOX 8-2

Core and Component Ideas in Engineering, Technology, and Applications of Science

Core Idea ETS1: Engineering Design

ETS1.A: Defining and Delimiting an Engineering Problem
ETS1.B: Developing Possible Solutions
ETS1.C: Optimizing the Design Solution

Core Idea ETS2: Links Among Engineering, Technology, Science, and Society

ETS2.A: Interdependence of Science, Engineering, and Technology
ETS2.B: Influence of Engineering, Technology and Science on Society and the Natural World

School Science vs. School Engineering

School engineering is fundamentally different from school science

- In school science, students study objects and phenomena that already exist
- In school engineering, students bring into existence objects that did not previously exist
- School engineering offers opportunities for synthesizing and applying what has been learned in inquiry based science and for authentic, cross-curricular collaboration among students

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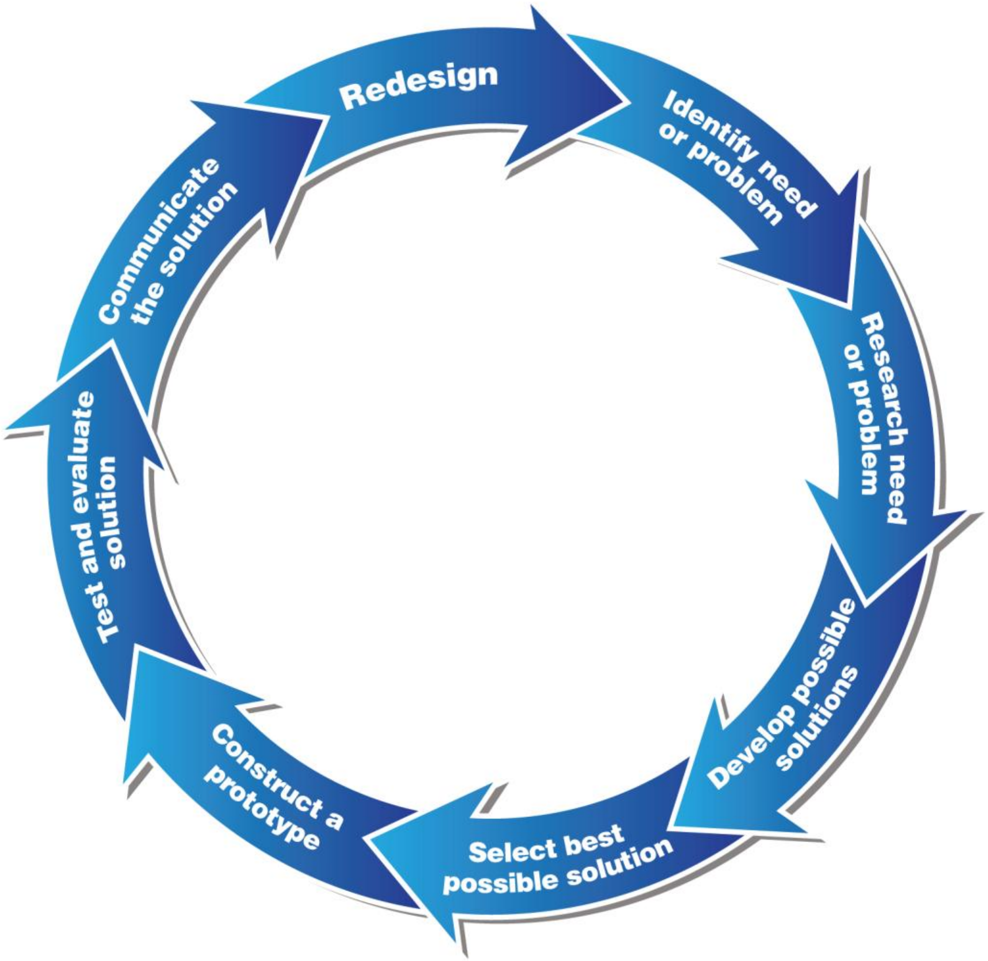
The School Engineering Process

DOE (2006). Massachusetts Science and Technology/Engineering Curriculum Framework



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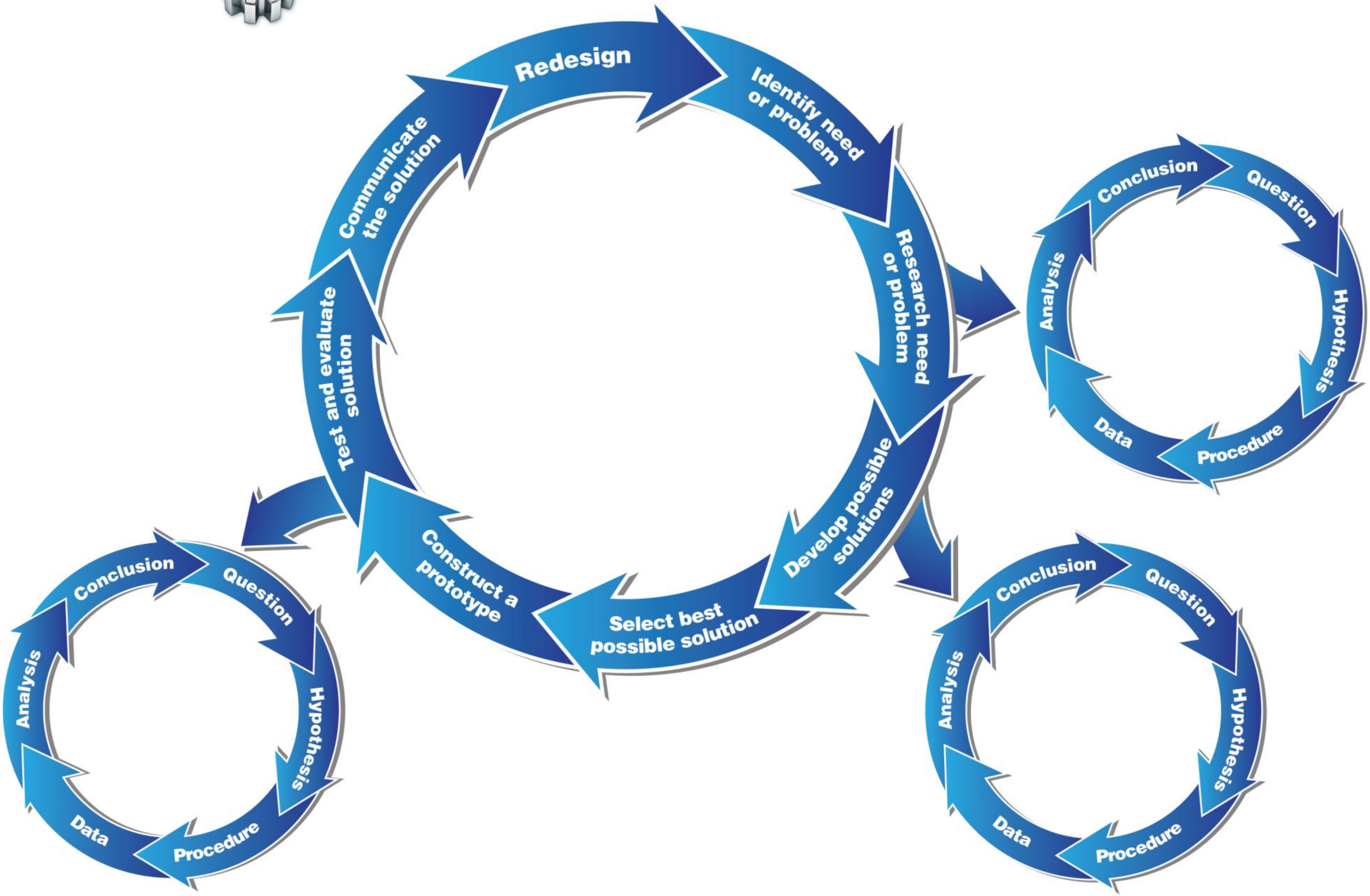

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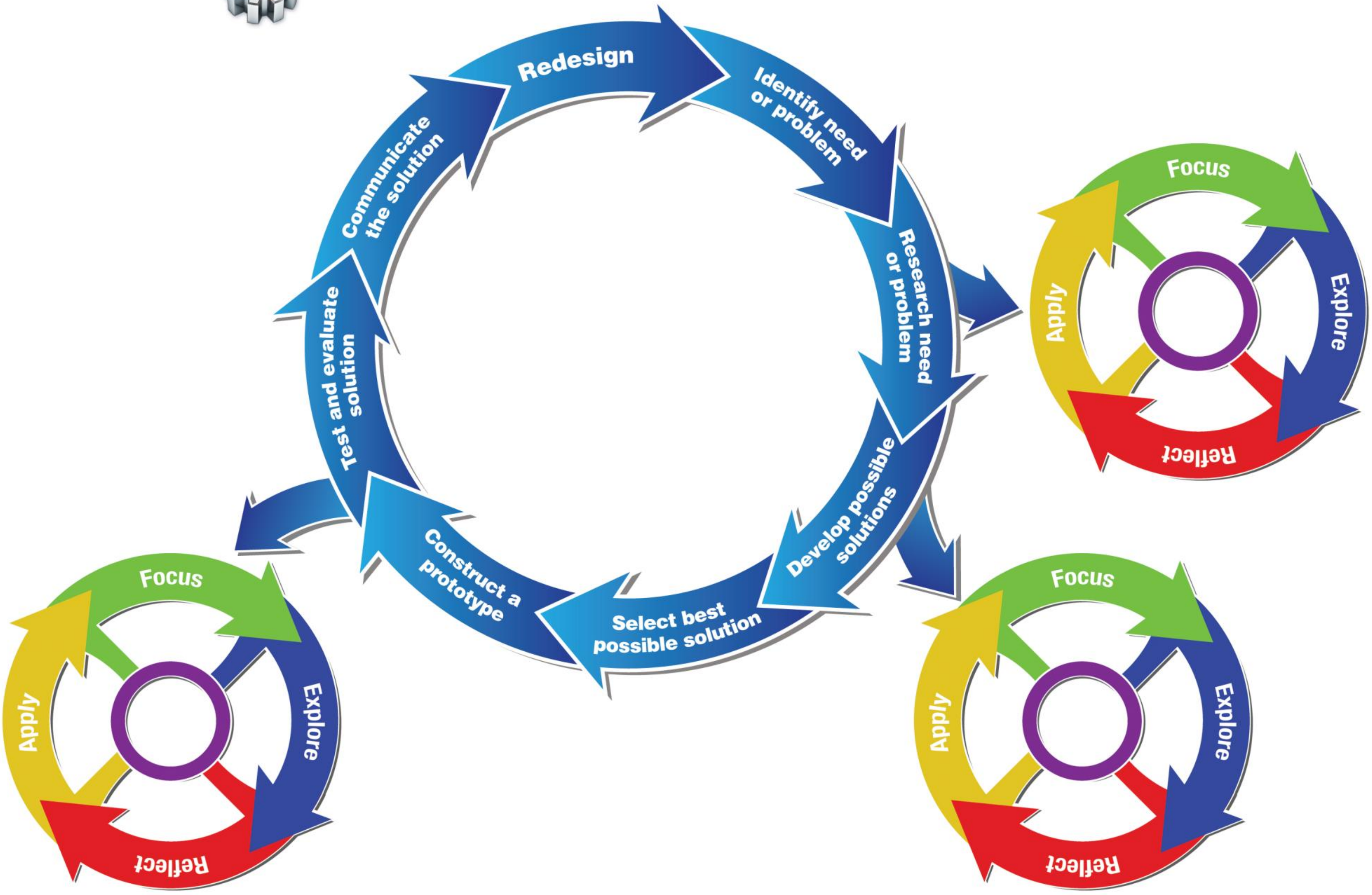


The Engineering Design Process in Action: IDEO Redesigns the Shopping Cart

Take notes about the following focus questions:

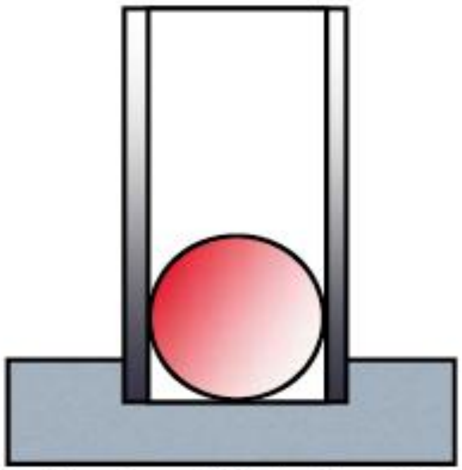
- Who are the designers – what are their backgrounds?
- What are the steps of their design process – what did they do?
- How did the designers work together – what are their group norms?
- Who did the designers talk to during the design process and what did they learn from them?
- How did YOU feel as you watched them do their work?

Design Challenge: Prototype to Think

- Assume that a steel pipe is imbedded in the concrete floor of a bare room as shown above. The inside diameter of the pipe is 0.1mm larger than the diameter of the red ping pong ball that is resting at the bottom of the pipe. Your team has been given the following resources:

- 4 feet of clothesline, one wooden ruler, a hand-held strainer, one box of Cheerios, a sponge, one roll of toilet paper, two flow-through tea bags, one light bulb, one soda straw, a CD, and an orange

- List all the ways you can think of to remove the ball without damaging the ball, the pipe, or the floor. Write one solution on each post-it and stick the post-its to your chart paper.



*James Adams; Conceptual Blockbusting, a Guide to Better Ideas

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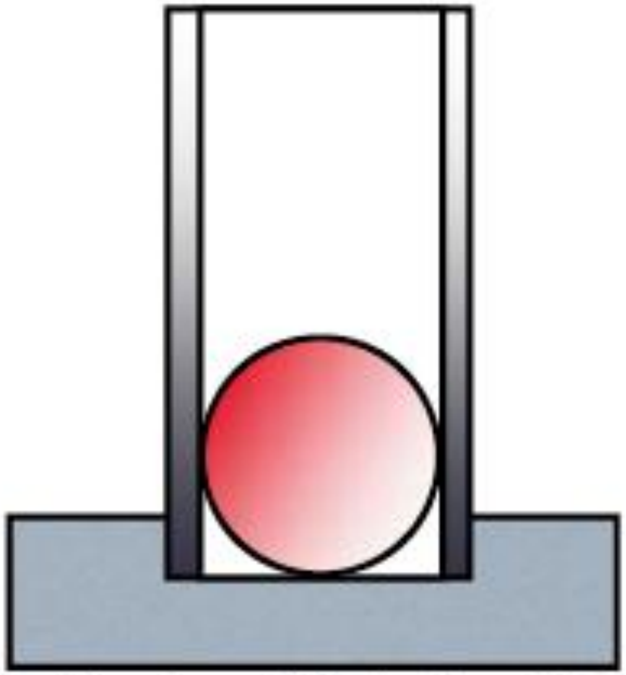
Build to Synthesize Learning

What solutions did you find?

- Choose one idea to create a "build to think" prototype
- What prior knowledge did you bring to your solution?
- In what context did you learn the prior knowledge you applied to solve this challenge?



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Connections to Science Curriculum

Literal Solution

- Wet the sponge with water from the bathroom, squeeze water into the pipe until the ball floats high enough to pick it up with fingers

Prior knowledge – physical science

- Water will flow into the small space around the ping pong ball – liquids take the shape of their container (Solids and Liquids unit)
- The ping pong ball will float on water – buoyant force (Floating and Sinking unit)

Connections to Science Curriculum

Lateral Solution

- Chew a tootsie roll until it gets soft, stick it to one end of the ruler, insert it into the pipe, stick it to the ping pong ball and lift the ball out

Prior knowledge – life science

- Like the way a butterfly unfurls its proboscis to eat (Life Cycle of Butterflies unit)
- Like the way a bee collects pollen on its legs (Plant Growth and Development unit)

The Keys to Innovative Engineering Thinking

- In order to think creatively and innovatively, students need exposure to a wide variety of experiences so they can apply what they've learned to engineering challenges in different ways (literal and lateral design thinking).
- Inquiry-based science units are built around objects and phenomena that have engaged humankind for centuries.
- Engineers draw on their academic and experiential knowledge to solve problems

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Connections to Real World

Why does this engineering challenge matter?

- A similar challenge occurred in August of 2011 when 33 miners were buried alive in Chile
- Clinton Cragg, a former Navy submarine captain and a NASA engineer, drew on his experience living in small confined spaces and designing unique, one-of-a-kind vehicles to design the rescue capsule that brought the miners to the surface
- Because the challenge involved human life, experts in medicine, psychology, and engineering worked together to determine the constraints of the problem and how to accommodate the miners’ physical and psychological needs as they ascended.

Cross-Curricular, Common Core and 21st Century Skills Connections

- Spatial reasoning and measuring in mathematics
- Visual, narrative, and verbal representations in language arts; speaking and writing
- Knowledge of geography, topography and cultural norms in social studies

21st Century Skills

- Innovation
- Self Direction and Self Regulation
- Collaboration
- Information Literacy
- Technology Literacy
- Critical Thinking and Reasoning

Engineering Design Challenges Provide a Context for Social and Emotional Learning

These social and emotional skills are valued in the engineering design process professionals use at IDEO:

- Empathize with the user
- Take another's perspective
- Defer judgment
- Give feedback tactfully
- Work collaboratively in support of another's idea

Dr. McMahon's research shows that elementary teachers perceive these 21st Century social and emotional skills are crucial to helping students learn the cognitive steps of the engineering design process.

Dr. McMahon's Research Findings

- Elementary teachers embed the steps of the engineering process (the cognitive aspect of engineering) into classroom collaboration (the social and emotional aspects of engineering)
- Engineers embed collaboration into the steps of the engineering process, which reflects their prior commitment to the cognitive aspects of engineering

Dr. McMahon's Research Implications

- It is essential that the social and emotional processes of collaboration be taught explicitly and ***in the context of*** the cognitive steps of the engineering process
- Teachers consider these 21st Century collaborative skills valuable across the curriculum
- Professional engineers regard these 21st Century skills as essential to engineering practice

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3. Disciplinary Core Ideas

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Thank You!

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