K-12 and Pre-College Engineering Division

Leveraging
Next Generation Science Standards
To Increase K-12 Engineering Education

ASEE 2013 Pre-Conference Workshop
June 2013

Presenters:
David Heil
Shannon McManus
Elizabeth Parry
Stacy Klein-Gardner
Shannon Weiss

Workshop Presenters

David Heil

President, David Heil & Associates, Inc., dheil@davidheil.com

Shannon McManus

Senior Professional Development Associate, Engineering is Elementary Curriculum Project at the Museum of Science, Boston, smcmanus@mos.org

Elizabeth Parry

Coordinator, K-20 STEM Partnership Development, NC State University

College of Engineering, elizabeth.parry.consulting@gmail.com

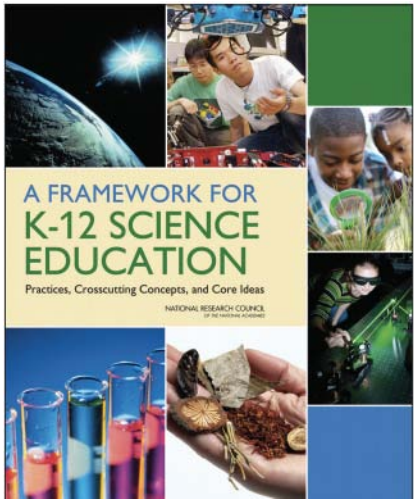
Stacy Klein-Gardner, Ph.D.

Director, Center for STEM Education for Girls, Harpeth Hall School, stacy.gardner@harpethall.org

Shannon Weiss

Project Coordinator, David Heil & Associates, Inc., sweiss@davidheil.com

A New Vision of Science Learning That Will Lead to New Approaches in Science Teaching



The framework was designed to help realize a vision for education in the sciences and engineering in which students, over multiple years of school, actively engage in science and engineering practices and apply crosscutting concepts to deepen their understanding of the core ideas in these fields.

Science and Engineering Practices

1. Asking questions and defining problems
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 and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

1. Patterns
2. Cause and effect
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter
6. Structure and function
7. Stability and change

Disciplinary Core Ideas

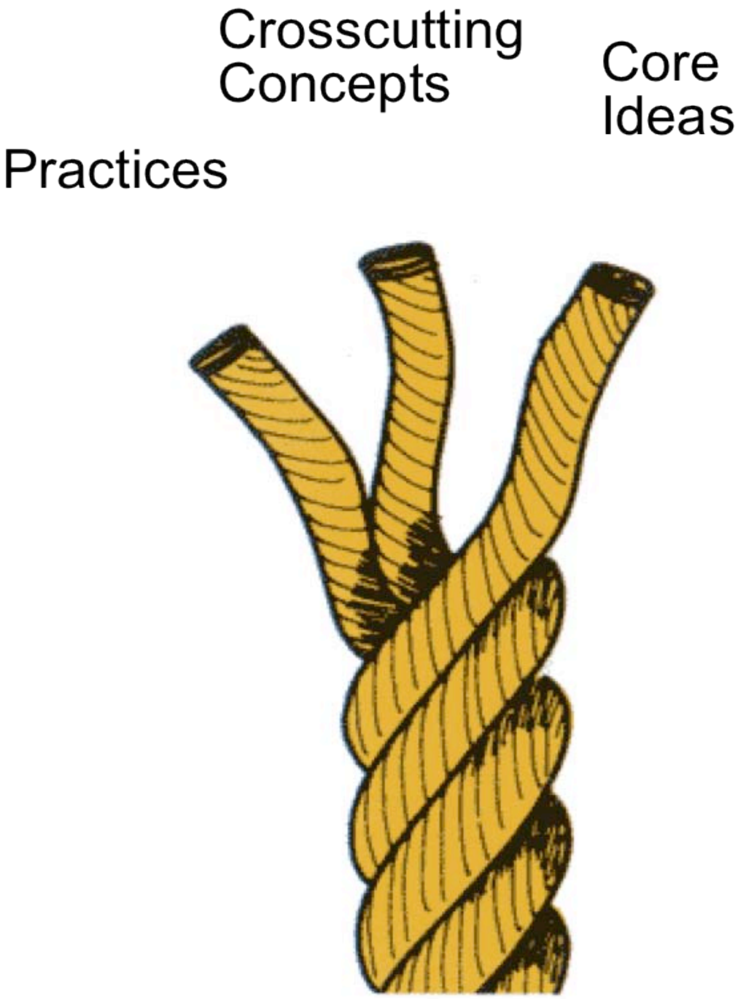
- Have broad importance across multiple science or engineering disciplines or is a key organizing concept of a single discipline

- Provide a key tool for understanding or investigating more complex ideas and solving problems

- Relate to the interests and life experiences of students or can be connected to societal or personal concerns that draw on scientific or technical knowledge

- Are teachable and learnable over multiple grades at increasing levels of depth and sophistication

NGSS Architecture



Integration of practices, core ideas, and crosscutting concepts.

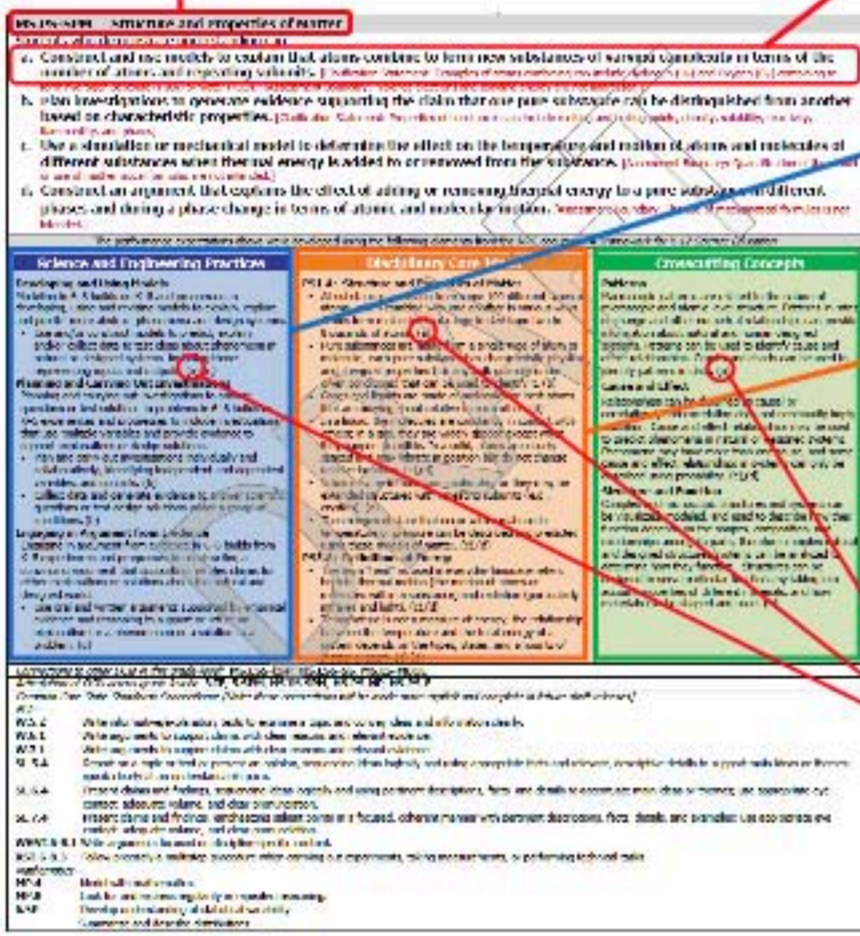
Inside the NGSS Box

Title and Code
Two standards at different grade levels may use the same name of they focus on the same topic. The code, however, is a unique identifier for each standard based on the grade level, content area, and topic of the standard.

Standard
A collection of several performance expectations describing what students should be able to do to master this standard

Performance Expectation
A statement that combines practices, core ideas, and crosscutting concepts into a single statement describing how students can show what they have learned.

Scientific & Engineering Practices
Practices are the activities that scientists and engineers engage in to either understand the world or solve a problem



Foundation Box
The practices, core disciplinary ideas, and crosscutting concepts from the *Framework for K-12 Science Education* that were used to form the performance expectations

Disciplinary Core Ideas
Core Ideas are those concepts in science and engineering that have broad importance within and across disciplines as well as relevance in people's lives.

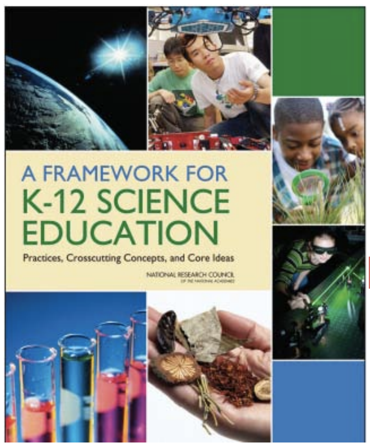
Crosscutting Concepts
Crosscutting Concepts are those ideas, such as *Patterns* and *Cause and Effect,* which are not specific to any one discipline but cut across them all.

Connection Box
Other standards in the *Next Generation Science Standards* or in the *Common Core State Standards* that are related to this standard

Lowercase Letters
Lowercase letters at the end of Practices, Core Ideas, and Crosscutting Concepts designate which Performance Expectation incorporates them.

2012-2013

Important Work Still Ahead



NEXT GENERATION SCIENCE STANDARDS

- Curriculum
- Teacher Professional Development
- Instruction
- Assessments

K-2-ETS1 Engineering Design

K-2-ETS1 Engineering Design

Students who demonstrate understanding can:

K-2-ETS1-1. Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

K-2-ETS1-2. Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

K-2-ETS1-3. Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in K–2 builds on prior experiences and progresses to simple descriptive questions.

- Ask questions based on observations to find more information about the natural and/or designed world. (K-2-ETS1-1)
- Define a simple problem that can be solved through the development of a new or improved object or tool. (K-2-ETS1-1)

Developing and Using Models

Modeling in K–2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions.

- Develop a simple model based on evidence to represent a proposed object or tool. (K-2-ETS1-2)

Analyzing and Interpreting Data

Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.

- Analyze data from tests of an object or tool to determine if it works as intended. (K-2-ETS1-3)

Disciplinary Core Ideas

ETS1.A: Defining and Delimiting Engineering Problems

- A situation that people want to change or create can be approached as a problem to be solved through engineering. (K-2-ETS1-1)
- Asking questions, making observations, and gathering information are helpful in thinking about problems. (K-2-ETS1-1)
- Before beginning to design a solution, it is important to clearly understand the problem. (K-2-ETS1-1)

ETS1.B: Developing Possible Solutions

- Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. (K-2-ETS1-2)

ETS1.C: Optimizing the Design Solution

- Because there is always more than one possible solution to a problem, it is useful to compare and test designs. (K-2-ETS1-3)

Crosscutting Concepts

Structure and Function

- The shape and stability of structures of natural and designed objects are related to their function(s). (K-2-ETS1-2)

Connections to other DCIs in this grade-level: will be available on or before April 26, 2013.

Articulation of DCIs across grade-levels: will be available on or before April 26, 2013.

Connections to K-2-ETS1.A: Defining and Delimiting Engineering Problems include:
Kindergarten: K-PS2-2, K-ESS3-2

Connections to K-2-ETS1.B: Developing Possible Solutions Problems include:
Kindergarten: K-ESS3-3, **First Grade:** 1-PS4-4, **Second Grade:** 2-LS2-2

Connections to K-2-ETS1.C: Optimizing the Design Solution include:
Second Grade: 2-ESS2-1

3-5-ETS1 Engineering Design

3-5-ETS1 Engineering Design

Students who demonstrate understanding can:

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in 3–5 builds on grades K–2 experiences and progresses to specifying qualitative relationships.

- Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost. (3-5-ETS1-1)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (3-5-ETS1-3)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.

- Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem. (3-5-ETS1-2)

Disciplinary Core Ideas

ETS1.A: Defining and Delimiting Engineering Problems

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (3-5-ETS1-1)

ETS1.B: Developing Possible Solutions

- Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. (3-5-ETS1-2)
- At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (3-5-ETS1-2)
- Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3)

ETS1.C: Optimizing the Design Solution

- Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3-5-ETS1-3)

Crosscutting Concepts

Influence of Science, Engineering, and Technology on Society and the Natural World

- People's needs and wants change over time, as do their demands for new and improved technologies. (3-5-ETS-1)
- Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. (3-5-ETS-2)

Connections to other DCIs in this grade-level: will be available on or before April 26, 2013.

Articulation of DCIs across grade-levels: will be available on or before April 26, 2013.

Connections to 3-5-ETS1.A: Defining and Delimiting Engineering Problems include:

4th Grade: 4-PS3-4

Connections to 3-5-ETS1.B: Designing Solutions to Engineering Problems include:

4th Grade: 4-ESS3-2

Connections to 3-5-ETS1.C: Optimizing the Design Solution include:

4th Grade: 4-PS4-3

EiE Engineering is Elementary

Developed by the Museum of Science, Boston

Shannon McManus

Engineering is Elementary is a

- research-based,
- standards-driven,
- classroom-tested
- curriculum that integrates engineering and technology concepts and skills with elementary science topics.

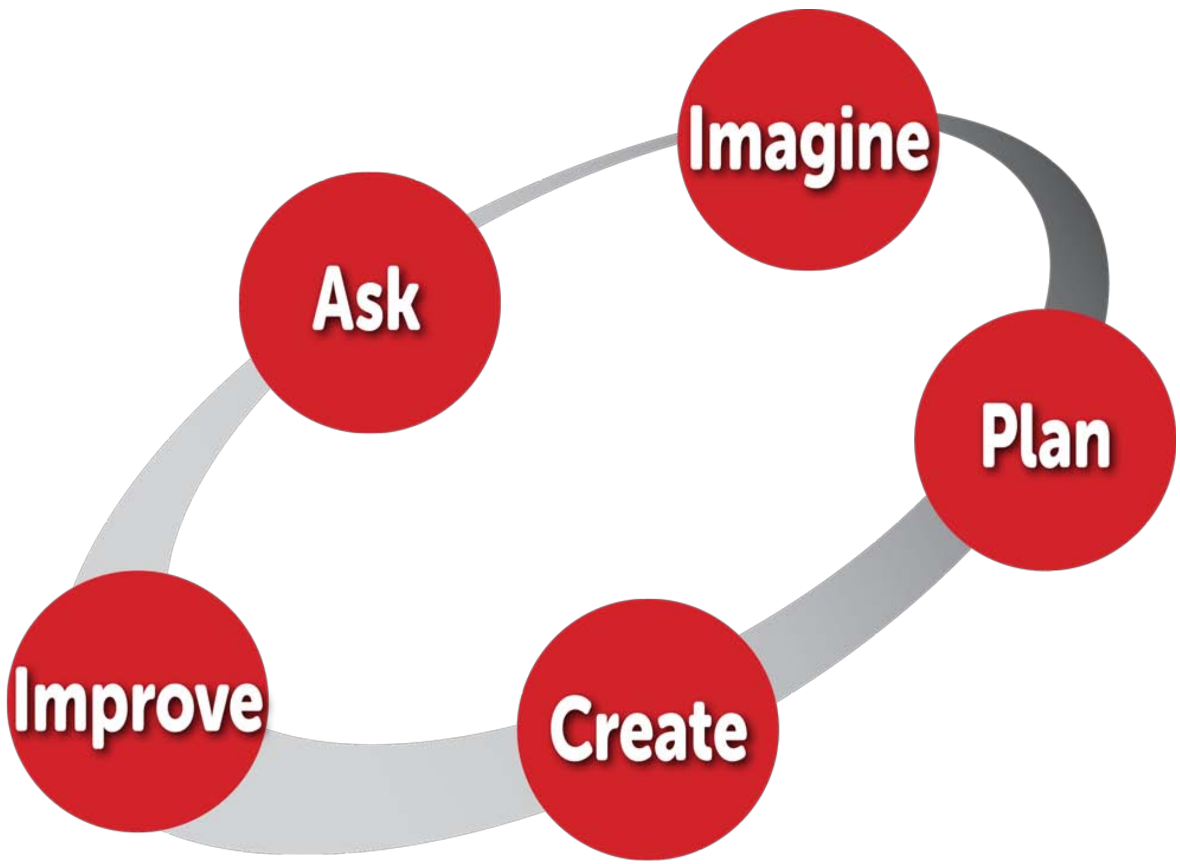
	SCIENCE TOPIC	UNIT TITLE	ENGINEERING FIELD	STORY SETTING
EARTH SCIENCE	Water	**Water, Water Everywhere:** Designing Water Filters	Environmental	India
	Air & Weather	**Catching the Wind:** Designing Windmills	Mechanical	Denmark
	Earth Materials	**A Sticky Situation:** Designing Walls	Materials	China
	Landforms	**A Stick in the Mud:** Evaluating a Landscape	Geotechnical	Nepal
	Astronomy	**A Long Way Down:** Designing Parachutes	Aerospace	Brazil
	Rocks	**Solid as a Rock:** Replicating an Artifact	Materials	Russia
LIFE SCIENCE	Insects/Plants	**The Best of Bugs:** Designing Hand Pollinators	Agricultural	Dominican Republic
	Organisms/Basic Needs	**Just Passing Through:** Designing Model Membranes	Bioengineering	El Salvador
	Plants	**Thinking Inside the Box:** Designing Plant Packages	Package	Jordan
	Ecosystems	**A Slick Solution:** Cleaning an Oil Spill	Environmental	USA
	Human Body	**No Bones About It:** Designing Knee Braces	Biomedical	Germany
PHYSICAL SCIENCE	Simple Machines	**Marvelous Machines:** Making Work Easier	Industrial	USA
	Balance & Forces	**To Get to the Other Side:** Designing Bridges	Civil	USA
	Sound	**Sounds Like Fun:** Seeing Animal Sounds	Acoustical	Ghana
	Electricity	**An Alarming Idea:** Designing Alarm Circuits	Electrical	Australia
	Solids & Liquids	**A Work in Process:** Improving a Play Dough Process	Chemical	Canada
	Magnetism	**The Attraction is Obvious:** Designing Maglev Systems	Transportation	Japan
	Energy	**Now You're Cooking:** Designing Solar Ovens	Green	Botswana
	Floating & Sinking	**Taking the Plunge:** Designing Submersibles	Ocean	Greece
	Light	**Lighten Up:** Designing Lighting Systems	Optical	Egypt

20 EiE Units

EiE Unit Structure

- Prep Lesson: Technology in a Bag
- Lesson 1: Engineering Story
- Lesson 2: A Broader View of an Engineering Field
- Lesson 3: Scientific Data Inform Engineering Design
- Lesson 4: Engineering Design Challenge

The Engineering Design Process

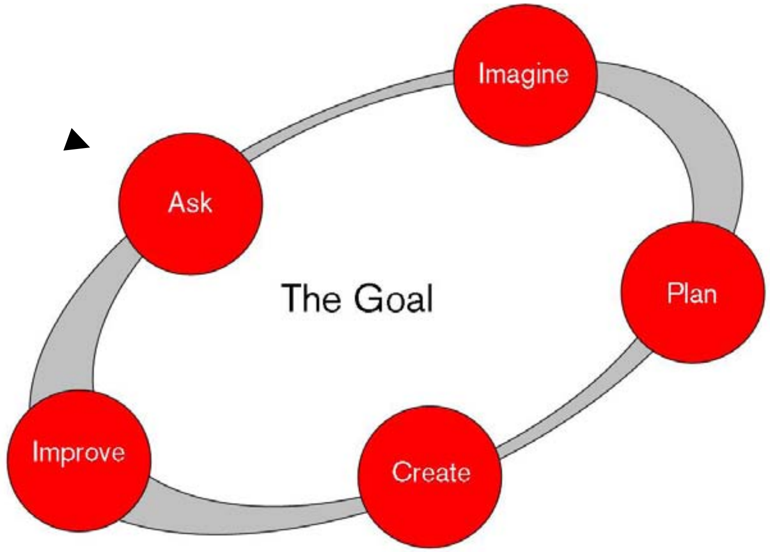


Catching the Wind
Mechanical Engineering: Designing Windmills

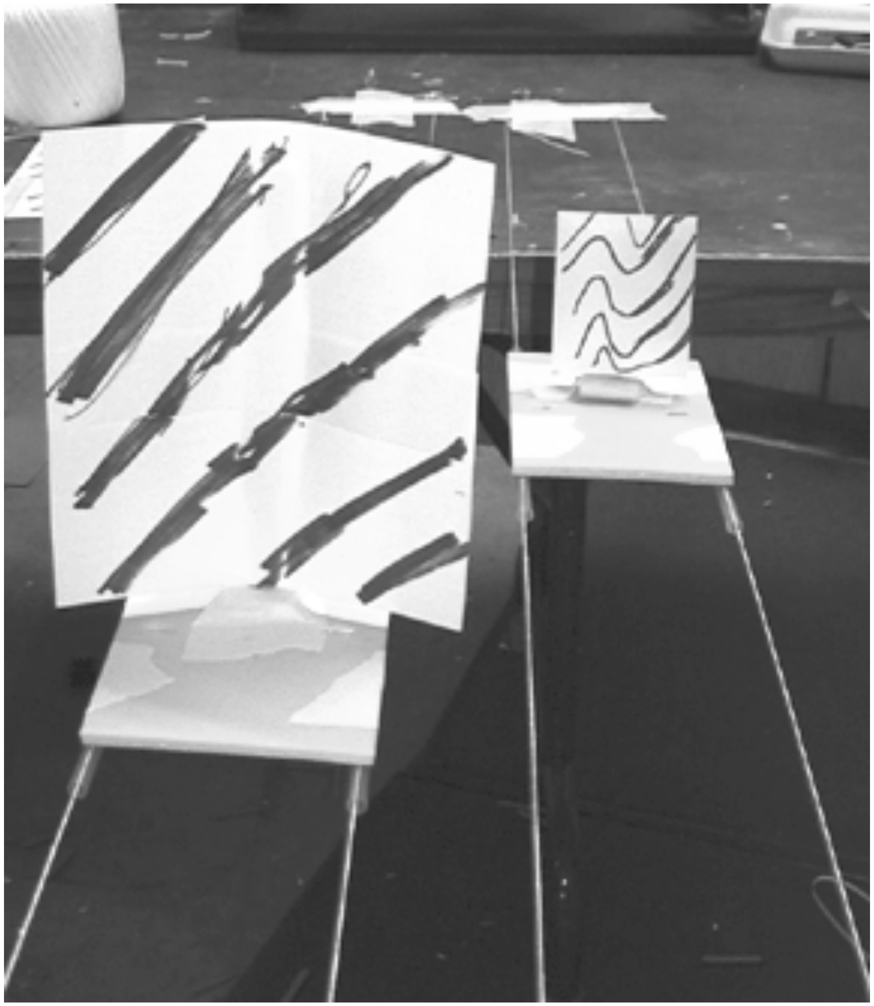
- Unit Goal: Work as mechanical engineers to design blades for a windmill that capture the wind's energy to do useful work.

ASK

In order for you to complete this challenge, what do you need to know?



Lesson 3 Set-Up



Predict

- What are some properties of a wind catcher (sail) that might be important to moving the raft?

Properties of Sail Materials

Object/Material	Properties
Aluminum foil	
Card stock	
Felt	
Tissue Paper	
Plastic sheet	
Paper (cup)	
Copy Paper	
Wax Paper	

Name: ______________________________ Date: _____________

Be a Mechanical Engineer!

B

1. Circle the **material(s)** you predict will work well in a sail design.

aluminum foil	paper	plastic bag	wax paper
tissue paper	cup	felt	index card

Why do you think so?______________________________________

____

2. Put an "X" through the **material(s)** you predict will NOT work well.

aluminum foil	paper	plastic bag	wax paper
tissue paper	cup	felt	index card

Why not?____

____

3. Circle the shape(s) you predict will work well for a sail.

square	triangle	circle	other

Why do you think so?

____

Targeted NGSS Science Content:

- Properties of Matter
  - Disciplinary Core Idea for Grades 2 and 5
    - Example: 2-PS1-2.Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.
- Forces and Motion
  - Disciplinary Core Idea for Grades K and 3

Targeting NGSS Engineering Practices:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Targeting NGSS Engineering Practices:

- Asking questions and defining problems
- **Developing and using models**
- Planning and carrying out investigations
- **Analyzing and interpreting data**
- Using mathematics and computational thinking
- **Constructing explanations and designing solutions**
- **Engaging in argument from evidence**
- Obtaining, evaluating, and communicating information

Targeting NGSS Engineering Practices:

EiE Engineering is Elementary

Developed by the Museum of Science, Boston

Engineering is Elementary:

EiE@mos.org

www.eie.org

National Center for Technological Literacy:

www.nctl.org

Family Science & Engineering

Leveraging Next Generation Science Standards to Increase K-12 Engineering Education

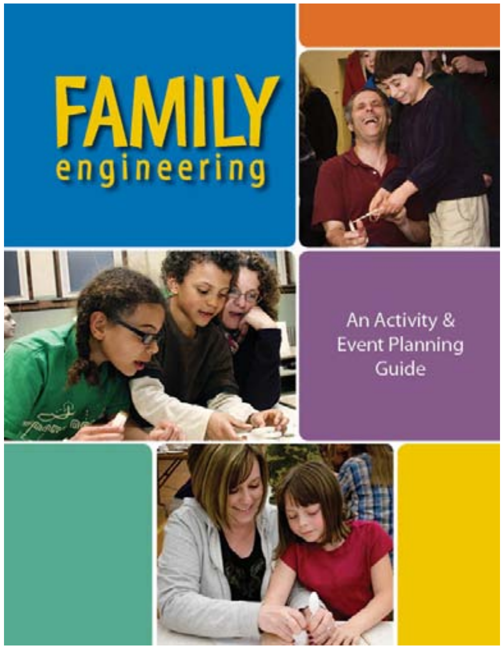
June 23, 2013

ASEE K-12 and Pre-College Engineering Division Pre-Conference Workshop

David Heil
President, David Heil & Associates, Inc.
Founding President, Foundation for Family Science & Engineering

Foundation for Family Science & Engineering

Resources for Family STEM Learning



Family Science & Family Engineering

Informal education programs that actively engage elementary-aged children and their families in fun, hands-on science and engineering activities and events.

- Fun and engaging
- Families learning together
- Simple materials
- Easy to facilitate
- Suitable for a variety of settings

- Accessible for diverse audiences
- Explore science and engineering concepts and careers
- Promotes 21st Century skills of inquiry, creativity, teamwork, and collaborative problem solving

Family Engineering Program Development Partners And Funders

Foundation for Family Science & Engineering

Michigan Tech

Michigan Technological University

American Society for Engineering Education

ASEE

National Science Foundation

WHERE DISCOVERIES BEGIN

Family Science & Engineering Program Goals

1. Engage families in science and engineering with fun, hands-on activities.
2. Increase public understanding and appreciation of the role science and engineering play in everyday life.
3. Introduce children at an early age to the many career opportunities in science and engineering.
4. Increase parents' interest in and ability to encourage their children to pursue an engineering or science career.
5. Provide age-appropriate resources to support volunteers in conducting informal education programs with elementary-aged children and their parents.

The evidence is consistent, positive, and convincing:

families have a major influence on their children's achievement in school and through life.

A New Wave of Evidence: The Impact of School, Family, and Community Connections on Student Achievement

Henderson and Mapp, 2002

Family Science and Family Engineering Support Next Generation Science Standards

Science and Engineering Practices:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

A Framework for K-12 Science Education
National Research Council, 2012

What Does a Family Science and Engineering Event Look Like?

Self Directed Openers

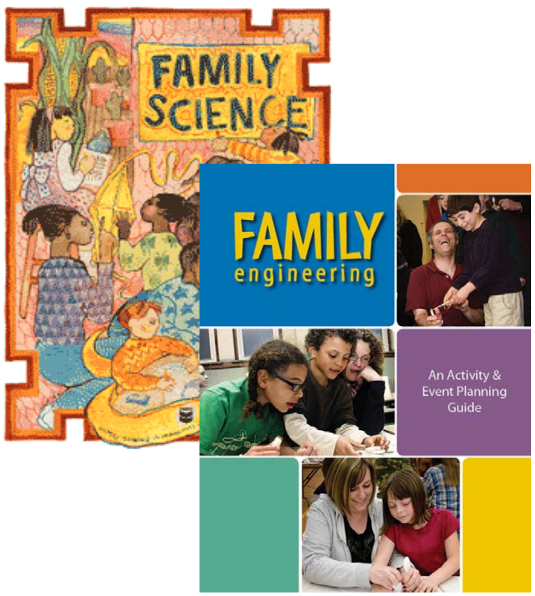
Facilitated Investigations & Engineering Challenges

Who Can Organize a Family Science or Family Engineering Event?

- K-5 classroom teachers and administrators
- Parent teacher organizations (PTA)
- Professional scientists & engineers
- College science and engineering (STEM) students
- High school science or engineering clubs
- Members of professional science and engineering societies
- Informal educators at museums, community centers, scouts, etc.
- Businesses and organizations that support STEM education
- Parents

Getting Involved in Family Science and Family Engineering

- **Attend a Training Workshop**
  Join the growing network of trained volunteers – contact us to set up a customized training workshop in your school district or state.



- **Host a School or Community-Based Event**
  Helpful resources: *Family Engineering: An Activity & Event Planning Guide* and *Family Science.*

Family Engineering Event Starter Kit

Foundation for Family Science & Engineering

To learn more about Family Science or Family Engineering, contact us at:

4614 SW Kelly Avenue, Suite 100
Portland, Oregon 97239
Telephone: (503) 245-2102
Email: info@familyengineering.org

www.familyscience.org

www.familyengineering.org

MS-ETS1 Engineering Design

MS-ETS1 Engineering Design

Students who demonstrate understanding can:

MS-ETS1-1. **Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.**

MS-ETS1-2. **Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.**

MS-ETS1-3. **Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.**

MS-ETS1-4. **Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades 6–8 builds on grades K–5 experiences and progresses to specifying relationships between variables, clarify arguments and models.
- Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. (MS-ETS1-1)

Developing and Using Models
Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.
- Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. (MS-ETS1-4)

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.
- Analyze and interpret data to determine similarities and differences in findings. (MS-ETS1-3)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.
- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-ETS1-2)

Disciplinary Core Ideas

ETS1.A: Defining and Delimiting Engineering Problems
- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1)

ETS1.B: Developing Possible Solutions
- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4)
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3)
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3)
- Models of all kinds are important for testing solutions. (MS-ETS1-4)

ETS1.C: Optimizing the Design Solution
- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. (MS-ETS1-3)
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (MS-ETS1-4)

Crosscutting Concepts

Influence of Science, Engineering, and Technology on Society and the Natural World
- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ETS1-1)
- The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-ETS1-1)

Connections to other DCIs in this grade-level: will be available on or before April 26, 2013.

Articulation of DCIs across grade-levels: will be available on or before April 26, 2013.

Connections to MS-ETS1.A: Defining and Delimiting Engineering Problems include:
Physical Science: MS-PS3-3

Connections to MS-ETS1.B: Developing Possible Solutions Problems include:
Physical Science: MS-PS1-6, MS-PS3-3, **Life Science:** MS-LS2-5

Connections to MS-ETS1.C: Optimizing the Design Solution include:
Physical Science: MS-PS1-6

Findings from the National Academies

"As STEM education … does not reflect the natural interconnectedness of the four STEM components in the real world …."

"… potential value, related to student motivation and achievement, in increasing the presence of …, especially, engineering in STEM education … in ways that address the current lack of integration in STEM …"

"… the most intriguing possible benefit of K–12 engineering education relates to improved student learning and achievement in mathematics and science and *enhanced interest* in these subjects because of their relevance to real-world problem solving. .. limited amount of reliable data …"

To make a world of difference

What does engineering in STEM look like in K-12?

- **Engineering "the verb" or the process of engineering design**
- **Essential ideas of engineering:**
  - ✓ *Constraints, criteria and fair test*
  - ✓ *Failure, Improvement and Iteration*
  - ✓ *Systems thinking*
  - ✓ *Collaboration*
  - ✓ *Communication*
  - ✓ *Creativity*
  - ✓ *Ethical Considerations*
  - ✓ *Optimism*
- **Goal is to *create more—and more diverse--engineering and technologically literate citizens***

Because engineers are essential to our health, safety and happiness

Because dreams need doing

nc state ENGINEERING

The Four Key Elements of Engineering in K-1 (NC Engineering Connections)

- Engineering habits of mind
- Engineering design
- Systems thinking
- Problem solving

To help shape the future

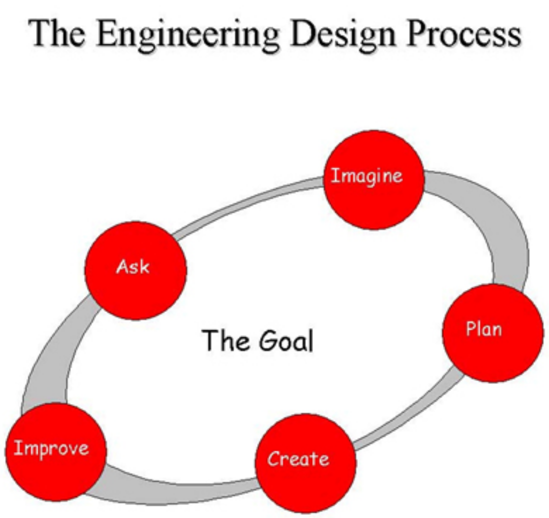
Engineering habits of mind

- Communication
- Collaboration
- Optimism
- Systems thinking
- Ethical thinking
- Creativity




To make a world of difference

Engineering Design Process

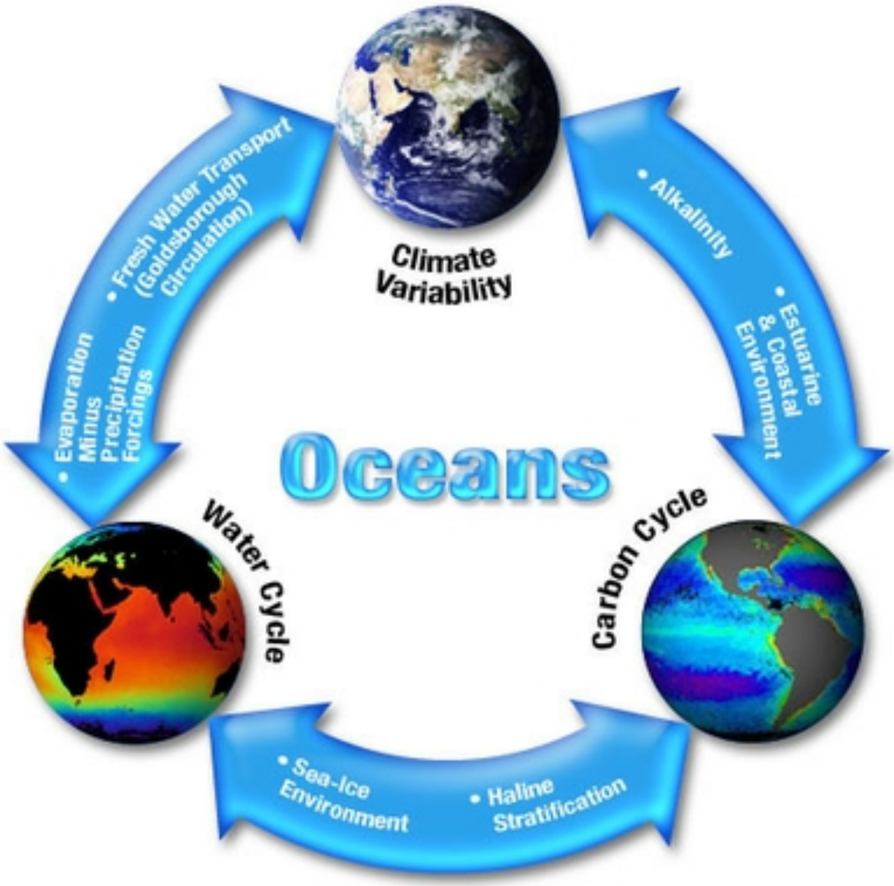


Grades K-5, based on Engineering is Elementary from Museum of Science, Boston

Grades 6-12 based Engineering the Future and the NASA design process

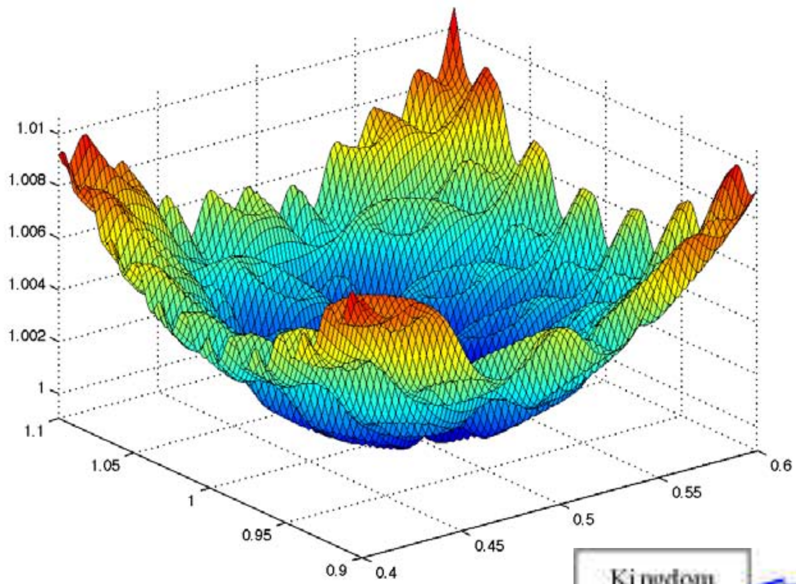
Because engineers are essential to our health, safety and happiness

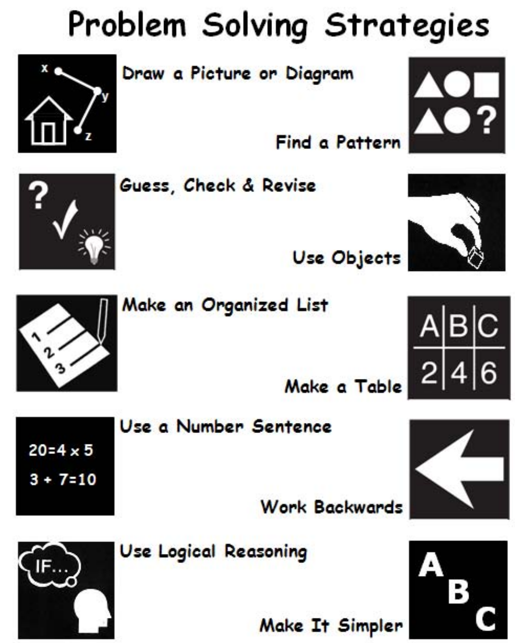
Systems Thinking

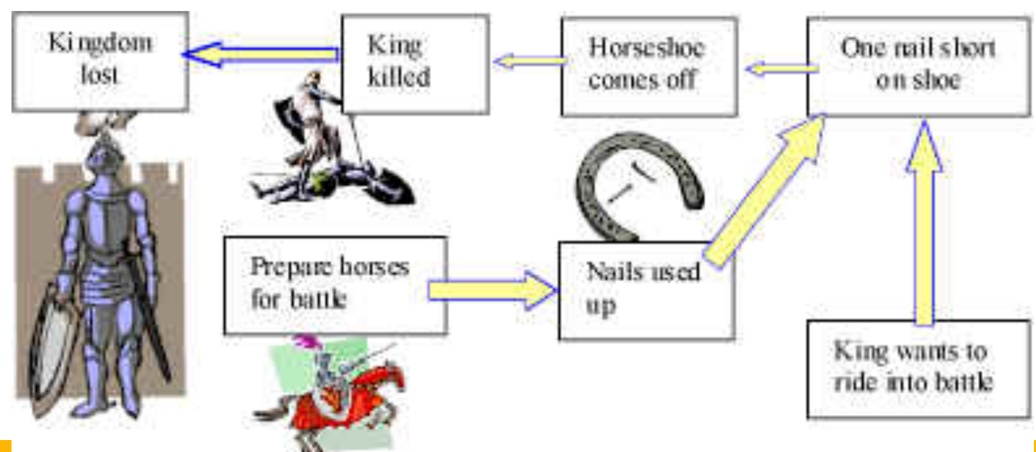


Because dreams need doing

Problem Solving







To solve problems creatively

NGSS MS-ETS1-1.

Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

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Because engineers are essential to our health, safety and happiness

NGSS MS-ETS1-2.

Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

To make a world of difference

NGSS MS-ETS1-3.

Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Because dreams need doing

NGSS MS-ETS1-4.

Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

To solve problems creatively

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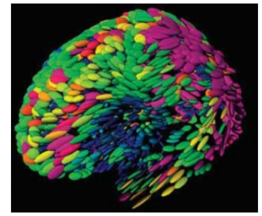


The Grand Challenges for Engineering

(www.engineeringchallenges.org)








Because dreams need doing

Why engineering in K-12?

To solve problems creatively.

Because engineers are essential to our health, safety and happiness.

To help shape the future.

To make a world of difference.

Because dreams need doing.

Just a few reasons why people choose engineering.

HS-ETS1 Engineering Design

HS-ETS1 Engineering Design

Students who demonstrate understanding can:

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.

- Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1)

Using Mathematics and Computational Thinking

Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-4)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories.

- Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2)
- Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)

Disciplinary Core Ideas

ETS1.A: Defining and Delimiting Engineering Problems

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1)

ETS1.B: Developing Possible Solutions

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)
- Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)

ETS1.C: Optimizing the Design Solution

- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)

Crosscutting Concepts

Systems and System Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. HS-ETS1-4)

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3)

Connections to other DCIs in this grade-level: will be available on or before April 26, 2013.

Articulation of DCIs across grade-levels: will be available on or before April 26, 2013.

Connections to HS-ETS1.A: Defining and Delimiting Engineering Problems include:

Physical Science: HS-PS2-3, HS-PS3-3

Connections to HS-ETS1.B: Designing Solutions to Engineering Problems include:

Earth and Space Science: HS-ESS3-2, HS-ESS3-4, **Life Science:** HS-LS2-7, HS-LS4-6

Connections to HS-ETS1.C: Optimizing the Design Solution include:

Physical Science: HS-PS1-6, HS-PS2-3

High School Engineering Education

Stacy Klein-Gardner, Ph.D.
Director, Center for STEM Education for Girls
Harpeth Hall School

Adjoint Associate Professor of the Practice of Biomedical Engineering, Vanderbilt University
stacy.gardner@harpethhall.org

CENTER FOR STEM EDUCATION FOR GIRLS

Center for STEM Education for Girls

- Founded in 2011 through a leadership grant from the Edward E. Ford Foundation
- STEM Think Tank and Conference – the nation's sole conference focused on females with input from university educators , informal educators, and corporate members that has grown out of the K12 schools
- STEM Consortium – leadership board
- STEM Summer Institute – a model program for STEM integration for girls
- STEM Resources – a variety of types with research to practice highlights

http://stemefg.org

CENTER FOR STEM EDUCATION FOR GIRLS

Literature

- Knight and Mappen (2011) relay that increasing women involvement in STEM is successfully achieved through civic engagement.
- Contextualizing STEM subjects with practical problems can help contribute to girl's present and future interest in the subjects (Halpern et al. 2007)

STEM Summer Institute – A Model Program For STEM Integration

Stacy Klein-Gardner, Ph.D.
Director, Center for STEM Education for Girls
stacy.gardner@harpethhall.org

STEM Summer Institute (SSI) 2012

- Two-week long program that focused on engaging sixteen rising 9th and 10th grade underrepresented girls in STEM in Davidson County, TN
- Focus on enrichment of their self-efficacy and increased knowledge of engineering

Research Questions

- *Question 1.* How does participation in the STEM Summer Institute increase or change participants' understanding of the nature of engineering?
- *Question 2.* How does participation in the STEM Summer Institute increase participants' self-efficacy?

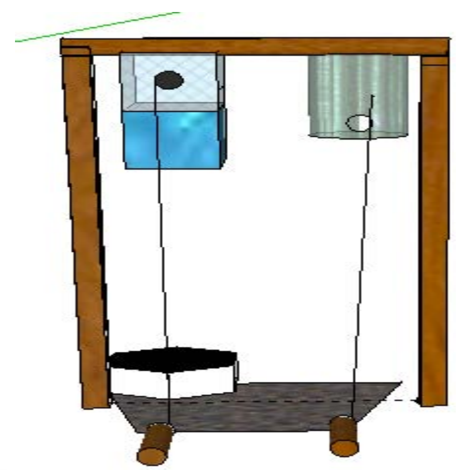
Program Participants 2012

- Of the sixteen participating girls,
  - eight were African American,
  - one was African American/Hispanic,
  - one was Hispanic,
  - two were Asian,
  - and four were Caucasian.
  - Three of these students immigrated to the US within a year of participating in the SSI.


MISSION:
To build the capacity
of the people of
Kamagambo, Kenya
to advance their own
comprehensive
well-being

SSI 2012

- Partner with Lwala Community Alliance
- Tippy Tap hand-washing stations need improvement
  - Soap is often stolen
  - Not kid-friendly
- Use the engineering design process
- Kenyan culture and role of women
- Build on scientific knowledge
  - Stream study
    - Analyze data with Excel
  - Wastewater treatment plant
- Google SketchUp – CAD model



SSI 2012

- Engineering Design Competition – last day
  - Student teams present
    - Scientific poster with EDP
    - Prototype
    - Video of working prototype
    - Oral presentation

  - Judging
    - By engineers, SSI faculty, Lwala
    - Presentation
    - Written documentation of EDP in innovation portal

The Winner's Prototype is off to Kenya!

Details

- Two weeks in June
- Full day, non-residential
- Optional transportation assistance
- Lunch and snacks provided
- $300 registration fee
- Optional scholarship application
- Harpeth Hall faculty and Vanderbilt University School of Engineering faculty and graduate students

Innovation Portal and EDPPSR

- http://innovationportal.org
- Engineering Design Process Portfolio Scoring Rubric

- Use for formative and summative assessment

Understanding of Engineering Post-SSI

- Engineering design is not always creating something but it is more often improving what already exists.
- Engineering includes creating things to solve a problem.
- Engineering that is beyond such superficial ideas that suggest that engineers fix cars or build houses and bridges.
- Engineering comprises multiple disciplines and subject areas (such as math and science).
- **By the SSI introducing the girls to real-world issues in which they can offer applicable solutions, the girls were able to make feasible connections to engineering.**

Self-Efficacy Conclusions

- The SSI was effective in increasing the girl's self-efficacy
  - a greater belief in their success within STEM courses.
  - a greater feeling of inclusion both inside and outside the classroom
  - greater expectations in the outcomes of taking math courses and doing well in math.
  - confident in completing an engineering program.

NGSS Standards Met – Tippy Tap

- **HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.**

- **HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.**

- **HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.**

- HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

2013: Creating a Fish Farm Pond

- Partner with Lwala Community Alliance
- Residents of Lwala wish to become fish farmers
  - Problems with dry season and evaporation
  - Current model is a hole in the ground!
  - Using materials found naturally in Kenya, design a fish farm pond

NGSS Standards Met – Fish Pond

- HS-LS1-3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.
- HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
- HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
- HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

2013: Creating an Oven for Making Muffins

- Partner with Lwala Community Alliance
- Residents of Lwala wish to sell corn muffins
  - Women desire income to support their family
  - Using materials found naturally in Kenya, design an oven for baking corn muffins


got Christ?

NGSS Standards Met – Oven

- HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Implications and Suggestions

- Focus on service learning, learning within a context, and other unique needs of female and minority learners is critical.
- SSI can serve as an effective model for STEM-integrated curriculum both in summer programs and particularly in the classroom.

Implications and Suggestions

- Partner with area schools, informal educators, etc.
- Partner with community serving organizations
- **Look specifically at NGSS Disciplinary Core Ideas and the Engineering & Technology Standards – Teachers will appreciate the integration most as they have no time to spare!**

Stacy Klein-Gardner, Ph.D.
Director, Center for STEM Education for Girls,
Harpeth Hall School
Adjoint Associate Professor of the Practice of
Biomedical Engineering, Radiological
Sciences, and Teaching Learning
Vanderbilt University

stacy.gardner@harpethhall.org

SUMMER INSTITUTE
CENTER FOR STEM EDUCATION FOR GIRLS

Leveraging NGSS To Advance K-12 Engineering Education

- K-12 students will be exposed to disciplinary core ideas in engineering, engineering practices, and the engineering design process
- Curriculum developers will need assistance creating meaningful K-12 engineering instructional materials
- Engineering educators can contribute to K-12 teacher preparation and professional development
- Engineering educators can assist with engineering-related teaching and learning in both formal and informal settings
- Engineers and engineering educators can serve as community resources, role models, and active participants in future K-12 education

Research & Evaluation

- Need To Measure NGSS Impacts As Implemented
  - General interpretation/implementation of NGSS
  - Specific interpretation/implementation of Engineering practices and standards
  - Teacher professional development
  - New curricula and other instructional materials
  - Impacts on student learning, performance

- Great Opportunity For Higher Education Institutions To Contribute To Advancing The Field

Research & Evaluation

- Front-End Evaluation
  - Target audience interests, needs, and expectations
  - Testing preliminary program concepts, assumptions
  - Informs project planning and initial design
- Formative Evaluation
  - Testing/prototyping initial program products, strategies
  - Informs project refinement
- Summative Evaluation
  - Measuring program outcomes and impacts
  - Reporting to project partners, funders

Research & Evaluation

- Join An Existing Network Or Collaborative
  - Field-test site for emerging program
  - Implementation site for existing program
  - Research and/or evaluation partner

- Sharing Research & Evaluation Findings
  - Regional and National Conferences
    - ASEE K-12 and Pre-College Engineering Division
    - National Science Teachers Association (NSTA)
    - American Evaluation Association (AEA)
  - Publications focused on science and engineering education
  - Public funding agencies and private foundations