Problem Solving Approaches in STEM
Teaching, Research & Service in the “T” & “E” of Science, Technology, Engineering, & Mathematics

Prepare Technology & Engineering Education Teachers (Grades 6-12) & TVET Teachers
Introduction

Workshop Objectives

1. Discuss the concepts of STEM Education and Integrative STEM Education.

2. List and describe 5 common methods used to solve problems, including those used in STEM.

3. List the steps the engineering design process and apply them in solving an engineering design challenge.

4. List the components of an engineering design challenge.

5. Develop an engineering Design Challenge.
What is STEM Education?
Science, Technology, Engineering and Mathematics (STEM) and STEM Education are terms seen almost daily in the news.

Knowing the Terms Associated with STEM is Important
STEM Education Focuses on the Components of:

• **SCIENCE** – Study of the Natural World

• **TECHNOLOGY** – Modifying the Natural World to Meet Human Needs and Wants

• **ENGINEERING** – Applying Math & Science to Create Technology

• **MATHEMATICS** – Numbers, Operations, Patterns, & Relationships

These Terms Are Often Confused
What is Technology?

Modifying the natural world to meet the needs and wants of people.
What is Technology?

Technology can be used to describe a:

• **System**
  - Fuel System; Braking System; Wireless System

• **Device**
  - Fuel Injector; Smartphone; Computer;
What is Technology?

Human Innovation In Action

Steve Gleason
What is Engineering?

Engineering applies **math** and **science** to **Create Technology**
What is Engineering?

• Engineering is a Professional Occupation

• Engineering is about the **Design & Making of:**

<table>
<thead>
<tr>
<th>Structures</th>
<th>Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Products</td>
<td>Devices</td>
</tr>
<tr>
<td>Processes</td>
<td>Systems</td>
</tr>
</tbody>
</table>
How do Engineers Solve Problems in Engineering?

The Engineering Design Process
What is STEM Education?

STEM Education Defined

**STEM Education** is a teaching and learning approach in which science, technology, engineering, and mathematics (STEM) are purposely integrated.
Why STEM Education?

1. Globalization: A STEM Workforce is Needed to Compete in a Global Economy

2. Inventions and Innovations: Most Require Use & Knowledge in STEM

3. World Problems: STEM Professionals will need to work together to solve many of the world’s problem (e.g., the need for clean water and food)
What is STEM Education?

STEM Education is Typically Not Taught as a Single Course

It can be Integrated into Most Subject Areas
Benefit of STEM Education?

Why STEM Education?

It may improve **student learning** and **motivation** as it helps students clearly connect the concepts and practices of STEM together!

It can help students see the **BIG PICTURE**!
STEM Education Today
Introduction to Problem Solving
Problem Solving

Knowing How to Solve Problems is Important

Problem Solving is an Important 21st Century Skill
Problem Solving

Without Good Problem Skills – This Could Happen!
Introduction

There are many ways to Solve Problems:

1) Troubleshooting
2) Research and Development
3) Invention and Innovation
4) Scientific Method (Experimentation)
5) Engineering Design
Common Problem Solving Approaches
1. Troubleshooting
1. Troubleshooting

• Troubleshooting is a form of problem solving, often applied to repair failed products or processes.
1. Troubleshooting

- Often used by technicians or repairmen.
- It is a **logical, systematic search** for the source of a problem so that the product can be fixed.
2. Research & Development
2. Research & Development (R&D)

- **Used in Business & Industry.**
- It is work directed toward the **innovation, introduction, & improvement** of products and processes.
3. Invention & Innovation
3. Invention and Innovation

- **Used in Business & Industry.**
- **Invention:** The creation of a product or process for the first time.

What has been the most important invention that has occurred in your lifetime?

Personal Computer
3. Invention and Innovation

• **Used in Business & Industry.**

• **Innovation:** Improvements or Significant Change to existing products, processes or services.
Problem Solving Approaches Used in STEM Education

4. The Scientific Method
5. Engineering Design
4. Scientific Method

Used in STEM Education
4. Scientific Method

- Science uses **Scientific Inquiry** to explore the natural world.

- **Scientific Inquiry:** The ways in which scientists study the natural world & propose explanations based on the evidence obtained from their work.
4. Scientific Method

Science often uses the **Scientific Method** to study the natural world.

The **Scientific Method** is a way to ask & answer **scientific questions** by **making observations & doing experiments.**
How do Scientists **Answer** Questions in Science?

The Scientific Method

1. **Question**
   - Ask yourself, “What do I want to learn more about?”, or “I wonder what would happen if...?”

2. **Hypothesize**
   - Research to help you make an educated guess, or hypothesis, and then answer your question.

3. **Experiment**
   - Test your hypothesis by making a plan and conducting an experiment.

4. **Observe & Record**
   - Make careful observations and write down what happens.

5. **Analyze**
   - Use your information to draw conclusions about your experiment. Was your hypothesis correct?

6. **Share Results**
   - Explain your results by presenting your experiment, observations, and conclusions.
Scientific Method

**Example**

**Observation:** Plants Need Light to Grow

1. **Question:** Do Plants grow differently in various levels of sunlight?
2. **Hypothesis:** Plants will grow better (e.g., taller) when given more light?
3. **Experiment** Try growing plants in various levels of sunlight (e.g., next to a window or in the shade).
4. **Observe & Record:** Collect Data
5. **Analyze:** Plants grow taller when given more lights.
6. **Share Results**
4. Scientific Method

Asking Questions

One Solution

Using the Scientific Method

1. **QUESTION**
   - Ask yourself, “What do I want to learn more about?” or “I wonder what would happen if...?”

2. **HYPOTHESIZE**
   - Research to help you make an educated guess, or hypothesis, and then answer your question.

3. **EXPERIMENT**
   - Test your hypothesis by making a plan and conducting an experiment.

4. **OBSERVE & RECORD**
   - Make careful observations and write down what happens.

5. **ANALYZE**
   - Use your information to draw conclusions about your experiment. Was your hypothesis correct?

6. **SHARE RESULTS**
   - Explain your results by presenting your experiment, observations, and conclusions.
4. Scientific Method

**Scientific Method**

1. **Question:** Are the colors of the candy equally distributed in a bag of M&Ms?

2. **Hypothesis:** The colors are not equally distributed.

3. **Experiment:** 5 Bags – Count the Colors in Each Bag
# 4. Scientific Method

## 4. Observe & Record

<table>
<thead>
<tr>
<th>Bags/Colors</th>
<th>Red</th>
<th>Yellow</th>
<th>Brown</th>
<th>Blue</th>
<th>Orange</th>
<th>Green</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bag #1 N =</td>
<td>9</td>
<td>19</td>
<td>3</td>
<td>7</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Bag #2 N =</td>
<td>10</td>
<td>9</td>
<td>7</td>
<td>12</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Bag #3 N =</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>8</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Bag #4 N =</td>
<td>8</td>
<td>6</td>
<td>2</td>
<td>10</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Bag #5 N =</td>
<td>12/4</td>
<td>12/5</td>
<td>7/8</td>
<td>5/10</td>
<td>6/11</td>
<td>4/8</td>
</tr>
</tbody>
</table>
4. Scientific Method

5. Analyze: \((N=5)\)

- **Red** = 49
- **Yellow** = 59
- **Brown** = 37
- **Blue** = 52
- **Orange** = 40
- **Green** = 43

6. Share Results:

- ★ The Hypothesis is Supported
- ■ The Hypothesis is Not Supported

**Hypothesis:** The colors are not equally distributed
5. Engineering Design

Used in STEM Education
How do Engineers Solve Problems in Engineering?

The Engineering Design Process
5. The Engineering Design Process

A Problem Solving Process Used by Engineers
5. The Engineering Design Process
5. The Engineering Design Process

**Used To Solve Problems**

<table>
<thead>
<tr>
<th>IPST’s 7-Step Technological Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Identify the Problem, Need, or Preference.</td>
</tr>
<tr>
<td>2. Information Gathering to Develop Possible Solutions</td>
</tr>
<tr>
<td>3. Selection of the Best Possible Solution</td>
</tr>
<tr>
<td>4. Design and Making</td>
</tr>
<tr>
<td>5. Testing to See if it Works</td>
</tr>
<tr>
<td>6. Modifications and Improvement</td>
</tr>
<tr>
<td>7. Assessment</td>
</tr>
</tbody>
</table>

**Many Models**

**Many Solutions**

**National Curriculum 2551**
5. The Engineering Design Process

Used To Solve Problems

1. Identify a Challenge
2. Explore Ideas
3. Plan and Develop
4. Test and Evaluate
5. Present the Solution
Engineering Design Challenges

Objective
Helps Students Learn How to Apply the Problem Solving Approach Used by Engineers
Engineering Design Challenge Components

1. **Conditions**: The setting, situation or context of the problem.

What’s the Situation Here?
Engineering Design Challenge Components

2. Challenge: A clearly written challenge or problem statement that clarifies what students are required to do.

What could students be challenged to do?
Engineering Design Challenge Components

3. Criteria and Constraints:

- Criteria relate to the challenge presented and are those things that must be followed or satisfied when completing the challenge.

1. Must be able to hold 10 kilograms.
2. Must be able to float on its own without tipping.
3. Must stay afloat at least 5 min.
Engineering Design Challenge Components

3. Criteria and Constraints:

- **Constraints** are typically **limits related to the challenge or problem that must be followed.**

1. **Time** - Activity must be completed in 15 minutes.
2. **Must use only tools & materials supplied.**
3. **Must be no larger than 50cm square.**
Engineering Design Challenge Components

4. Resources: The materials, tools, or equipment that is provided or can be used to help solve the problem or complete the challenge.
Engineering Design Challenge Components

5. Evaluation: How the solution to the problem will be assessed & evaluated.
Engineering Design Challenge Components

1. Context/Situation
2. Challenge
3. Criteria & Constraints
4. Resources
5. Evaluation

**Situation:** The Street Has Flooded
**Challenge:** Develop a safe way to “float” across it
Engineering Design Challenge

1. Situation:  Street Flooded
2. Challenge:  Develop a Method to Transport a Large Item & Keep it Dry!
Engineering Design Challenge

Workshop Activity
Engineering Design Challenge Activity

**Purpose:** To let you learn how to use the problem solving approach known as the **Engineering Design Process**
Engineering Design Challenge #1

1. **Situation:** An engineering company has developed a new “panel construction method” that can be used to quickly build tall houses. *They need to test their idea.*

2. **Challenge:** Build the tallest structure that has the most stories.

3. **Criteria & Constraints**

   - **Criteria:** Must use at least 25 cards; base can be any size; must stand by itself for at least 1 min.
   - **Constraints:** 15 minutes Time Limit; Cards Cannot be cut, but may be bent; Must use only resources provided, but not all resources must be used;
Engineering Design Challenge #1

4. Resources:
   • 52 Playing Cards;
   • 20cm x 20cm board;
   • 10 small paperclips;
   • 20cm tape;
   • 5 straws;
   • Mobile Device;

5. Evaluation: Tallest Standing Structure
Main Objective: To Learn How to Use the Engineering Design Process

1. Identify a Challenge
2. Explore Ideas
3. Plan and Develop
4. Test and Evaluate
5. Present the Solution
Begin the Challenge!

15 Minutes
Engineering Design Challenge #1

CONGRATS!

THE WINNER IS...

[Images of card structures and a person standing in front of a card replica of a building]
World Record

The largest playing card structure

Bryan Berg constructed a free-standing house of cards that measured 7.86 m (25 ft. 9.44 in) tall.
Reflection

What did you Learn in this Design Challenge?
Engineering Design Challenges

Lesson Objectives

Students Learn How to:

1. Solve Problems Using the Engineering Design Process
2. Be Creative & Innovate
3. Work Together as a Team
5. Use Mobile Learning
Engineering Design Challenges

5. Use Mobile Learning
Engineering Design Challenge #1

What STEM Concepts & Practices Could Students Learn in this Engineering Design Challenge?

**Science:** Models; Hypothesis Testing; Cause & Effect; Material properties; Empirical Evidence; Scientific Laws

**Technology:** building systems; structures; foundations; prefabricated materials

**Engineering:** Strength of Materials & Shapes; Structure & function; Stability; Models.

**Math:** Measuring; Geometry; Patterns; Scale;
Identify the Concepts & Practices of STEM

**REVIEW Content Standards**

- ITEEA Standards for Technological Literacy: Content for The Study of Technology
- Next Generation Science Standards
- Math Standards

Standards Are Used to Identify Lesson Objectives
Engineering Design Challenge #2 - Example

Paper Table
1. Context/Situation

- Paper makes up very large percentage of municipal solid waste, typically more than any other material thrown away.

- A group of engineers is interested in exploring how recycled newspaper can be used as a building material.

- In order to study and test their ideas, engineers want to build small model tables using supports (i.e., legs) made of newspaper.
2. Challenge

- This is a small group challenge.
  - You will be divided into “engineering teams” of 3-4 students and given a supply of building materials.
  - Your team’s challenge in this activity is to try and build a newspaper table that is capable of holding a book.
  - A bonus will be given to the team that holds the most weight.
The tower must be built using only the materials provided and not all materials must be used.

Your team will be given a tabletop that is 20cm x 20cm in size.

The book must be able to evenly and freely sit on top of the table.
3. Criteria & Constraints

- The table must be build using at least one support (i.e., leg).
- The height of the table must be 20cm.
- After completed, the table must be able to stand-up by itself and hold the weight of the book for at least one minute.
- The activity must be completed in 15 minutes.
4. Resources

- **Building Materials:**
  - 4 full-size pieces of newspaper
  - 10 paper clips
  - Tabletop
  - 60cm of masking tape

- **Building Tools:** Ruler & Scissors
- **Weight:** Book(s)
5. Evaluation

- **10 points**: Supports textbook for at least 1 minute.
- **9 points**: Supports weight for less than 1 minute.
- **5 points**: Table support not completed – effort shown.
- **3 points**: Very little effort shown.
- **2 Bonus Points**: The table that holds the most weight.
Purpose of Engineering Design Challenges
**Major Objective:** To Learn How to Apply the Engineering Design Process

1. Identify a Challenge
2. Explore Ideas
3. Plan and Develop
4. Test and Evaluate
5. Present the Solution

Many Solutions
What Students Should Learn

Table Activity: Lesson Objectives

1. How to use the Engineering Design Process.
2. To Learn and Think About the Recycling of Materials.
3. To Learn to Think about the Strength of Materials.
Learning Can Be Fun!
ENGINEERING
DESIGN
CHALLENGE
Examples
Engineering Design Challenge

Keep it Cold!

- **Situation:** I am going to road trip of 3 hours and I need to keep my medicine on ice. *I don’t have a cooler.*
- **Challenge:** In small groups, develop a cooler that keeps ice cool for a minimum of 3 hours.
- **Criteria and Constraints:**
  - **Criteria:** Must use free materials in class and natural materials outside. Ice must be visible after 3 hours & medicine dry.
  - **Constraints:** 3 ice cubes, 15 minutes to complete activity.
- **Resources:** Ice cubes, Containers for Ice, Medicine, Packaging materials, Natural materials from outside.
- **Evaluation:** Ice visible at the end of 3 hours.
Applying the Engineering Design Process
Applying the Engineering Design Process
Applying the Engineering Design Process
Applying the Engineering Design Process
Applying the Engineering Design Process
Applying the Engineering Design Process
Engineering Design Challenge

Candy Dispenser

Situation: A store owner wants to give a small amount of M&Ms “free” to children when they come into her store.

Challenge: Develop a prototype of a “candy dispenser” that dispenses a few M&M’s candy to children.
Applying the Engineering Design Process
Applying the Engineering Design Process
Applying the Engineering Design Process
Applying the Engineering Design Process
Applying the Engineering Design Process
What does STEM Education Look Like in the Classroom?
A STEM Education Classroom

- The Instructor is Purposely Teaching Students that the STEM Subjects and their associated Concepts are Not Independent, But Connected.

- **Math** (Magnification)
- **Science** (Studying Plant Cells)
- **Technology** (The Microscope)
- **Engineering** (Built the Microscope)
A STEM Education Classroom

The Instructor is Purposely Teaching Students about Practices used in STEM.

Students Using the Scientific Method to Study Cell Growth

The Instructor Provides Opportunities for Students to USE Both Science (e.g., the scientific method) and Engineering (e.g., engineering design process) Practices

Which Practice Do You Use?
A STEM Education Classroom

Which Practice Do You Use?
Depends on the Activity?

For Example

Scientific Method: Test Temperatures Inside & Outside of a Greenhouse

Engineering Design: Build a Greenhouse
A STEM Education Classroom

Which Practice Do You Use?
Depends on the Activity?

For Example

Scientific Method: Measure the Speed of Wind
Engineering Design: Build an Anemometer

Scientific Method: Measure Power Generated by a Windmill
Engineering Design: Build a Windmill
A STEM Education Classroom

Which Practice Do You Use? Depends on the Activity?

For Example

Scientific Method: Analyze Bags of M&Ms: Colors, Number Per Bag, or Weight, etc.

Engineering Design: Build an M&M Dispenser
## Similarities & Differences
Scientific Method vs Engineer Design Process

<table>
<thead>
<tr>
<th>The Scientific Method</th>
<th>Engineering Design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ask a Question</strong></td>
<td>Identify the Problem or Need</td>
</tr>
<tr>
<td>Do Background Research</td>
<td>Do Background Research</td>
</tr>
<tr>
<td>Construct a <strong>Hypothesis</strong>, Identify Variables</td>
<td>Brainstorm <strong>Solutions</strong> (Consider Criteria &amp; Constraints)</td>
</tr>
<tr>
<td>Design Experiment &amp; Establish Procedures</td>
<td>Choose Best Solution</td>
</tr>
<tr>
<td><strong>Test Hypothesis by Doing an Experiment</strong></td>
<td>Build a Model or Prototype</td>
</tr>
<tr>
<td>Analyze Data and Draw a Conclusion</td>
<td>Test, Evaluate, &amp; Redesign as Necessary</td>
</tr>
<tr>
<td>Communicate Results</td>
<td>Communicate Results</td>
</tr>
</tbody>
</table>

- **Close-Ended: One Solution**
- **Open-Ended: Many Solutions**
A STEM Education Classroom

Instructors as Facilitators

STEM Concepts and Practices Being Purposely Integrated

Project-Based Learning

21st Century Skills & STEM Careers Being Promoted

Student-Centered Learning
ENGINEERING DESIGN CHALLENGE Workshop Activity
Workshop Activity

Working in small groups, Develop 1-2 Engineering Design Challenges appropriate for Thai Education Students.

We will Share your activities with the group.
Workshop Activity

Required for Each Design Challenge:

• **Lesson Objectives**
  – In addition to the major objective (i.e., learn how to solve a problem using the engineering design process)

1. Situation or Context
2. Challenge
Engineering Design Challenge Idea

• **Situation:** *Bike For Mom*
• **Challenge:** Design and Build a “new bike” model.
Engineering Design Challenge Ideas

• Situation: Dangerous Animal in a Cage
• Challenge: Develop a safe Feeder

• Situation: Mobile Phone Dead
• Challenge: Develop a battery charger

• Situation: Lots of Trash
• Challenge: Develop an attractive or innovative trash can
Engineering Design Challenge Ideas

• **Situation:** River Flooded
  • **Challenge:** Develop a bridge out of recyclable materials that can hold a person.

• **Situation:** Raining
  • **Challenge:** Develop an umbrella

• **Situation:** Earth Quake
  • **Challenge:** Develop a warning system
HELPFUL WEBSITES
http://pbskids.org/designsquadd
http://tryengineering.org
http://teachers.egfi-k12.org
http://www.nasa.gov/audience/foreducators/index.html

Intel® Education STEM Resources
Supporting K-12 Science, Technology, Engineering, and Math

Science, Technology, Engineering, and Math (STEM)
Intel believes that young people are the key to solving global challenges. A solid math and science foundation coupled with skills such as critical thinking, collaboration, and problem solving are crucial for their success. To help educators foster the next generation of innovators, Intel provides STEM curriculum, competitions, and online resources to encourage students' interest and participation.

STEM Unit Plans from Designing Effective Projects: Follow a design process for creating successful projects that integrate technology; browse a library of project-based units to adapt for your own use.
https://www.teachengineering.org/index.php
http://stem.wesfryer.com/home/engineering-design-challenges

STEM Curriculum Resources by Dr. Wesley Fryer

Engineering Design Challenges

These are engineering design challenges we’re using as STEM class lessons in Spring 2015. Links to additional resources for more are included too.

Challenge #1 - Paper Table

Summary: With your team in 20 minutes, construct a table using provided materials that will support a heavy dictionary at least 8 inches off the table for at least 60 seconds.

Materials:
1. 20 pieces of newspaper
2. 3 feet of masking tape
3. 1 piece of cardboard
4. 1 dictionary

Restrictions:
1. Materials CANNOT be directly taped to the table

Challenge #2 - Straw Structures
Thank You!
ขอบคุณครับ
References

• ITEEA Standards for Technological Literacy: http://www.iteea.org/TAA/PDFs/xstnd.pdf
• Next Generation Science Standards: http://www.nextgenscience.org/
• Math Standards: http://www.corestandards.org/Math/
• Understanding Integrated STEM Education: Report on a National Study (ASEE, 2013).
• STEM Integration in K-12 Education: http://www.nap.edu/catalog/18612/stem-integration-in-k-12-education-status-prospects-and-an