GRADE LEVEL: 3-8 | TIME REQUIREMENT: 4 HOURS

ENGINEERING SKILLS

1 READING | 3 ACTIVITIES

INTRODUCTION

STEM is the most powerful way to teach science because it integrates science content with problem solving, communication, and calculation. The resources in this section all explore topics using a STEM approach.

OBJECTIVE

Pair the reading with one or more of the activities. The most natural pairing is between **Kaiser Ship Building** and **Assembly Lines**. **Necessity Cards** can be used to encourage students to think creatively and to take on challenges themselves. Depending upon your objectives and on your estimation of student background knowledge, you might ask students to use only existing technologies in the **Necessity Cards** activity. **Inspected By** presents a chance for students to engage in quantitative analysis. Again, evaluating a process reminds them that engineering is not just for products, but for processes as well. These last two activities could also be used as stand-alone exercises to practice collaboration (**Necessity Cards**) or quantitative skills (**Inspected By**).

STANDARDS

NGSS DCI ETS1.A
Defining and Delimiting Engineering Problems

NGSS DCI ETS1.B
Developing Possible Solutions

NGSS DCI ETS1.C
Optimizing the Design Solution

NGSS DCI ETS2.B
Influence of Engineering, Technology, and Science on Society and the Natural World

NGSS SEP
Asking Questions and Defining Problems, Analyzing and Interpreting Data, and Engaging in Argument from Evidence

NGSS CCC
Patterns, Scale, Proportion and Quantity

PERFORMANCE EXPECTATIONS

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.

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.

READING (1)

1. KAISER SHIP BUILDING

Description
A short reading describing how an assembly line was optimized to meet production needs. It is valuable for students to understand that processes, not just products, are engineered. This reading describes how the traditional process of ship building was adapted to make it faster and more efficient.

ACTIVITIES (3)

1. ASSEMBLY LINES

Description
An activity in which students optimize their own hands-on assembly line. Using only ballpoint pens, students work in groups to quickly assemble the pens. Groups practice and optimize their process and then compete together to see which group had the fastest method. Differences in group size can become a discussion point, and a debriefing of how the different groups collaborated to improve their process is a chance for a productive discourse on effective teamwork and problem solving. We suggest using the activity at the beginning of their school year to set expectations for group work and collaboration.

Supplies
6 "Clickable" ballpoint pens per group

Instructions
Show the students how to take apart and reassemble a pen. Show how many parts there are and make sure they all know how to put them back together. Explain that students need to work in their team to optimize an assembly line to put the pens together. They can practice and iteratively improve their process, competing against the clock for 10-15 minutes. The pens have to be assembled correctly and have to work. After the practice times, have the teams compete to see which can put six pens together fastest. (It's a good idea to keep extra pen parts on hand.)

2. NECESSITY CARDS

Description
An activity in which students brainstorm solutions to problems. In groups, students are presented with challenges faced by the Allies in World War II. To fit your needs, you can adjust how much time they spend brainstorming and how they present their products. You could go as far as having them draw plans and make prototypes, or you could be as brief as an outline of ideas. The real key to the success of this activity is getting students to participate in accountable talk and into thinking of constraints and possibilities in innovation.

Supplies
Copies of the cards at the end of the activity.

Instructions
Divide students into teams and have each team take a card. Individually, students write down their ideas for solutions, then share them with the group, with the goal of creating a consensus solution. If you have more time, you can have groups get really involved and make prototypes and presentations, or you can just let them brainstorm and share ideas.

3. INSPECTED BY

Description
An activity in which students practice their quantitative skills to consider quality control. Groups count up the number and color of M&Ms in the bag they are given. Students then graph the number of each color and calculate percentages. When they compare their results across the class and pool them, there is another chance for students to practice using productive, accountable talk. In this activity students will also gain experience looking at variation and how pooling data can sometimes hide variation.

Supplies
1 Bag of plain M&Ms per team

Instructions
Explain that the candies are not to be eaten until after the investigation. Students in groups will count the number of candies per color and the total number of candies. You can then ask students to make a bar graph of results. Compare bar graphs across the class: Is the same color always the most frequent? Is the total number of candies consistent? What do the results tell you about the process of bagging candies?

ADDITIONAL RESOURCES

To learn more about the use of engineering in World War II, try these books:

+ *Engineers of Victory* by Paul Kennedy, Random House
+ *Freedom's Forge* by Arthur Herman, Random House

ACTIVITY

NECESSITY CARDS

INTRODUCTION

It doesn't take just smarts and creativity to make an invention work. It also takes necessity. Unless there is a strong need or desire for change, a new idea usually won't be adopted right away. A new idea needs people to invest time and money, and so there usually needs to be some sort of problem that forces people to make a change.

World War II was a time when there was a great need for change, from the battlefields to the factories and even to everyday life. The United States had to prepare its military, industry, and people for a war taking place all over the world. The country had to do all that without some of the important resources its factories were used to having because those resources were now under the control of the enemy.

Soldiers making adjustments to a radio transmitter and receiver on a radio-controlled target plane.
(Image: The National WWII Museum, 2011.065.1176.)

NAME: **DATE:**

Directions: Your team will get a card describing a problem that needs a solution. These all represent challenges the United States faced in World War II. Your assignment is to develop a detailed plan using what you know to propose a solution to the problem. Present your problem and your ideas to the class. Include how your solution plans will be developed. Your results will certainly involve diagrams and some written explanation.

Make a plan:

1. Make a list of what you know about the ideas in the problem.

2. Brainstorm a list of ways your team thinks you could solve the problem.

3. Evaluate that list for the solutions that are best, easiest, cheapest, etc.

4. Pick one of the solutions to develop further.

REMOTE CONTROL

Sometimes air missions were very dangerous, and risking a crew was not a good idea.

It would be great if there were a way to send aircraft on missions and control them from the ground with no crew on board.

PORTABLE RATIONS

There was an abundance of rations for soldiers in the field, but they took up space and were heavy and needed heating up.

It would be great if there was a packaged food that could be eaten without heating and that had ample energy and vitamins and nutrients.

ALTERNATIVE FUEL

Fuel, which was in short supply, was necessary to use as gasoline for tanks, planes, cars, and generators. Rationing helped, but areas of conflict prevented exploration and development of new oil wells.

It would be great to have a way to make fuel from alternate resources that were readily available.

STOPPING INFECTIONS

All through history more soldiers died of infections than anything else. Infections are caused by bacteria that reproduce exponentially and make people sick.

It would be great to stop infections somehow, either by removing bacteria, killing bacteria, or treating wounds differently.

PORTABLE POWER

There were often power outages on bases that depended on generators or in cities occupied by troops.

It would be great to have lights, radios, and other equipment that had a way for their users to generate electricity.

PORTABLE PENS

Pilots had to make notes on maps, but the pens they used were fountain pens that spilled ink and got clogged and smeared.

It would be great to have an easier way to record information in the field and write on maps.

TREATING TRAUMA

When someone gets injured badly, he or she often loses a lot of blood. This loss of blood has serious effects on the body—causing a condition called shock. Blood transfusions can be used to treat shock, but it is hard to get enough blood, to preserve it, to make sure it's the right type, and to get it to wounded soldiers.

It would be great to have a way to treat trauma from shock by either giving more fluid to the body, by finding a way to treat symptoms of shock, or by preserving blood more effectively.

HIGH ALTITUDE FLIGHT

Planes are vulnerable to being shot down when they fly at low altitude. But flying at high altitude is difficult because the air is thin. At high altitude, the air pressure is so low that fight crews get very cold and have trouble getting enough oxygen. They can bundle up and use oxygen tanks, but that limits how long they can stay up in the air.

It would be great to have a way to fly at high altitude and have planes with higher air pressure.

MALARIA

Mosquitoes were prevalent and were biting troops, especially in the Pacific Theater. Many of these mosquitoes carried malaria. Malaria is a disease caused by single-celled parasites. The drugs used for malaria were not that effective and caused many side effects.

It would be great to have a way to prevent mosquito bites, get rid of mosquitos, or cure malaria.

INSULATING CIRCUITS

Almost all the equipment in World War II used electrical circuits. Airplanes, tanks, ships, trucks, radios, radar—all depended on electrical circuits. Those circuits used wires that needed to be insulated. Insulation of wires needs a material that doesn't carry electricity and that can be easily and cheaply wrapped around a wire.

It would be great to have a material that could insulate wire and that could be produced with existing material.

AMPHIBIOUS VEHICLES

Though our ships, trucks, and tanks were numerous, it was a demanding job to go from one to the other. Also, getting trucks, tanks, and soldiers from transport boats to shore was difficult. It was also especially hard to move people and material around on the islands in the Pacific where conditions were wet and rainy.

It would be great to have vehicles that could move from water to land more easily.

PARACHUTE FABRIC

Parachutes were made of silk. Silk was light and strong and performed well in this function. But silk comes from caterpillar cocoons and is slow to make and is expensive. Also, silk also came from parts of Asia that the Japanese came to control.

It would be great to have a fabric that would be strong and light like silk but was easier and cheaper to make.