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
ASSEMBLY LINES

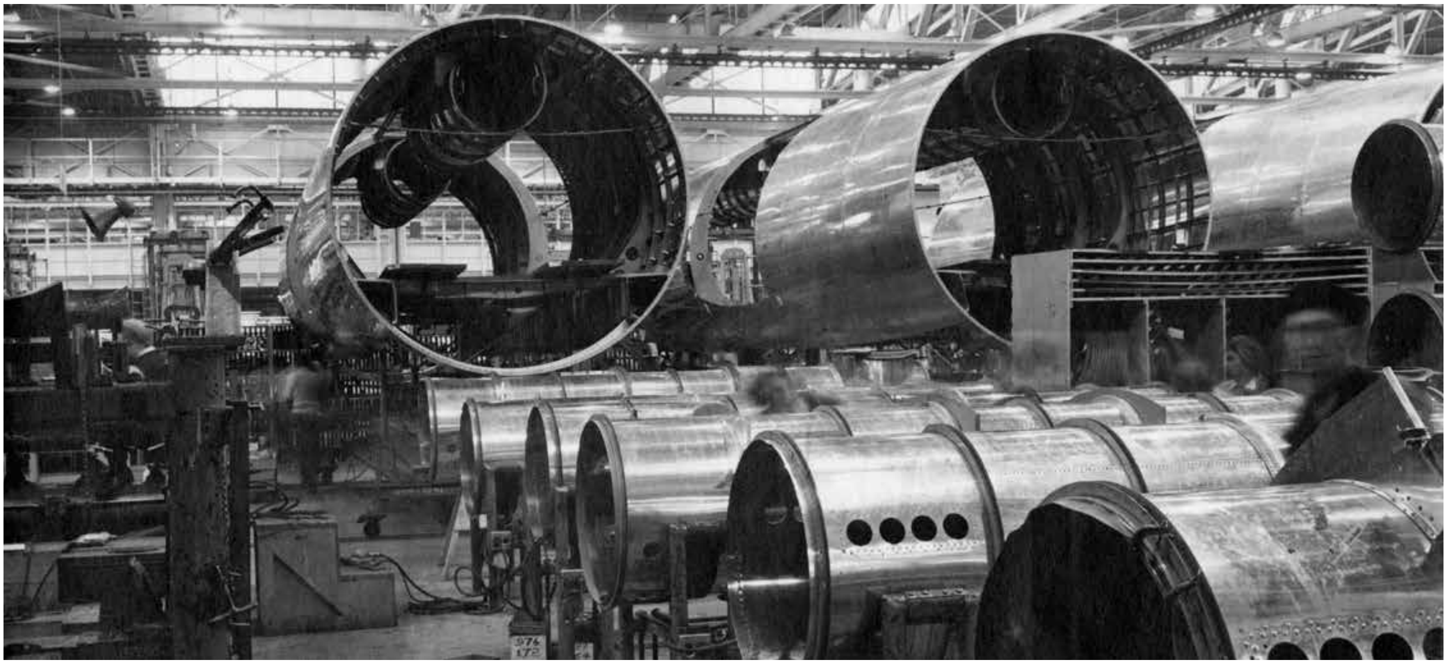
INTRODUCTION

At home, do you put all your clothes in one drawer all mixed up, or do you have a drawer for socks, a drawer for shirts, and places in your room for every kind of thing? For school, do you just shove everything loose in your backpack, or do you have a notebook with dividers and sections for every class? Does your school have buses that roam the neighborhood looking for kids who need to come to school, or do they have set bus routes, with planned stops and pickup and drop-off times?

These are all questions about systems engineering. A systems engineer designs processes and procedures and systems to get things done efficiently. If you keep your clothes organized in different drawers, you are a systems engineer. The person at your school who sets up buses and drop-off points might be called an operations manager. Operations research is another name for systems engineering.

One way that engineers make things better is by taking already-made things apart to see how they work and to make improvements. This process is called reverse engineering. For example, in World War II, the United States captured a deadly Japanese plane called a "Zero" and took it apart to see how it worked. This procedure provided information on the strengths and weaknesses of the Japanese planes and the best ways to defeat them.

One strategy for putting things together efficiently is to use an assembly line. In an assembly line, all the different tasks to make something are divided up and put in order so that one person does a specific task. For example, cars are usually built on an assembly line. This approach is easier because one part is added in only one place at one time. For example, tires and tools needed for assembly are located in a specified place. Likewise, windshields are assembled in a different location. This approach means that if something goes wrong, like if the carburetor doesn't work, you can determine where something wasn't put together properly and how the error might be corrected. Every car should come off the assembly line the same because the same person put together the same parts in the same order for every car.



Employees work on airplane parts on an assembly line at an airplane factory. Alliance, Ohio. Circa 1942-1945.
(Image: The National WWII Museum, 2013.176.057.)

NAME: **DATE:**

Directions: Design an assembly line to manufacture ballpoint pens. Your team will design and test processes to put the pens together. You will modify (**adapt**) your design and practice your process to get faster and more efficient. This is what we call optimization.

At the end of your practice time there will be a competition. The team that can assemble six pens that work in the shortest amount of time will win.

TRIAL	VARIABLE CHANGED	TIME	CHANGE IN TIME	NOTES / OBSERVATIONS
Trial 1				
Trial 2				
Trial 3				
Trial 4				
Trial 5				
Trial 6				
Trial 7				

1. Describe your first assembly line attempt (include a diagram of your process):

2. Describe your final assembly line attempt (include a diagram of your process):

3. If you were starting an assembly line again, what would you be sure to do this time around?