LESSON PLANS, READINGS & ACTIVITIES

INNOVATION AND PROBLEM SOLVING

GRADE LEVEL: 3-8 | TIME REQUIREMENT: 1-2 CLASS PERIODS

INNOVATION AND PROBLEM SOLVING

1 READING

INTRODUCTION

The following is a short essay that presents a framework for understanding how innovation happens. Using examples from WWII innovations to introduce an Adopt-Adapt-Apply framework, the essay asks students to think of how they could use examples of WWII innovations to solve today's problems using this framework.

The Adopt-Adapt-Apply framework is used throughout the curriculum and is simple enough to explain and understand even if you use later parts of the book without this essay. However, this essay provides a model of how the WWII stories will be introduced and used throughout the curriculum.

OBJECTIVE

In the beginning of the year, you can use this essay and its prompts to begin a discussion about problem-solving, innovation, and STEM careers. The essay can serve as a framework for any other activities you choose to do from the curriculum. You can supplement the reading and discussion by showing the linked video on the Real World Science curriculum webpage.

STANDARDS

NGSS DCI ETS1.B
Developing Possible Solutions

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

NGSS SEP
Asking Questions and Defining Problems and Constructing Explanations and Designing Solutions

NGSS CCC
Systems and System Models

PERFORMANCE EXPECTATIONS

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.

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

ADDITIONAL RESOURCES

To learn more about problem solving and the ideas behind the Adopt-Adapt-Apply framework, try these books:

- *Where Good Ideas Come From* by Steven Johnson, Riverhead Books
- *Eureka* by Gavin Weightman, Yale University Press

Glider pilot in front of WACO CG4 Glider, May 1944.
(Image: The National WWII Museum, 2014.005.051.)

READING

ADOPT-ADAPT-APPLY

When the United States entered World War II in December 1941, success was not guaranteed. In the Japanese attack on Pearl Harbor, the event that led to the United States entering the war, about 3,500 military servicemen were killed or wounded, and more than a dozen ships and hundreds of aircraft were heavily damaged or destroyed. In just one morning, our already small military suffered a great loss. At that time, the German and Japanese militaries were 10 times as large as ours. Each of those nations had been spending years preparing for war, while the United States had hardly invested in its military since World War I.

At the same time, Great Britain, the biggest ally of the United States, was under siege and being targeted by frequent air attacks. Tens of thousands had died in cities and industrial areas as result of German bombing. The Atlantic Ocean was patrolled by German U-boats that terrorized shipping and passenger lines. France had fallen, with much of it under German occupation. Japan had conquered large parts of China and Southeast Asia and controlled the natural resources there, as well as the shipping lanes of the western Pacific.

And yet the United States and its allies won.

The people of the United States rallied to the war effort, enlisted in the military, grew Victory Gardens, recycled materials, and took jobs in factories. In the industrial sector, our nation's leaders turned to **Science, Technology, Engineering, and Mathematics (STEM)** professionals to solve big problems and help us win the war. The STEM innovations of World War II can be grouped into three categories:

ADOPT

Some existing civilian and military technologies were used for new military and war production purposes with little change.

ADAPT

Some existing technologies were modified to be used for new military and war production purposes.

APPLY

Some recent advances in our understanding of how the world works were put to use in new military technologies.

When you look at WWII innovations, you can use these categories to explain how things were developed. You can also use them to think of how innovation occurs today.

- **Is something made from new information (apply)?**
- **Is it lightly modified for a new purpose (adopt)?**
- **Is it changed to match a new necessity (adapt)?**

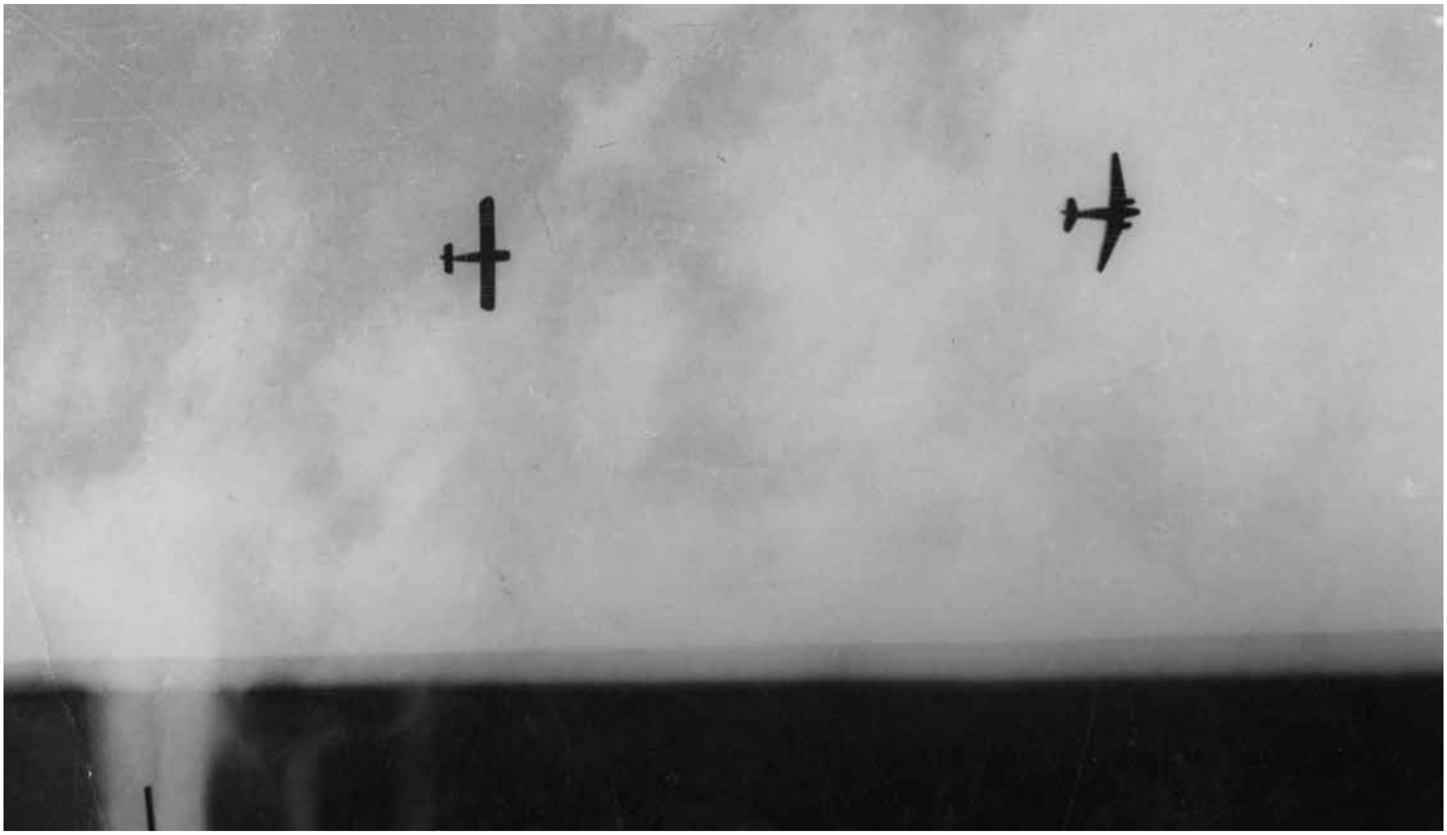
For example, the famous Higgins Boats, which made the landings at Normandy on D-Day possible, were developed by modifying boats Higgins Industries designed for fishing and working in the wetlands of south Louisiana. These boats are examples of **adaptations** of civilian technology for military use in the war. Similarly, the C-47 airplanes that dropped paratroopers behind enemy lines on D-Day were lightly modified from the DC-3 commercial airliner. The C-47 airplanes were **adopted** for military use.

Two of the biggest innovations of World War II, RADAR and atomic weapons, were **applications** of previous research. Great Britain was a center for the development of radio technology. While its cities and ports were under air attack by Germany, Great Britain sent some of its technology to the United States where it was then developed into RADAR that could be used in aircraft, boats, and ships to find the locations of enemy planes and ships. Another example of the application of discoveries is the development of atomic weapons. German scientists had discovered nuclear fission just before the outbreak of World War II. However, it was scientists in the United States who learned to control and deploy this discovery to make the first atomic bombs.

Today our society faces many problems, some of which seem as challenging as those faced by people in 1941. By looking back to the past and seeing how problems were solved, we can be better prepared to confront challenges today. We can **adopt** already existing technologies for new uses. We can **adapt** some past innovations to solve new problems. We can, and should, use our knowledge of both the past and the present to address some of today's most pressing needs.

1. **What are some technologies that you value? Write them down, and explain whether you think each is an example of adopt, adapt, or apply?**

NAME: **DATE:**



A C-47 pulling a glider across the sky. June 6 1944. D-Day, over the English Channel.
(Image: The National WWII Museum, 2011.178.014.)

2. **What is a big problem in the world today that matters to you? How could future STEM professionals (like you!) solve this problem?**

3. **Which of the three methods of innovation do you think will be the most important for solving the problems of today and tomorrow? Explain your thinking.**

LESSON PLANS, READINGS & ACTIVITIES

ENGINEERING SKILLS

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

READING

KAISER SHIP BUILDING

On July 30, 1942, a passenger ship named the *SS Robert E Lee* was carrying 407 crew and passengers steaming towards New Orleans. Waiting off the coast of Louisiana, a German submarine (U-boat) shot a torpedo at the ship, sinking it. Twenty-five people died, and the rest were rescued by a civilian tugboat and two US patrol boats.

The *Robert E Lee* wasn't the only victim of U-boats. By July 1942, in the Gulf of Mexico and off the East Coast of the United States, U-boats had sunk over 300 ships. Supplies to the United States were threatened, as were food and military supplies sent to Great Britain.

While the military sought solutions to decrease the threat of U-boats, the US government saw the need to quickly make many new transport ships. These new ships were needed to bring resources to the United States, to replace ships sunk by U-boats, and to ship manufactured goods overseas to support the war effort.

One of the companies that responded to government requests to build transport ships, which came to be called Liberty Ships and Victory Ships, was Kaiser. Kaiser was a company that had helped build the Hoover Dam—one of the biggest engineering projects in history. One of Kaiser's great innovations and contributions to the war effort was prebuilding parts and assembling them in place.

Kaiser Shipyards built plants to make Liberty and Victory ships on the West Coast of the United States, near San Francisco, California, and Portland, Oregon. Using their new assembly processes, Kaiser Shipyards built 1,490 ships during the war. At Kaiser a ship took two-thirds of the time and one-fourth of the money to produce than at other factories.

Traditionally, the hull of a ship was made first. The hull is most of what you see of a ship: the outside part that floats in the water and rises up to hold the decks and deckhouses. After the hull was made, all the workers making the parts inside the ship climbed in and out of the ship, making for a slow process.

Engineers at Kaiser came up with a new idea. While the hull was being built, the pieces for the decks and deckhouses would be assembled in another part of the factory. Then when the hull was finished, the decks and other parts would be lowered into the hull and welded in place. All the parts had to be exactly the right size so that they would fit. Eventually Kaiser engineers got the production time down to between 40 and 50 days for one ship. Imagine that—a ship 442 feet long and weighing about 32 million pounds being built in 45 days.

Kaiser engineers **adapted** the ship building process, optimizing it for speed. They did this in two ways: by using what they had learned about premaking pieces of a large structure during their construction of giant dams, and by using the experience of automakers to make a more efficient assembly process. With their new process, Kaiser's ships helped win the war by bringing supplies and materials to the battlefronts.

The Liberty ship *SS George Poindexter* is launched from Delta Shipbuilding Company shipyard, New Orleans, Louisiana, May 18, 1943.
(Image: The National WWII Museum, 1999.060.004.)

NAME: **DATE:**

1. **What is a process you use at home or at school that could be more efficient? (Like getting ready for school, packing lunch, putting away your clothes.) What could you do differently, and how would it change the process?**

2. **The reading describes the Kaiser Shipyard process as an <u>adaptation</u>. Do you agree? Can an argument be made that it is an adoption or application instead? Explain your thinking.**

Shipyard workers building an aircraft carrier, Newport News Virginia, January 21, 1944. *(Image: The National WWII Museum, 2011.102.411.)*

View of a Higgins boat assembly line, where PT Boats are being made. New Orleans, Louisiana circa 1941-1945.
(Image: The National WWII Museum, 2008.280.002.)

ACTIVITY
ASSEMBLY LINES

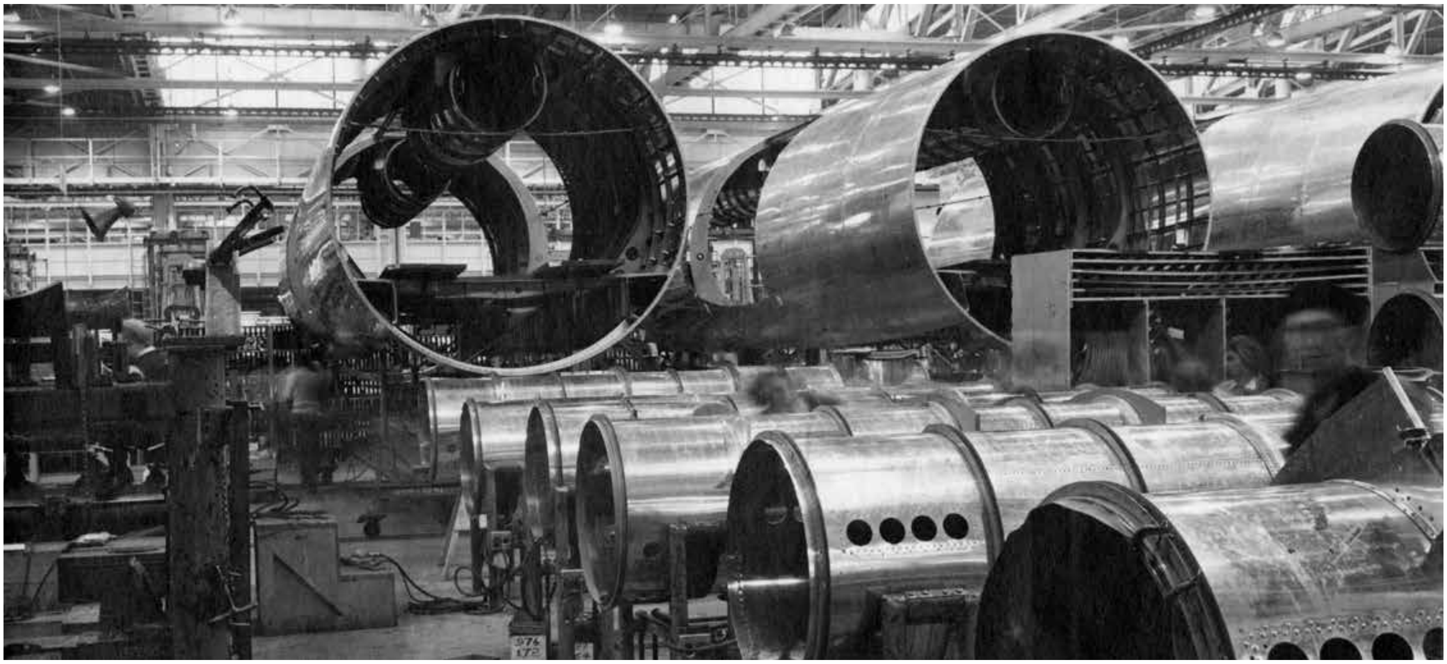
INTRODUCTION

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?

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.

ACTIVITY

INSPECTED BY

INTRODUCTION

When things are produced on a large scale, whether they are cars, planes, or candies, someone needs to make sure they came out right. This is called Quality Control.

Quality Control Engineers, or Inspectors, examine products carefully to make sure they meet their requirements. In this activity, you will act as quality control inspectors.

Take the package of candy your teacher gives you. Open it, but don't eat it!

1. Make a data table to record information about the contents.

DID YOU KNOW

Did you know that M&Ms were a WWII invention? Throughout the war they were only available to the military. Chocolate and sugar were rationed during the war, so sweets were hard to get.

NAME: **DATE:**

2. Record the number of pieces of candy in each color; also record the total number of candies in the bag.

3. Make a bar graph to show the number of pieces of each color. Calculate the percent of each color of candy in your bag. Share your data with the class.

4. What are the percentages of each color across the whole class?

5. Was anyone's bag very different from the rest?

6. Were the numbers of candies in each bag the same across the whole class?

7. If you had a giant container of these candies that held 5,000 of them, how many of each color would you expect to find?

8. What does the data tell you about the process for putting candies in a bag? Do you think someone is checking to make sure all the bags are filled the same?