Real World SCIENCE

Yesterday, Today + Tomorrow Teacher Guide

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THE NATIONAL WWII MUSEUM NEW ORLEANS


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ACKNOWLEDGMENTS

REAL WORLD SCIENCE: Yesterday, Today + Tomorrow

Teacher Guide

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The Museum wishes to thank the Northrop Grumman Foundation for their generous support of Real World Science.

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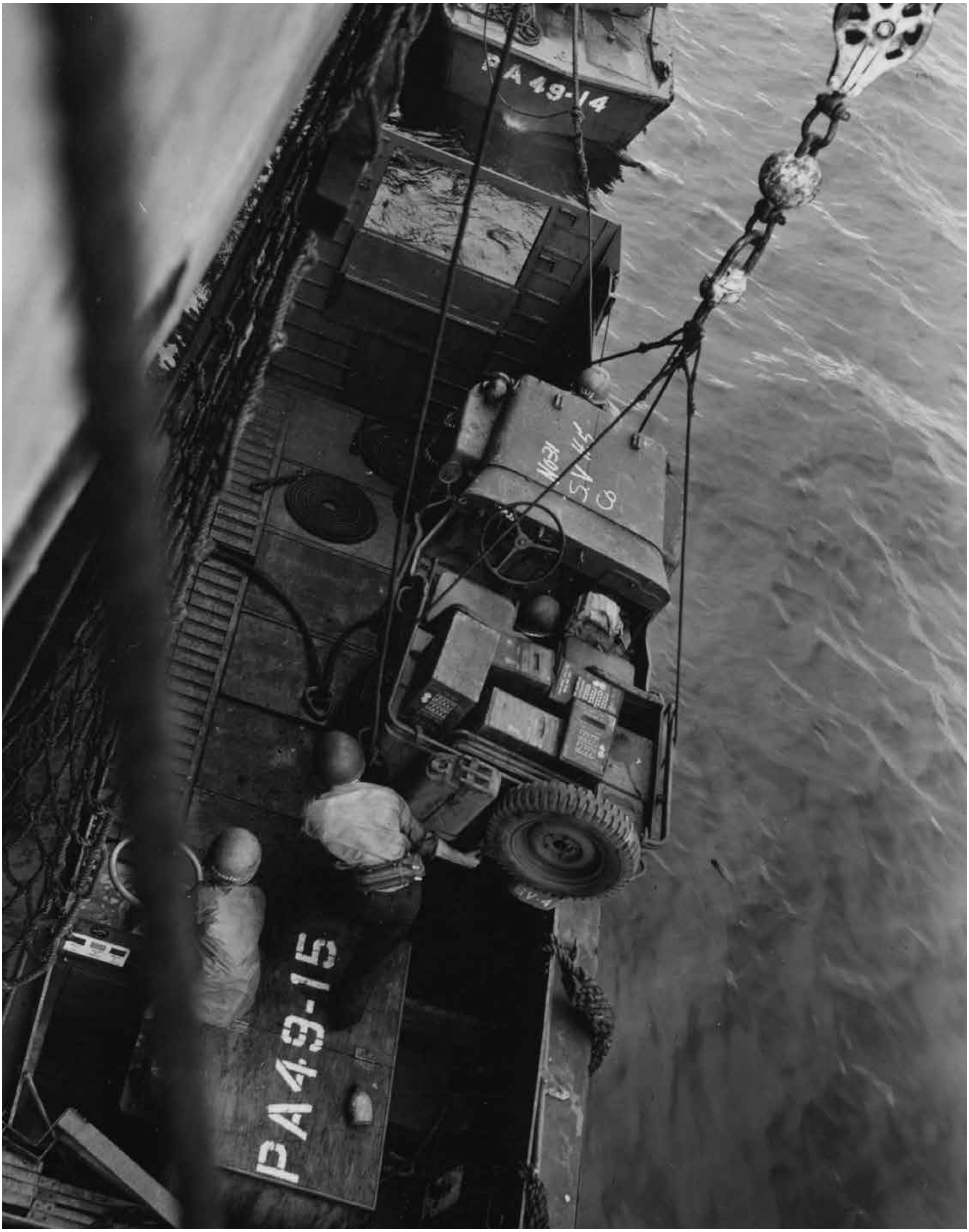
INTRODUCTION



A Jeep is lowered into an LCVP Higgins boat by crane. Guadalcanal, March 9, 1944.
(Image: The National WWII Museum, 2008.354.041.)

(Image: The National WWII Museum.)

A LETTER FROM THE PRESIDENT & CEO

STEPHEN J. WATSON

Dear Educators,

People sometimes ask me why we have STEM (Science, Technology, Engineering, and Mathematics) programs at The National WWII Museum since we are a history museum. When this question comes up, I take them to the US Freedom Pavilion: The Boeing Center to see our B-17 Flying Fortress and six other meticulously restored warbirds soaring overhead. Or, to the Louisiana Memorial Pavilion to see our LCVP prominently featured along with an exhibit on businessman Andrew Jackson Higgins, whose unique boat designs were critical in shaping the Allied war strategy. Or, to our STEM Innovation Gallery in the Kushner Restoration Pavilion that showcases a few examples of the countless ways in which innovation and ingenuity solved significant problems in World War II.

The National WWII Museum tells the story of the American experience in *the war that changed the world* — why it was fought, how it was won, and what it means today — so that all generations will understand the price of freedom and be inspired by what they learn. Here at the Museum, we firmly believe that the story of World War II must include the story of STEM professionals and the innovations they made possible. To students, we say that during World War II, people solved really big problems — seemingly impossible challenges — to secure victory. To solve the problems of today and the future, young people can learn from the solutions and approaches of the STEM professionals of the WWII generation.

On our New Orleans campus, The National WWII Museum brings the story of wartime STEM innovations to students through our annual Robotics Challenge, summer camps, field trips, special events, and more. Across the country, we bring this story into classrooms through our Real World Science curriculum and teacher training program, which includes virtual and in-person workshops as well as a weeklong summer seminar at the Museum.

Real World Science teaches science that elementary and middle school students need to know by connecting it to stories from World War II. Within the units in this curriculum are topics in Physical Science, Life Science, and Earth Science woven together with literacy skills and lessons of how real-life scientists and engineers work.

Thank you to the Northrop Grumman Foundation for their support of our Real World Science curriculum, summer seminar, and other teacher workshops.

Our hope is that Real World Science helps prepare students to solve big problems with STEM, just like ordinary and extraordinary people did during World War II.

Sincerely,

Stephen J. Watson
President & CEO, The National WWII Museum

INTRODUCTION AND HOW TO USE THIS BOOK

In 2011, the National Research Council of the National Academy of Science published *A Framework for K-12 Science Education*. This report was an effort by scientists and educators to more fully incorporate the practices of scientists and engineers into the architecture of science education. Today, most of the country has adopted some form of the Next Generation Science Standards (NGSS), which are based on the ideas originally outlined in *A Framework for K-12 Science Education*.

These standards require that changes are made to the way science is taught. First, these standards are three-dimensional. Students need to learn about the practices, ideas, and big concepts of the field together. Next Generation Science Standards also position experience before explanation and concepts before vocabulary. To do this successfully, teachers need to use storylines. By attaching to the lives of real people, storylines connect small ideas to big events. For example, students may more readily learn about electricity through investigating the properties of conductive playdough, or they may experiment with engineering practices by making complex circuits or connections between energy and matter. This 3-D method of teaching requires that teachers focus on phenomena as the basis of discussions with students.

The Real World Science curriculum provides teachers with phenomena-based activities that engage students in the practices of science and engineering. Though it is not a comprehensive curriculum and will not necessarily meet all of the standards or performance expectations of any particular grade level, it can supplement a teacher's own curriculum and connect to the history of science in a way that shows how scientific ideas have changed over time, all the while providing urgent contexts for solving problems.

More importantly, by invoking a war that touched the lives of everyone in the world, the curriculum illustrates problem-solving stories and important science ideas. This interdisciplinary curriculum incorporates not only history and science but also mathematics and literacy and is meant to support both teachers in self-contained classrooms as well as teams of teachers who work across disciplines.

Teachers may select freely from the activities that demonstrate the phenomena they wish to address in their classrooms and take advantage of curriculum readings to provide important context and extension. Finally, the curriculum can serve as a model on how to incorporate historical events that highlight compelling stories illustrating people using knowledge and problem-solving skills. Using examples of formative assessment, hands-on engagement, design-problems, and literacy connections, teachers can also develop their own lessons and create resources that draw upon their own knowledge and experiences.

Much of the power of a student's own experiences comes from the discussion of these experiences with peers and mentors. In this book we use the terms "productive talk" and similar language to refer to conversations that are based on evidence and proper reasoning. Kagan Structures are tools to promote cooperation and communication in the classroom and to encourage this kind

A Dodge WC54 Ambulance located in The National WWII Museum's STEM Innovation Gallery.

of productive conversation. References to these tools and terms are presented in the discussions of activities and readings.

Not all students will grow up to be scientists or engineers; however, through this curriculum we hope to spark student interest in the sciences. Providing the best possible science education to all students guarantees equity and ensures that our country, and the world, can develop the expertise we need in the future. In addition to these goals, the curriculum establishes that all our citizens, whether professional scientists and engineers or not, need to understand the nature of science. Our increasing dependence upon advanced technologies requires this understanding.

This volume is a collection of resources for teachers. In order to meet the needs of multiple grade levels, and the standards of multiple school systems, the resources are not structured as a series of lesson plans. Instead, these resources are divided by subject areas, and within each there are both readings and activities.

The teacher notes for each section describe how teachers can use any of the readings or activities on their own or together. Resources can be combined in multiple ways to fit into various methods of instruction. For example, the materials discussing soft circuits can be used when teaching electricity or when discussing the properties of materials. Likewise, the Assembly Line activity can be used as a team-building activity at the start of the term or at the beginning of a design project.

In the end, what matters is that these activities are used to engage students in exploring phenomena, in explaining what they experience, and in connecting their experiences to the very wide world around them.

Along with the NGSS documents, which can be accessed at **nextgenscience.org,** the books below may help teachers with selecting the approach that best informs Real World Science:

- *Teaching for Conceptual Understanding in Science* by Richard Konicek-Moran and Page Keeley, NSTA Press 2016.
- *What Are They Thinking? Promoting Elementary Learning Through Formative Assessment* by Page Keeley, NSTA Press 2016.
- *Total Participation Techniques Making Every Student an Active Learner 2nd Edition* by Persida Himmele and William Himmele, ASCD Press 2017.

To share how you have used the Real World Science curriculum, or ask advice on how to use it, email **realworldscience@nationalww2museum.org**

STEM AND INNOVATION IN WORLD WAR II

ROB CITINO, PHD

Executive Director, The Institute for the Study of War and Democracy;
Samuel Zemurray Stone Senior Historian

(Image: The National WWII Museum.)

The ancient Greek philosopher Heraclitus once noted that "War is the father of all things." Since war is a matter of life or death, a "to be or not to be" moment for the armies fighting it, human beings will bend all their energy, strength, and ingenuity to fight and win. In the modern era, that means harnessing the power of science, technology, engineering, and mathematics, now popularly referred to as STEM, to the war effort.

Never was this process clearer than in World War II. Global war required global military forces, and all the combatants recruited them. Tens of millions of human beings put on a uniform of some sort during the war, serving as soldiers, sailors, airmen, and marines. But marching alongside those millions was another force: the force of new machines, new weapons, and new technologies. Technology was a "force multiplier," making all those humans even more efficient at fighting and winning.

Technology was everywhere in World War II. Some forms, like "radio detection and ranging" (RADAR), helped you find the enemy; others, like "walkie-talkies," let you communicate more effectively with your own troops. Some new technology (B-17 strategic bombers and proximity fuses) killed; other forms, mass-produced penicillin, for example, saved thousands of lives that would surely have been lost in previous wars.

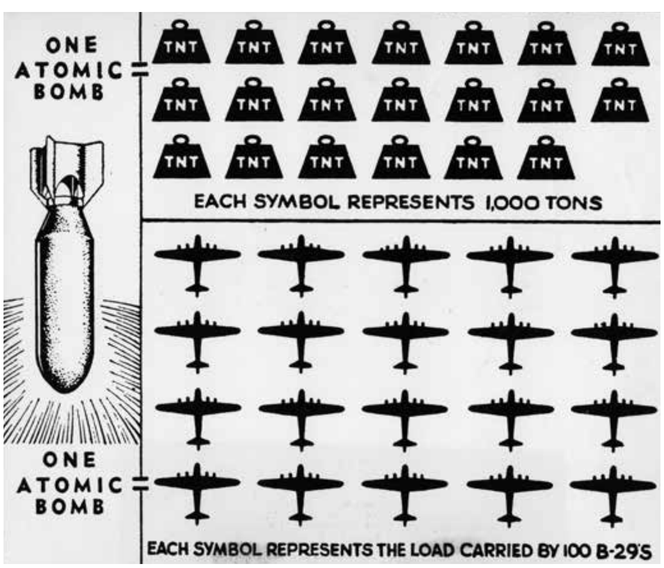
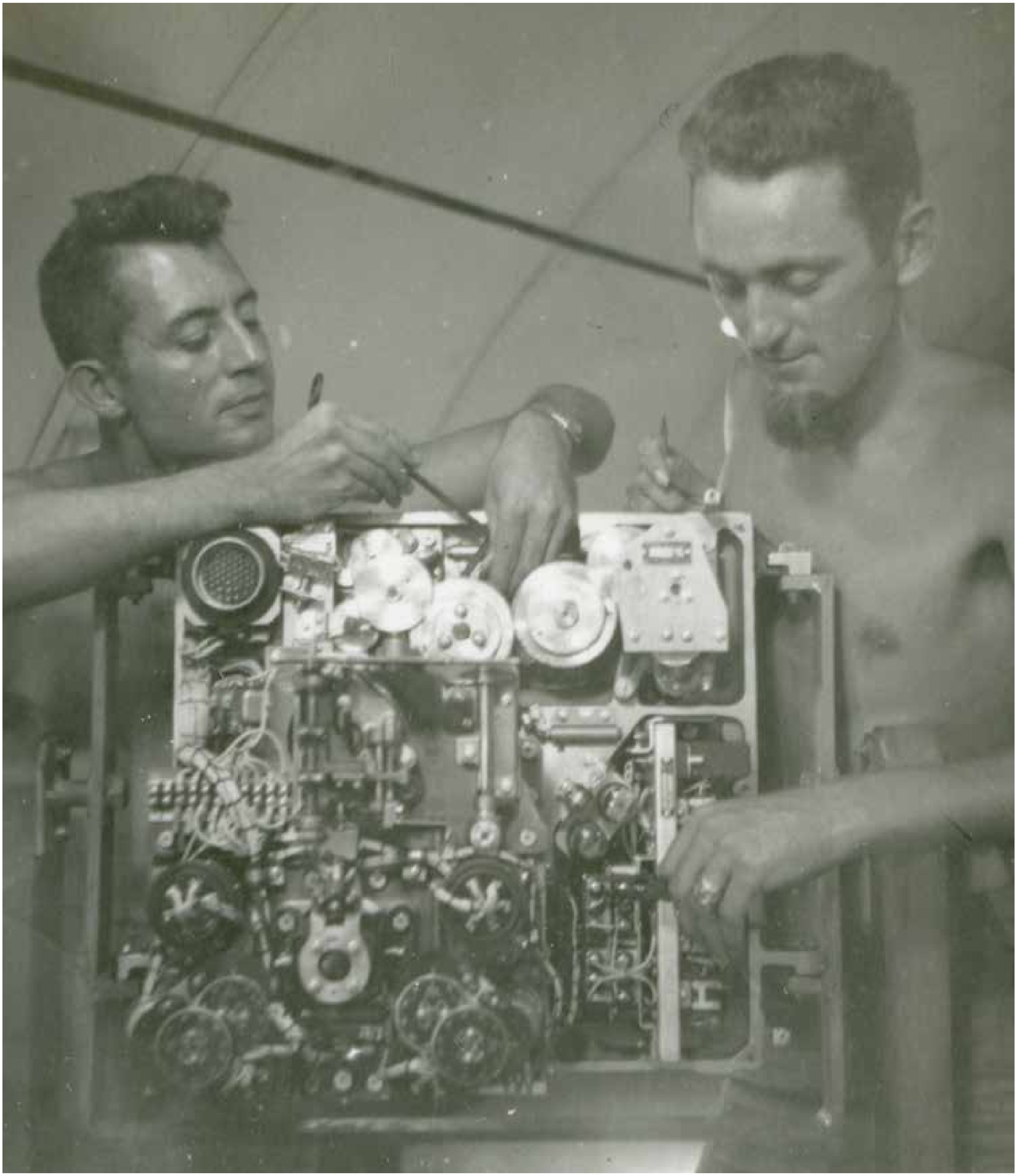


Chart illustrating the relative power of the atomic bomb. August 20, 1945.
(Image: The National WWII Museum, 2012.019.644.)

Now, STEM does not always mean a lone genius, staying up all night in her laboratory, and only emerging when she has the miracle invention that will win the war. Rather than solitary inventions, wartime scientists and inventors were more likely to adopt, adapt, and apply. Often, they took previously known technologies and employed them in the service of wartime. To give just one example, penicillin had been discovered in 1928 and was already seen as a "wonder drug" in killing bacteria. But the increased wartime need for penicillin to treat millions of wounded soldiers led to new experiments and techniques. All the major pharmaceutical companies in the United States were involved: Merck, Squibb, Pfizer, and others. Eventually, it was Pfizer that developed a process it called "deep tank fermentation," the technological breakthrough that made the mass production of penicillin possible and forever changed the face of war.

In fact, that might be the most important point to make about STEM in World War II. Modern warfare requires complex technologies, and rarely does it result from the work of a Thomas Edison-like genius. New high-altitude Boeing B-29 bombers, for example, were revolutionary machines, with pressurized crew compartments, automatic turrets, and analog computers. Each bomber consisted of over 8,000 separate parts and had 560,000 separate electrical connections. Designing and assembling a B-29 was a daunting task, requiring teams of scientists, technicians, and workers. The gigantic Boeing facility for B-29 production was located in Kansas, and so difficult was the development process that Boeing personnel dubbed it the "battle of Wichita."

In the end, you couldn't fight World War II without brave men and women, but you couldn't win it without up-to-date, cutting-edge science and technology. Those technological breakthroughs often appeared to be some sort of "miracle" (like iPhones and tablets today), but it was usually the result of a great deal of hard work, thousands of people, and millions of hours.



United States Army Air Forces servicemen working on a Central Fire Control Computer for a B-29. North Field, Tinian, 1945.
(Image: The National WWII Museum, 2014.153.030.)

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)?**

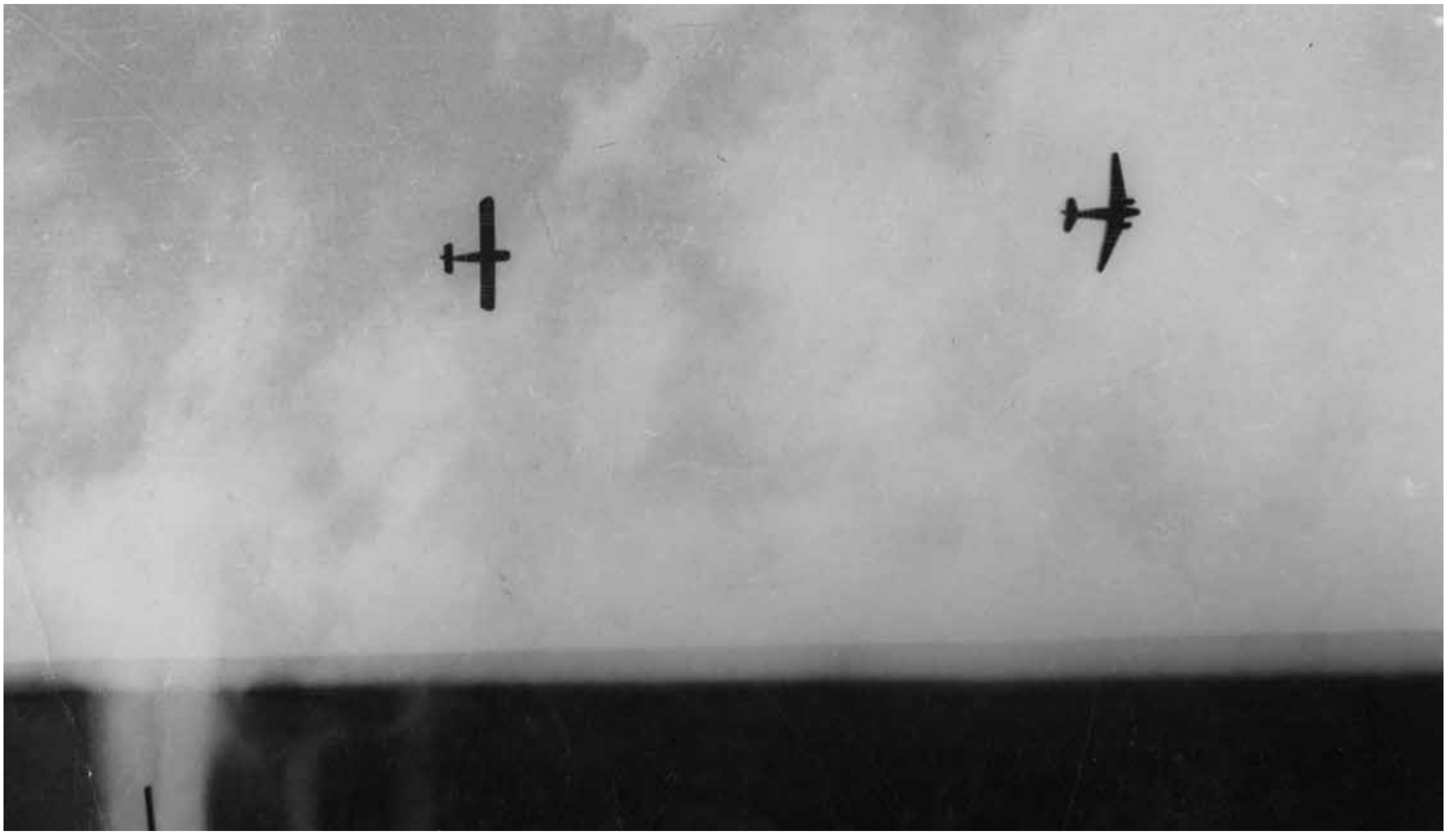
For example, the famous Higgins Boats, which made the landings at Normandy on D-Day possible, were developed by modifying boats Higgins Industries designed for fishing and working in the wetlands of south Louisiana. These boats are examples of **adaptations** of civilian technology for military use in 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 <u>adopt</u>, <u>adapt</u>, or <u>apply</u>?

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.

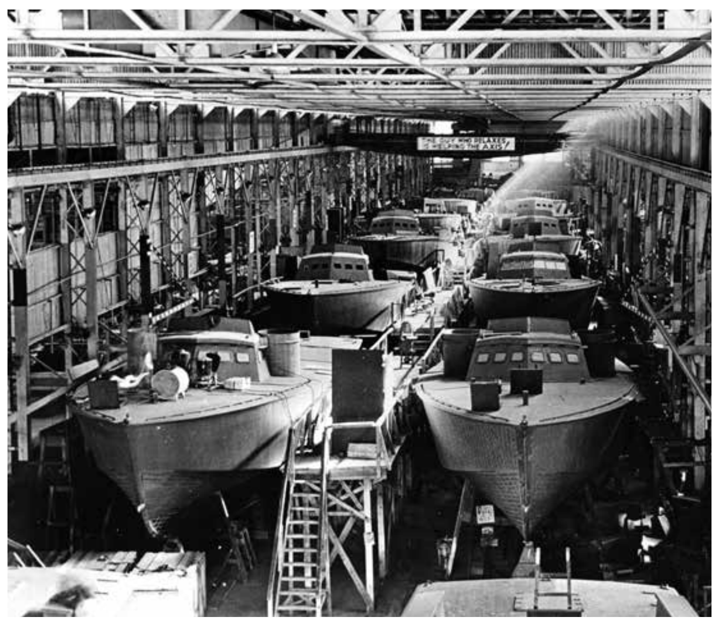
The Liberty ship *SS George Poindexter* is launched from Delta Shipbuilding Company shipyard, New Orleans, Louisiana, May 18, 1943.
(Image: The National WWII Museum, 1999.060.004.)

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 adaptation. 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

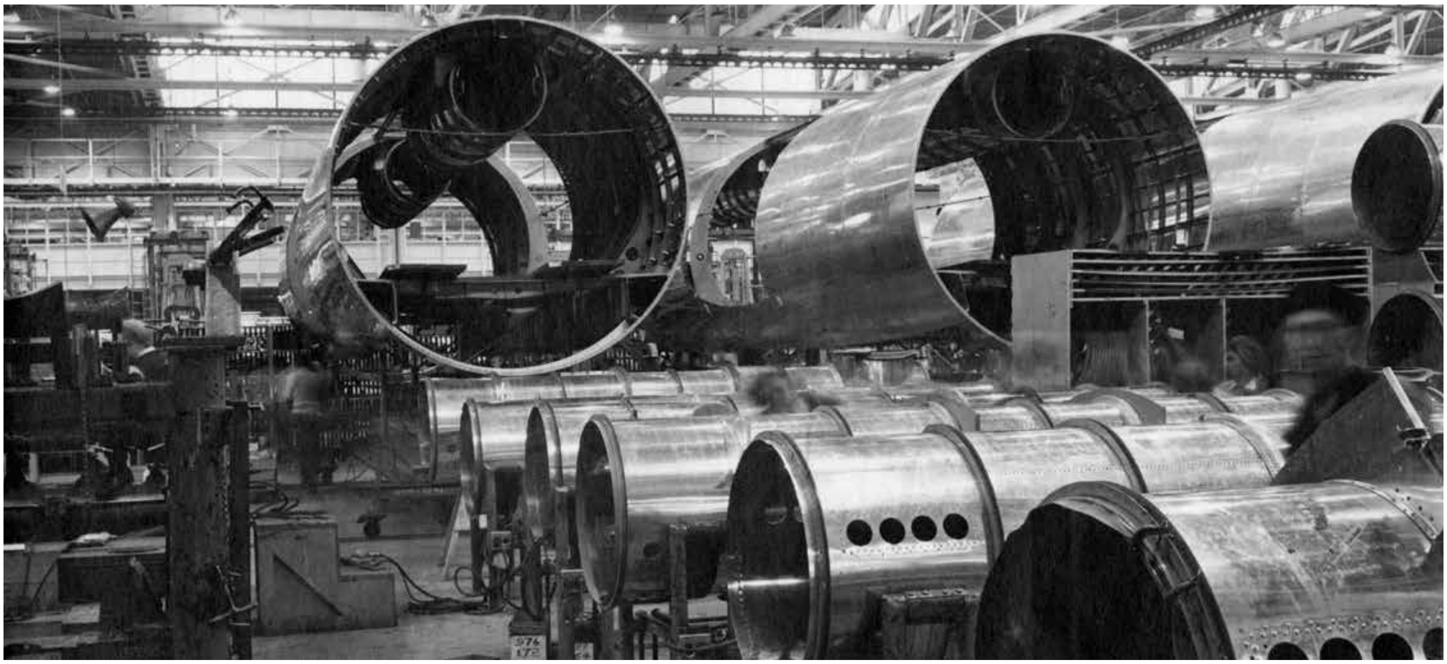
INTRODUCTION

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?

LESSON PLANS, READINGS & ACTIVITIES

PHYSICS: FORCES

GRADE LEVEL: 5-8 | TIME REQUIREMENT: 4 HOURS

PHYSICS: FORCES

2 READINGS | 2 ACTIVITIES

INTRODUCTION

You could use all four resources in sequence because they all focus on balancing forces and on using the engineering design process. They focus on two situations where engineering for use of forces were important in World War II. In the first case they look at the creation of the Higgins landing craft and what makes things buoyant. In the second they examine different aircraft and how their shapes determine their function.

OBJECTIVES

These resources give students the chance to investigate forces in flight, as they try to optimize a paper airplane design after reading about the use of a glider to make a rescue from the New Guinea highlands. They can also read about the development of the Higgins boat while investigating buoyancy and density. Both the flight and buoyancy investigations use a design project. The buoyancy investigation uses non-arithmetic means to investigate the relationship between density and buoyancy.

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
Structure and Function, 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-ETS1-3
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.

5-PS2-1
Support an argument that the gravitational force exerted by Earth on objects is directed down.

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-PS2-2
Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

READINGS (2)

1. BUILDING THE HIGGINS BOAT

Description
A reading to introduce the activity Sink or Float, in which students learn about the creation of the Higgins landing craft. After the reading, ask students why they think boats float. Point out that tankers and aircraft carriers weigh many tons, and yet they float. Try a think-pair-share or a Kagan protocol to get students to think and productively discuss their ideas. To supplement this reading, you can use the videos on the Real World Science site.

2. CATCH A GLIDER

Description
A reading to pair with Earn Your Wings. You can assign the reading and then ask students to discuss how different shaped aircraft create a different balance of forces leading to different functions. Have them share their ideas in groups. To supplement, watch a video of students making and testing paper airplanes on the Real World Science site.

ACTIVITIES (2)

1.SINK OR FLOAT

Description
This resource takes students through a simple activity to show how density is critical to floating. Then another investigation quantitatively looks at the relationship between mass, volume, and floating. The first activity involves engineering, as the students change the shape of the material to make it float through a few design cycles.

Supplies (per group)
1 Ball of Sculpey clay (or similar polymer clay)
1 Plastic bin filled 1/3 with water
Blocks of different kinds of wood
Squares of tile, glass, metal
Metric rulers
Cooking (or other) mass scale

Instructions
Have the students test the ball of clay in the bin of water to see if it floats. When it doesn't, have them reshape the ball to get it to float. When students get it to float, have them add toy soldiers or pennies to see how much the boat can hold. After they put the clay away, have students measure the mass and calculate the volume of each block of wood or other material and then see if they sink or float.

2. EARN YOUR WINGS

Description
An engineering design activity that has students test different paper airplane designs, optimizing them through the design process. At the end, diagrams of the plane are drawn showing the forces acting on it when it is in flight.

Supplies (per group)
Sheets of plain paper
Measuring tape
Timer

Instructions
Have students make two paper airplanes: "hotdog (lengthwise)" and "hamburger (widthwise)." Once the airplanes are folded, have students test them and decide what variable to optimize (e.g., speed, distance, time in air). Students should then iteratively modify the airplanes until they are satisfied with the design.

ADDITIONAL RESOURCES

To learn more about these subjects in World War II, try these books:

+ *Andrew Jackson Higgins and the Boats That Won WWII* by Jerry Strahan, LSU Press 1998
+ *Lost in Shangri-La* by Mitchell Zuckoff, Harper Perennial 2012

READING

BUILDING THE HIGGINS BOAT

In 1938 Andrew Jackson Higgins was a flamboyant and ambitious owner of a small boat company in New Orleans, Louisiana. His 75 employees at one boatyard made fishing boats for Louisiana fishermen. As war approached, the military was looking for a company to design and build craft that could transport men and troops from large ships onto the shore.

At first, the Navy looked to large shipbuilders on the East Coast. These companies had been making boats for the military and industry for years. The landing craft that these companies made didn't perform well when tested by the military. They fell apart when traveling fast on waves, or they were stopped by submerged logs and sand bars.

Then the military came to New Orleans to see Higgins who quickly assembled a landing craft for them, **adapting** the design of his fishing boats which performed well in the shallow waters of swamps and marshes of Louisiana. Higgins then took the boats to Lake Pontchartrain and showed how well they worked by landing them up the Lake's seawalls and pulling them off again.

Later Higgins created a different version of his landing craft (more **adaptation**), this time with a combination door/ramp on the front. This door/ramp could be lowered to let soldiers off more easily and also allowed jeeps and small tanks to be moved on shore. All these landing craft were made of plywood and were built quickly and cheaply.

During World War II, the Higgins company made more than 20,000 boats for the military. Over 12,000 of these mostly wooden boats became the landing craft used on the beaches of Normandy for D-Day. General Dwight D. Eisenhower, the Supreme Allied Commander and future President of the United States, would later say that these were the boats that "won the war for us." The vessels came to be called "Higgins Boats" by soldiers and the Marines who rode to battle in them.

Today we face many big problems, and we can solve them in the same way Higgins did—with knowledge, persistence, creativity, and collaboration.

A full LCVP in training maneuvers at Morro Bay, California, January 1944.
(Image: The National WWII Museum, 2011.065.068.)

LCPL, LCVP, and barrage balloon on Lake Pontchartrain, July 1944.
(Image: The National WWII Museum, 2008.379.019.)

NAME: **DATE:**

LCVPs loading before going ashore in Guadalcanal, March 1944.
(Image: The National WWII Museum, 2008.354.070.)

1. Describe a problem facing the world today that you think could be solved using the same sort of approach Higgins used.

READING

CATCH A GLIDER

By the spring of 1945, the end of World War II was within sight for the Allies. Germany had surrendered on May 8th, and after many tough battles in the Pacific, the Allies were getting closer and closer to the mainland of Japan.

In 1944, New Guinea had been taken back from Japan. An American base at Hollandia (now called Jayapura) had a good port and landing strip. Hollandia had been a Japanese base, and now the Americans used it as part of the supply route for the continuing battle in the Philippines. To the south of Hollandia were mountains that reached over 5,000 feet in altitude. In those mountains, one high valley, called Baliem, had been given a more fanciful name—Shangri-La.

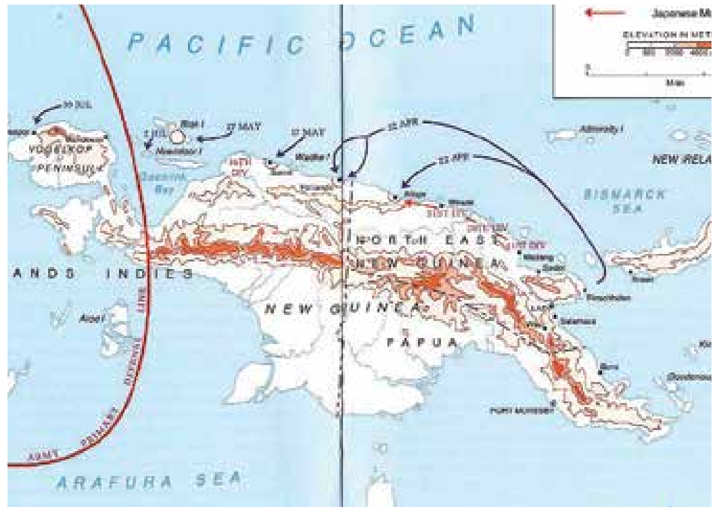
Westerners had discovered the valley in 1938 when an explorer named Richard Archbold was looking for new animals in New Guinea. The approximately 200,000 native people who lived in small villages in this 20km-by-80km valley kept animals and large gardens. After the American forces took New Guinea from the Japanese and started flying over the island to Australia, they began mapping the island. When the valley was rediscovered, news reporters called the valley Shangri-La after a fictional place in a novel called *Lost Horizon*. By that time, the war had been going on for almost four years, and military personnel had been working six or seven days a week even if they were just office workers or supply clerks far from the battlefield. Officers tried to keep up the morale of their workers and soldiers by planning relaxing events.

On May 13, 1945, Lieutenant John McCollum took a group of 19 of his staff on what he hoped would be an enjoyable sight-seeing flight over the valley so that they could see this strange place and bring back more stories about it. With four other crewmen he loaded his passengers, who included some WACs (Women's Army Corps), into a large C-47 cargo plane and headed for the valley.

On the way, something went wrong, and the plane crashed into the side of a mountain at the edge of the valley. The crash was bad, and only five people survived, with two of those five dying of their injuries soon after the crash. Corporal Margaret Hastings, Sergeant Kenneth Decker, and Lieutenant McCollum were injured, but left the crash site for the valley floor.

When the plane did not return to its base, search planes were sent to look for it. The valley was so large that it took some time to find the survivors. The three survivors were finally spotted on May 17. Shortly after, two medical paratroopers and 10 other paratroopers were dropped nearby to help. Other planes dropped food and tents and other supplies.

The southern part of the island was still unexplored and possibly held Japanese troops. The spot in the valley where the survivors were stranded was hundreds of miles from the US base in Hollandia. High mountains and dense jungles separated them



1940s map of New Guinea.
(Image: Courtesy of the United States Army.)

from safety, and the rough ground and dense forest prevented the construction of a landing strip for a plane. It took six weeks to make a rescue plan to attempt to rescue the survivors from the valley.

The final plan involved another C-47 and a glider. The glider, which was built of aluminum and balsa plywood frames covered with canvas, had a simple steering system. Such gliders were normally used to drop a few people and heavy supplies. For this mission, the Americans would **adopt** the glider for a new use.

The C-47 carried the glider to the valley, and then a glider pilot landed the light craft near the camp site of the survivors. The survivors and paratroopers were then loaded into the glider. If that was not risky enough, the next part certainly was. The same C-47 that had carried the glider returned, dangling a loop of cable that rescuers hoped would latch onto a hook on top of the glider. The C-47 eventually made its target. The glider would be pulled across the rugged valley floor before being lifted into the air. But it took a few passes to successfully hook the glider, and it took several more trips to get all of the survivors, medics, and paratroopers out to safety. By the last trip the canvas floor was torn, and the passengers could see through the floor to the valley below as they rose up, towed by the C-47.

1. Why was the glider made of flimsy material like balsa plywood and canvas?

NAME: **DATE:**

Glider troops about to board in Italy, August 1944.
(Image: The National WWII Museum, 2002.337.825.)

2. What was daring about the rescue attempt? What could have gone wrong?

3. The description says this plan was an innovation by adoption. Do you agree or disagree? Explain your reasoning.

ACTIVITY
SINK OR FLOAT?

INTRODUCTION

How do boats float? Considering the extreme weight of battleships, barges, and aircraft carriers, how and why do they not sink?

Take a ball of clay and place it gently in the bin of water. What happens?

If you change the shape of the clay, can you make it float? Try and then describe your results.

Draw a diagram of your best-designed floating clay-boat clay. Draw and label the forces acting on it when it is floating.

Pool your data as a class and make a scatter plot. Each point should represent the mass and volume of one of the objects you measured. The axes should be mass (y axis) and volume (x axis).

Make the dots for the objects a different color if they sank or floated.

NAME: **DATE:**

Your teacher has given you some objects to investigate.
Fill the table with the data you collect from these objects.

The computation of length x width x height gives the volume of a polygonal or squarish object. You can get the mass from a weighing scale.

OBJECT	MASS (g)	VOLUME (cm^3)	SINK OR FLOAT?

1. What is the pattern in the graph? Describe in words the relationships between mass and volume and floating.

2. Can you tell in advance if something will sink or float? How?

ACTIVITY
EARN YOUR WINGS

INTRODUCTION

You are going to make two paper airplanes, and then test them.

One design will begin with a lengthwise fold of the paper—this is the "Hotdog" plane. The other design will begin with a widthwise fold—the "Hamburger" plane.

After your tests, you are going to decide if you want to optimize your plane design for speed, distance, or time in the air, and you will choose one of the two designs.

If you record the distance and the time in air, you can also calculate the speed. Record data for 3 trials of both planes.

Record the details from your investigations and design changes below:

PLANE	SPEED	DISTANCE	TIME IN AIR
Hamburger Trial 1			
Hamburger Trial 2			
Hamburger Trial 3			
Hotdog Trial 1			
Hotdog Trial 2			
Hotdog Trial 3			

1. Which plane will you adapt to make your final design? Which factor will be optimized?

NAME: **DATE:**

DESIGN 1	
Draw Diagram:	**Data:**
How will you modify your design based on the evidence?	**Expected outcome:**

DESIGN 2	
Draw Diagram:	**Data:**
How will you modify your design based on the evidence?	**Expected outcome:**

2. Summarize your results. How did you improve your plane through cycles of the design and testing process?

3. Draw below a diagram of your best plane. Indicate the forces acting on the plane when it is flying.

LESSON PLANS, READINGS & ACTIVITIES

CHEMISTRY: PROPERTIES OF MATERIALS

GRADE LEVEL: 5-8 | TIME REQUIREMENT: 3 HOURS

CHEMISTRY: PROPERTIES OF MATERIALS

1 READING | 2 ACTIVITIES

INTRODUCTION

World War II came at a time when most manufacturing used natural materials. Clothes were mostly cotton and wool, with some linen and silk. Tires were made of rubber from the sap of a tropical plant, and shoes were made of leather, wood, and that very same kind of rubber. The makeup of the furniture in a house or classroom from World War II and even the clothes that students would have worn is radically different from those today.

One of the key things for students to learn in elementary and middle school science is that materials can be identified by their physical and chemical properties. Engineers, manufacturers, and inventors design materials to have specific properties. Leading up to World War II, this design was done by creating different metallic alloys and by choosing plant and animal products to make fibers. Shortages caused by the outbreak of the war and the diminished access to materials were the impetus for scientists to create new materials. The world of today, dominated by materials made from petroleum products, is a result of the revolution in materials science that started in World War II.

OBJECTIVE

Starting with a reading that asks students to consider the makeup of the built world they live in and to compare it to the past, these resources introduce students to the field of Materials Science. One activity is an experience with an unusual material, that also gives students experience with electricity and circuits. You could supplement this, if you want, with students making and/or testing the properties of other unusual materials, like slime, or oobleck, or bubble solutions. The second activity has students exploring how WWII-era advertisements promoted new technologies and manufacturing, and comparing them to the way science and technology are communicated today.

STANDARDS

NGSS DCI PS1.A
Structure and Properties of Matter

NGSS DCI PS3.A
Definitions of Energy

NGSS DCI ETS2.A
Interdependence of Science, Engineering, and Technology

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

NGSS SEP
Developing and Using Models

NGSS SEP
Obtaining, Evaluating, and Communicating Information

NGSS CCC
Patterns

NGSS CCC
Energy and Matter

PERFORMANCE EXPECTATIONS

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.

5-PS1-1
Develop a model to describe that matter is made of particles too small to be seen.

5-PS1-3
Make observations and measurements to identify materials based on their properties.

MS-PS1-3
Gather and make sense of information to describe that synthetic materials that come from natural resources and impact society.

READING (1)

1. THE MOTHER OF INVENTION

Description
This short reading introduces the idea of material properties and gets students to think of how things are made and modified to match the needs of a community, population, or country. The reading will set up the activities in this unit. You can try grouping students in pairs or fours to read together or in turns, and to answer the questions.

ACTIVITIES (2)

1. SOFT CIRCUITS

Description
This is an activity that explores the properties of materials, conductivity, and complex circuits. Working in groups, students will be able to answer questions about these concepts through experiments making complex circuits. The worksheet that is included with this activity asks students to draw one of their circuits to demonstrate how electricity flows. Additional activities can consist of having students create parallel and series circuits, and then drawing both circuits on their worksheet.

Supplies (per group)
A tennis-ball sized lump of dough (see recipe below)
2 9V batteries with snap wires
A handful of small LED lights of 3-5V

To make the dough:
Recipe is enough for one class — dough will stay fresh for at least one month when wrapped in plastic.

Ingredients:
- 4 Cups water
- 6 Cups white flour
- 1 Cup table salt
- 3/4 Cup cream of tartar
- 4 Tbsp vegetable oil
- Food coloring

Combine five cups of flour and all other ingredients in a pot. Place the pot on the stove over medium heat and stir continuously. The mixture will begin to boil and start thickening. With the heat still on, keep stirring until the mixture forms a single ball. Remove the mixture from the heat, and place the ball of dough on a lightly floured surface and allow it to cool. Once cool, knead the remaining flour into the dough until it reaches a nice consistency.

The high concentration of salt is what makes the dough conductive. The cream of tartar makes the dough smooth and not so sticky.

Instructions
Demonstrate where everyone can see, under a document camera or at the front of the room, how to construct a simple circuit with the dough. Make two small balls of dough that are close together but not touching. Insert one battery wire in each ball, and then connect one of the lights across the balls. Explain that students might have to rotate the wires across the balls (LED bulbs are polar) before the LED lights up. Students are likely to be very surprised when they see the light go on. Next, show them what happens when the two lumps touch—that the light short circuits and goes out. Go around the room, making sure everyone understands, and ask questions to encourage further exploration. Exploration can include setting up multiple batteries and lights in different types of circuits.

2. ANTIQUE ADS

Description
An activity that uses a modified version of Claim Evidence Reasoning to discuss the relationship between technology, engineering, and society. This activity is a thinking scaffold that has students make a claim, provide evidence to support their claim, and then connect the two with reasoning. Students will work in small groups to analyze WWII advertisements and share and compare their findings with those of the rest of the class.

Supplies
Copies of the handout and reproductions (available from Real World Science site) for each student.

Instructions
Lead students in discussions by having students compare WWII advertisements from *Time* or *Newsweek* to modern technology and other ads they have seen. Use the modified Claim Evidence Reasoning framework to structure their thinking.

READING
MOTHER OF INVENTION

Many things have to come together to make an invention. The timing has to be right, and the inventor has to have a vision of how the creation will fill an important need. One of the major areas of innovation in World War II was in developing new kinds of materials.

PLASTICS IN THE PAST

Today when we say plastic, what we mean is a synthetic polymer, but really all plastic means is a material that is easy to shape. A polymer is a chemical that is made of a repeated chain of smaller chemicals or molecules.

Humans have been using polymers (wood, paper, horn, cotton, linen) for millennia. Rubber and other polymers from plant sap were used for many purposes for centuries until in the 1840s engineers learned to strengthen rubber by treating it with sulfur.

The first synthetic polymers were made in 1860 when John Wesley Hyatt treated cotton fiber with camphor to create celluloid. Celluloid, which could be carved or shaped and then polished, was meant to replace expensive and rare substances like horn, tortoiseshell, and ivory. Although celluloid was important in some manufacturing, in most areas natural polymers were still cheap and plentiful enough to be used instead of human-made ones.

In the early 1900s, chemical engineers began working with a new substance called coal tar.

Coal tar is a by-product of coal production, and engineers learned to make many products from it including dyes and sulfa drugs that were used to fight infections in the human body before penicillin.

A soldier inventories the pharmaceuticals in the hospital at a training camp. *(Image: The National WWII Museum, 2011.065.1960.)*

Medical technicians in a laboratory at Cape Gloucester, New Britain, August 1944. *(Image: The National WWII Museum, 2008.354.216.)*

In 1907, Leo Baekeland made the first completely synthetic plastic. He made it from coal tar and called it Bakelite. Throughout the decades before World War II, more and more plastics were made from coal tar and oil. Although radios, telephones, fancy furniture, jewelry, and sculptures were made from synthetic polymers, most manufactured products still used natural materials.

That all changed with the beginning of World War II.

Suddenly electronics systems were needed for tens of thousands of aircraft, boats, ships, radios, and radar systems. All of this equipment needed plastic insulation around their wires. The United States needed rubber for Jeep and airplane tires, tank treads, and soldiers' boots; however the plants that supplied the natural rubber were primarily grown on islands now controlled by the Japanese. Silk, also grown in Asia, was used for both parachutes and pantyhose. Women turned in their pantyhose to make more parachutes, but it wasn't enough, and at the same time plant polymers commonly produced in the tropics were harder to get.

By 1935, a polymer named nylon had been discovered, but it was more expensive than the silk and linen it was meant to replace. During wartime those natural materials were in short supply, and so nylon was used to make parachutes, ropes, and parts of clothing. The balance between the cost of synthetic and natural polymers had changed—manufacturers began developing ways to make products out of polymers from oil to replace plant materials. During World War II, plastic production in the United States increased 300 percent.

NAME: **DATE:**

PLASTICS TODAY

Look around the room you are in. What are all the objects in the room made of? What are your clothes, your backpack, your shoes made of? Chances are most of the objects are made of polymers, and many are synthetic. Synthetic means that it is made from polymers engineers created from oil or another source.

A B-29, the only WWII aircraft with a pressurized cabin, flying over Guam. *(Image: The National WWII Museum, 2010.216.358.)*

1. Fill in the data table below. What are objects in the classroom made of? Are they natural or synthetic?

OBJECT	MADE OF	SYNTHETIC OR NATURAL

2. Are the materials mostly natural or synthetic?

3. What is one object on the list that is synthetic and that you think would have been made of natural materials during World War II? Explain.

ACTIVITY
SOFT CIRCUITS

INTRODUCTION

With the onset of World War II, the United States needed to produce much-needed supplies and equipment fast. However, this rush to become an arsenal of democracy also created shortages in materials. This situation was made worse by interrupted supply chains from other countries. For the first time it became necessary to make polymers synthetically instead of just modifying natural products. During the war, manufacturers rushed to design polymers for specific purposes, but polymers didn't truly become a big industry until the end of the war. Once the process began, however, synthetic polymers dominated industrial manufacturing, and they still do today.

You are going to investigate a material with unusual properties. Follow your teacher's instructions, and use the materials you are given to conduct your investigation.

Rolls of copper signal wire (for telephones) are stacked at a signal camp in Naples, Italy, 1944.
(Image: The National WWII Museum, 2002.337.455.)

NAME: **DATE:**

1. What do you think is unusual about the material you are investigating?

2.What do you think gives it this unusual property?

3. Draw a diagram of one of the circuits you made, and show how electrical energy flows through it:

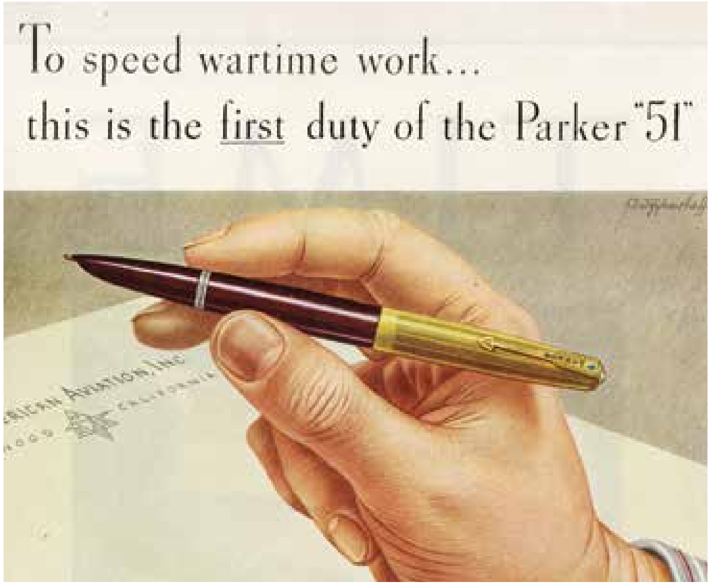
4. What is a substance on which you would like to experiment? Describe its properties and what need it would fulfill.

ACTIVITY
ANTIQUE ADS

INTRODUCTION

New materials and new solutions to pressing problems were critical to the victory of the Allied powers in World War II. Manufacturers advertised what they were making for the war effort in popular magazines even though people couldn't always buy these products. Companies believed that by communicating their efforts to support American troops in the war, people would be generally supportive of their company and would buy other products they made.

You will get a copy of a WWII magazine advertisement to investigate.



Ballpoint pens were a WWII innovation, and this *Time* advertisement for Parker Pens highlights this.
(Image: Education Collection of The National WWII Museum.)

Cadillac didn't make cars during the war years, but made engines and parts for planes.
(Image: Education Collection of The National WWII Museum.)

NAME: **DATE:**

1. What product is advertised? Is it a product people could buy?

2. Summarize the advertisement—Describe what you see, what you read, and what the images used are communicating.

3. How is it different than advertisements you might see today?

LESSON PLANS, READINGS & ACTIVITIES

CHEMISTRY: MIXTURES AND REACTIONS

GRADE LEVEL: 5-8 | TIME REQUIREMENT: 3 HOURS

CHEMISTRY: MIXTURES AND REACTIONS

1 READING | 2 ACTIVITIES

INTRODUCTION

World War II required massive changes in the everyday lives of Americans, whether on the Home Front or serving overseas. While many Americans had learned to be creative to make ends meet and to keep food on the table during the Great Depression, the changes brought on by World War II were huge by comparison. All through World War II, growing Victory Gardens, cooking your own produce, and canning to preserve foods were both family survival strategies and government programs.

Although you might not initially think so, cooking is, to put it simply, applied chemistry. Recipes are instructions to make both mixtures and controlled chemical changes. Physical and chemical properties and physical and chemical changes are important topics for elementary and middle school science. The difference between physical and chemical changes can be difficult for students to comprehend. Thus, examples, especially those that connect to everyday life, are valuable.

OBJECTIVE

Use these three resources together to introduce the ideas in an engaging sequence that will introduce chemistry concepts while connecting them to nutrition and cooking. You can start by introducing rationing, and the limits on resources and consumption that created challenges during WWII. Then students will make some food that they might like to eat, exploring chemistry, physical and chemical changes, and properties of materials.

STANDARDS

NGSS DCI PS1.A
Structure and Properties of Matter

NGSS DCI PS1.B
Chemical Reactions NGSS DCI PS3.A: Definitions of Energy

NGSS DCI LS1.A
Structure and Function

NGSS DCI LS1.C
Organization For Matter and Energy Flow in Organisms

NGSS SEP
Developing and Using Models

NGSS SEP
Constructing Explanations and Designing Solutions

NGSS CCC
Structure and Function

NGSS CCC
Energy and Matter

PERFORMANCE EXPECTATIONS

5-PS1-1
Develop a model to describe that matter is made of particles too small to be seen.

5-PS1-4
Conduct an investigation to determine whether the mixing of two or more substances results in new substances.

MS-PS1-2
Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-LS1-2
Develop and use a model to describe the function of a cell as a whole and ways the parts of cells contribute to the function.

READING (1)

1. RATIONALE FOR RATIONING

Description
This reading provides a real-world context for the activities in this unit. This resource answers the questions of why people needed to grow and make their own food and why they had to understand the chemistry of how prepared food is made. Have students work in groups using Kagan structures to discuss the reading. How do students think rationing would work today? How much of products like sugar do they consume compared to the WWII-rationed amount? What do students think might be rationed today that was not rationed then?

ACTIVITIES (2)

1.KITCHEN SCIENCE: GUMMIES

Description
Engage students in exploring changing properties of materials by making mixtures. Is the result of this recipe a chemical or a physical change? The process in this recipe is a physical change in which the long molecular strands of gelatin dissolve in the heated mixture and then, as they cool, stretch and tangle to form a gel. Vitamin C is a nutritional benefit that also lowers the pH, which humans also find to be yummy. To add a demonstration of chemical change, cook some pancakes on a hotplate. The key difference between chemical and physical change is in what molecules are present before and after. At both the beginning and the end of this activity, you will have gelatin, water, and vitamin C. The molecules have mixed and changed their form after warming and then cooling—an example of physical change. In the pancakes, there is odd-tasting baking soda present before while carbon dioxide gas makes bubbles and fluffs the batter. The chemical composition and the types of molecules present, are different before and after cooking—an example of chemical change. Another activity that can be added to demonstrate physical change in a dramatic way uses only two supplies—a pint mason jar and a half-cup of heavy cream. The mixture will first become whipped cream, and then with continued shaking will separate into butter and finally into buttermilk. Before and after, it is water, fat, and a small amount of protein and sugar; the shaking separates the mixture into parts.

Supplies (per group)
Silicone candy mold and dropper
1/2 Cup fruit juice
1/2 Tbsp vitamin C powder (optional)
2 Tbsp powdered gelatin (unflavored)
2 Tbsp sugar
Small saucepan, rubber spatula, and hotplate

Instructions
Remind students to be very careful with the hotplate, and enforce the use of safety goggles to avoid hot splatter. Students will need to keep the temperature at medium so that they don't evaporate too much juice. Add the vitamin C, and then add the gelatin very slowly. Refrigerate or freeze the gummies if you can so that it cools quickly. If not, the activity will still work, but will take longer to solidify. There are more detailed instructions in the student activity on page 56.

An alternate activity that demonstrates physical change is the making of butter. All you need for this activity is a pint mason jar with a lid and 1/2 cup of heavy whipping cream. Have the students take turns shaking the mason jar. If it starts cold, it will take about 5-10 minutes of shaking to become whipped cream. You'll notice this change because there is no more sloshing in the jar. It will then take another five minutes to separate into butter and buttermilk. If it starts warm, the mixture will go straight to butter in about 10 minutes.

For the pancake demonstration, bring some batter, or prepare it in front of the students and cook it on a hotplate in a small pan. Show the bubbles forming and break open a pancake to show the bubbles that make it fluffy.

If you do make butter AND pancakes, they go pretty well together.

2. KITCHEN SCIENCE: PICKLES

Description
An activity that demonstrates physical change, but one that has further connections to chemistry and biology. Give each group of students sliced cucumbers, or give them a safe butter knife and a whole cucumber. With the butter knife students will make relatively thick slices, but the activity will still work. Ideally the pickles would sit in the briny vinegar for 24 hours, but they are pretty crunchy and yummy an hour after. The pickles will stay good in the fridge for a month. This is an example of physical change because there is no change in the arrangement of molecules. Brining in this way creates a greater concentration of salt and acid in the liquid outside the membranes of the fresh cucumber. The salt and vinegar molecules move inside the cucumber (diffusion), pickling it. Some water may also leave the cucumber (osmosis), which is why you don't want to make the solution too strong. If you leave a cucumber slice on a plate covered in salt, it will become limp, because of osmosis. A variation of this activity would be to pickle other vegetables, like beets or green beans.

Supplies (per group)
1 Pint-sized mason jar with lid
1 Cucumber, thinly sliced
3/4 Cup hot water
3/4 Cup white vinegar
1 Tbsp kosher salt or sea salt
Dill, peppercorns, or other seasonings (optional)

Instructions
Add the sliced cucumbers to the jar with the seasonings (if you are using them). In a separate container, dissolve the salt in the hot water and mix with the vinegar. Add that mixture to the jar, and then close the lid. Shake well.

READING

THE RATIONALE FOR RATIONING

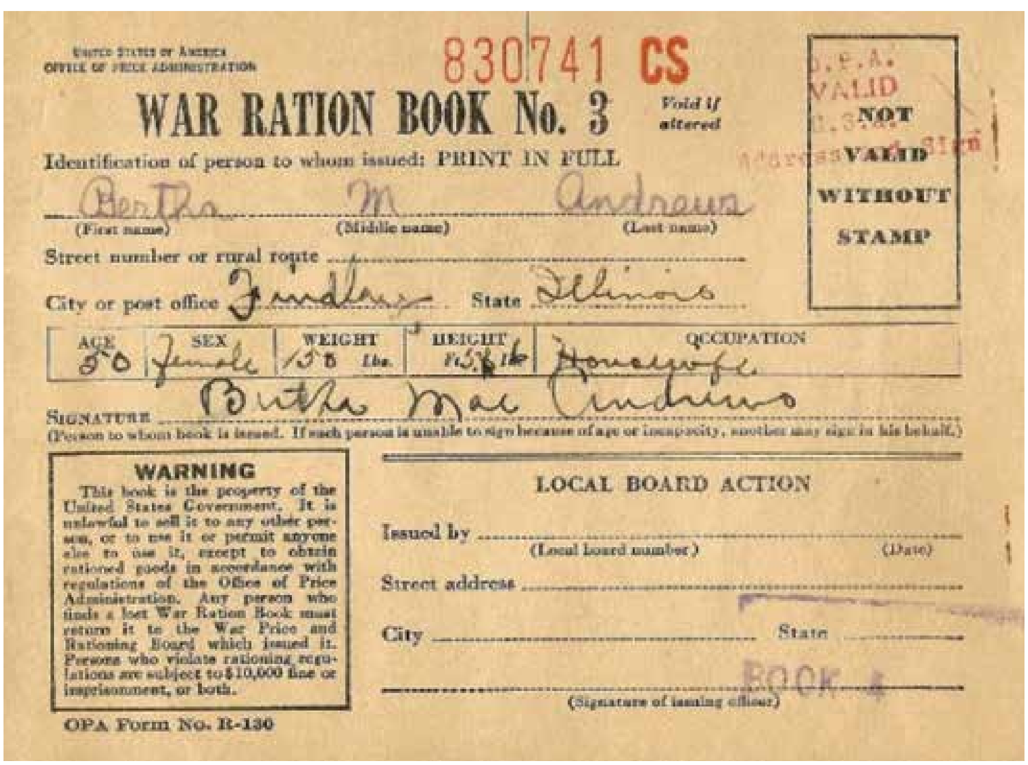
Many materials were in short supply during World War II. There were 16 million US troops fighting for victory, and 117 million people on the Home Front working hard to support them. Propaganda posters displayed throughout communities all told Americans how important it was to support the war effort in any way they could. People grew their own food, saved and reused material as much as possible, and went without some household items and personal comforts in order to aid the war effort.

One of the most dramatic ways World War II affected people's lives was rationing. Rationing is a systematic program or regimen that limits the amount of materials and supplies that an individual can purchase or consume. During the war, rationing controlled prices and supported equitable distribution of resources. Tires (and anything else made of rubber), sugar, meat, butter, cheese, milk, eggs, tea, chocolate, cloth, wood, metal, leather, paper, ink, bicycles, cars, fuel, and shoes were all rationed at times during World War II.

In the spring of 1942, every family registered for rationing through their local schools. On a trip to a grocery store for any rationed item you wished to purchase, you needed to be able to pay for it with both money and ration stamps. As supplies and conditions changed, the types of stamps and what was rationed also often changed. Stamps had to be torn out in front of the grocer at the time of sale so that people wouldn't try selling individual stamps.

To make groceries last longer, families were encouraged to can their own food. Since canning usually needed sugar, families who were canning could apply for more rations of sugar. Otherwise, families could only get one pound of sugar every two weeks for each person in the house.

Along with rubber for new tires, gasoline for cars was also rationed. The amount of gasoline you were entitled to depended on your job. This method allowed drivers to buy enough gas to get to and from work. If you could take the bus to work, or if you worked at home, you got an A-sticker for your car and you got about three gallons of gas a week. Supplies got even tighter in early 1945. As the Allies began to liberate parts of Europe, the United States took responsibility for providing food to refugees. The war had caused a great deal of damage to farms and manufacturing in Europe, and supplies to clothe and feed the people there had to be brought in. Rationing didn't last long in the United States after the war, but in England, which suffered a great loss of production of food and goods from the war, rationing lasted until 1954—nine years after the end of World War II.


UNITED STATES OF AMERICA
OFFICE OF PRICE ADMINISTRATION

830741 CS

WAR RATION BOOK No. 3

Void if altered

NOT VALID WITHOUT STAMP

Identification of person to whom issued: PRINT IN FULL

Bertha M Andrews
(First name) (Middle name) (Last name)

Street number or rural route

City or post office Findlay State Illinois

AGE	SEX	WEIGHT	HEIGHT	OCCUPATION
50	female	158 lbs.		Housewife

SIGNATURE Bertha Mae Andrews
(Person to whom book is issued. If such person is unable to sign because of age or incapacity, another may sign in his behalf.)

WARNING

This book is the property of the United States Government. It is unlawful to sell it to any other person, or to use it or permit anyone else to use it, except to obtain rationed goods in accordance with regulations of the Office of Price Administration. Any person who finds a lost War Ration Book must return it to the War Price and Rationing Board which issued it. Persons who violate rationing regulations are subject to $10,000 fine or imprisonment, or both.

OPA Form No. R-130

LOCAL BOARD ACTION

Issued by
(Local board number) (Date)

Street address

City State

(Signature of issuing officer)

The front cover of a WWII ration book.
(Image: The Education Collection of The National WWII Museum.)

NAME: **DATE:**

A US Government poster explaining how to use ration books.
(Image: The Education Collection of The National WWII Museum.)

1. What circumstances do you think could lead the government to start rationing today?

2. Do you go grocery shopping with your family? How would your shopping trips change if you had to use a ration book like the ones in World War II? Think about butter and sugar or about things that might not have been necessities then, but are today.

ACTIVITY
KITCHEN SCIENCE: GUMMIES

INTRODUCTION

During World War II people were encouraged to make do with what they had, so many grew and prepared their own food. These activities were due to prices, shortages, and rationing. One ingredient that families were able to incorporate into their recipes was gelatin. This ingredient was universally used in creating dishes and desserts using fruit, juice, or vegetables, but could also be used with dishes made with meat and broth!

GELATIN
is a protein that comes from the tissues of animals. Proteins are one of the basic molecules that make up all living things.

SUGAR
is a carbohydrate, which is another one of those molecules that make up living things.

In this activity you are going to use the physical properties of materials to make a delicious snack out of protein and sugar.

You will need the following:

- Silicone candy mold and dropper
- 1/2 Cup fruit juice
- 1/2 Tbsp vitamin C powder (optional)
- 2 Tbsp powdered gelatin (unflavored)
- 2 Tbsp sugar
- Small saucepan, rubber spatula, and hotplate

Mix the juice, sugar, and vitamin C together in the pan.

Heat them up, but do not bring them to a boil. Very slowly, while stirring constantly, add the gelatin. Use the spatula to smash any bubbles of gelatin powder so that the mixture isn't lumpy. The mixture will start to get thick.

When you've added all the gelatin, turn the heat off.

Use the dropper to transfer the mixture to the mold.

Place the mold in the freezer and wait 20 or 30 minutes.

NAME: **DATE:**

1. What do you see happening to the mixture as it cools?

2. Is mixing these ingredients an example of a chemical or a physical change?

3. As the gummies cool and solidify is this a chemical or physical change?

4. Design an investigation to figure out what one component of the mixture adds to the gummies: What if you used tea instead of juice? What if you added less gelatin or more vitamin C?

ACTIVITY
KITCHEN SCIENCE: PICKLES

INTRODUCTION

During World War II, many kinds of foods were in short supply. Families were encouraged to keep Victory Gardens in which they grew their own produce. People were urged to can what they could not eat fresh so that they could eat later when those foods were out of season. Because citizens were coming out of the Great Depression, growing and cooking food at home was not unusual. Such home-based activities are less common today because of how dependent we have become in many parts of the country on industrial agriculture.

CANNING

takes advantage of the principles of biology. Microbial growth can be reduced and food can be altered with the addition of some simple ingredients. Refrigerator pickles are an example of this simple use of technology to extend the shelf life of fresh produce. This process will allow fresh vegetables to be kept for a month or more while refrigerated.

You will need the following:

- 1 Pint-sized mason jar with lid
- 1 Cucumber, thinly sliced
- 3/4 Cup hot water
- 3/4 Cup white vinegar
- 1 Tbsp kosher salt or sea salt
- Dill, peppercorns, or other seasonings (optional)

Add the sliced cucumbers to the jar with the seasonings (if you are using them).

In a separate container, dissolve the salt in the hot water and mix with the vinegar.

Add that mixture to the jar, and then close the lid. Shake well.

Your pickles can be enjoyed in an hour or two and can be preserved at cool temperatures for a month.

NAME: **DATE:**

1. What is happening to the cucumber slices in the jar? Is this an example of a chemical change or a physical change?

2. Draw a diagram to explain your thinking:
- **Define diffusion.**
- **Define osmosis. (diagram of osmosis and diffusion)**

3. Go back to your diagram and explain where osmosis and diffusion are occurring in the jar.
Why does pickling slow microbial growth?

LESSON PLANS, READINGS & ACTIVITIES

CHEMISTRY: ELEMENTS AND THE PERIODIC TABLE

GRADE LEVEL: 6-8 | TIME REQUIREMENT: 4 HOURS

CHEMISTRY: ELEMENTS AND THE PERIODIC TABLE

1 READING | 3 ACTIVITIES

INTRODUCTION

If you refer to the Adopt-Adapt-Apply model, most innovations are of the **Adapt** kind in that they take something and modify it for a new purpose, or they improve it to better fulfill its original purpose. Very few innovations are of the **Apply** kind—where pure science and basic facts are developed into a technology. **Apply** innovations are very exciting because they are often some of the most ground-breaking and furthest-reaching innovations.

The Manhattan Project represents an example of an **Apply** innovation. The basic knowledge of how atoms are structured and of what makes something one element and not another, all culminated in an investigation in a Berlin lab in 1938. That basic knowledge, combined with the discovery of a new element seven years and countless hours of work later, unlocked the secret of atomic energy and atomic weapons.

The Manhattan Project succeeded because of the work of some of the best scientists in the world, but it also took huge investments by two Allied countries, as well as lots of work from civilians and military personnel who had no idea what they were working on. The Manhattan Project at once represented a pinnacle of human scientific achievement, but also a led to a new era of fear and danger.

Many scientists were uncomfortable with what they had accomplished, and those results certainly changed the world forever, in profound ways.

OBJECTIVE

Together these resources introduce students to the basis of chemical diversity—the periodic table and nuclear structure. They start with historical context, describing the Manhattan Project and its race to understand and control fission. Then they have students explore the periodic table and nuclear structures, looking at patterns and building models. Electrons are not explicitly discussed, because the phenomena discussed have to do with nuclear physics and chemistry. But you could easily add in electrons if you need to.

STANDARDS

NGSS DCI PS1.A
Structure and Properties of Matter

NGSS DCI PS3.A
Definitions of Energy

NGSS DCI ETS2
Links Among Engineering, Technology, Science, and Society

NGSS SEP
Developing and Using Models

NGSS CCC
Structure and Function

NGSS CCC
Energy and Matter

PERFORMANCE EXPECTATIONS

NGSS DCI MS-PS1-1
Develop models to describe the atomic composition of simple molecules and extended structures.

NGSS DCI MS-PS1-3
Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

READING (1)

1. BIG SCIENCE

Description
This reading introduces the context for the rest of the unit and outlines for students the problem of understanding how to manipulate elements. Have students discuss what it might have been like to work in the Manhattan Project as a scientist. There are some great video selections on the Real World Science website to flesh out this reading.

ACTIVITIES (3)

1. BUILD A TABLE

Description
In this activity students will have the information about all the elements known when Mendeleev developed the first Periodic Table. Have the students work in structured groups to organize the elements based on their characteristics. If the students have learned already about the periodic table, you might find that they are trying to reproduce it here. Any form of organization is acceptable, as long as there is group consensus on the organization and group members can justify that choice based on characteristics of the atoms.

Supplies
A set of Element cards for each group

Instructions
Set up groups using your strongest Kagan structures or other cooperative learning methods to make sure groups reach consensus and everyone participates. Explain what the information on each card means, and ask the students to arrange the cards in a structure that makes sense to them. Be sure to have groups present to the whole class their organization and thinking so that they can see alternate ways of organizing the elements.

2. BUILD AN ATOM

Description
Students will use periodic tables to build small atomic nuclei. Then they will look at models you provide of larger atoms to identify them based on the number of particles they contain. If you want, you can use these models as a base for exploring electrons and ions. Since electrons and ions were largely irrelevant to the nuclear physics at the heart of the Manhattan Project, these activities don't focus on those aspects of atoms, but can be easily added.

Supplies (for each group)
3 Containers (small mason jars or pill bottles will work)
1 Cup each of 2 kinds of dried beans
1 Periodic table

Instructions
To make the best model, the two kinds of beans should be similar in size but different in color—kidney beans and pinto beans or black beans, for example. If you want to extend your model to electrons, you can use lentils or another small bean.

Each group will make a model of three small elements and will fill in the responses to the prompts. Then you will give students some atomic models, and they will count the parts of the models and use a periodic table to identify them. For these unknowns, pick smaller atoms like sodium and chlorine. You could make one different unknown for each group and then have the groups trade unknowns.

3. BUILD AN ISOTOPE

Description
This activity follows naturally from the previous. In building and discussing models of isotopes, students will naturally analyze what makes an atom one element and not another. The activity also gets students to look at what makes some nuclei less stable than others.

Supplies
(The same supplies used in Build an Atom)
Corn puffs, extra beans, salad spinner (optional)

Instructions
If you do this activity immediately following Build an Atom, students can just modify the models they have already built. After they make their own isotopes, you will show them the isotopes of Uranium and a Plutonium model. The main objective of this is to get students to see how comparatively large the nuclei of these elements are and how small the difference in physical characteristics between isotopes is. If you wish, you can demonstrate how centrifuges are used to separate isotopes. Put kidney beans and corn puff cereal inside a salad-spinner. When you spin this kitchen centrifuge, you will see that the beans tend to go to the outside and the cereal to the inside. However, the difference in mass is small, so it is still hard to separate the mixture. Such differences are why the Manhattan Project had so much trouble getting enough Uranium 235 to make an atomic bomb.

ADDITIONAL RESOURCES
To accompany these activities, try these books:

+ *Bomb: The Race to Build—and Steal—the World's Most Dangerous Weapon* by Steve Scheinken, Square Fish 2018 (middle school, fiction).
+ Trinity: A *Graphic History of the First Atomic Bomb* by Jonathon Fetter Vorm, Hill and Wang, 2013 (middle and high school, graphic non-fiction).

READING
BIG SCIENCE

Lise Meitner, an Austrian physicist, was in Stockholm, Sweden, in December 1938. She had been head of the Chemistry Department at the University of Berlin, but was forced to leave in April 1938 because of the Nuremberg laws against people of Jewish descent like herself. Meitner fled with forged papers and a diamond ring to bribe border officials, first to The Netherlands and then on to Sweden.

That December, Meitner got a letter from colleagues in Berlin. She had begun a series of experiments together with these colleagues. Her colleagues had collected the data from the experiments and could not explain the results. The experiment involved aiming a ray of neutrons at a sample of Uranium. Instead of producing a new, larger element, they observed a large burst of energy and some smaller elements. Meitner had talked with the Nobel Prize-winning physicist Nils Bohr while in The Netherlands. Based on these conversations and others with her nephew who was also a physicist, Meitner made some calculations and explained what had happened using a new term—nuclear fission.

Two papers, published in early 1939, described the experiment and explained the results. Nils Bohr went to a conference in the United States and discussed the discovery there. When World War II began in Europe in September 1939, there was concern that Berlin, where the discovery of this new source of great energy had been made, was also the capital of a ruthless fascist country.

Within two years, the United States and Great Britain agreed to collaborate on turning this basic science discovery of nuclear fission into a practical application. Worried that German scientists were ahead in a race to build a new kind of bomb, Britain sent many of its top nuclear scientists to the United States where a giant top-secret project was given the code-name the Manhattan Project.

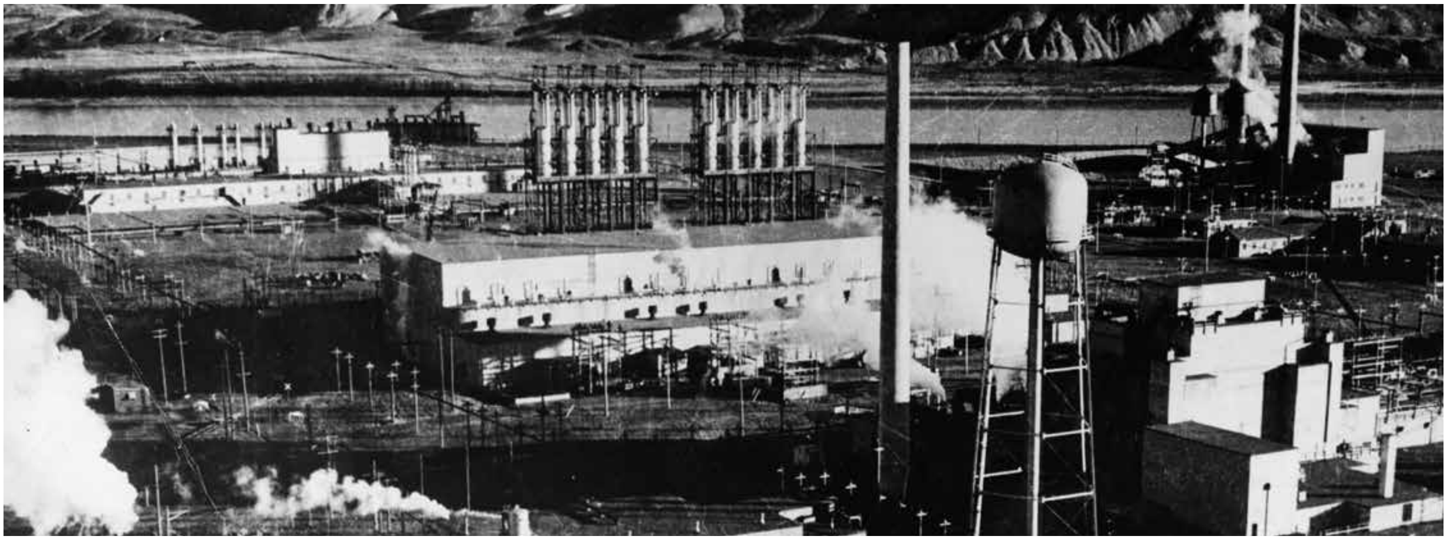
With a budget of about $2.2 billion in today's money, the Manhattan Project grew to employ about 130,000 people across the United States. Almost all of the people knew what their individual jobs were, but they had no idea about the true nature of the project. All they knew was that it was important and very secret. Cities sprang up in rural Tennessee and Washington around science research complexes there. A town was built in the mountains of New Mexico where 5,000 residents shared a single post office box. Twenty-one of the scientists working in the Manhattan Project were, or eventually received, a Nobel Prize. Many of them were refugees from Axis-occupied territories. This huge effort and unprecedented investment in science research led to amazing accomplishments and to a complicated legacy.

Bags of uranium ore are unloaded as a soldier guards the shipment. Fort Smith, Canada, August 20, 1945. *(Image: The National WWII Museum, 2021.019.464.)*

By July 1945, less than seven years after the discovery of nuclear fission, this new source of energy had been **applied** to make three atomic bombs. Two of those bombs were made of an element discovered in the project—plutonium. Along the way, many useful discoveries, including the use of nuclear reactors as electrical power plants, were made and also led to an understanding of how nuclear radiation could lead to death and disease. Many of the scientists who worked on the Manhattan Project later said they had regrets about what they had produced.

Along with atomic energy and atomic weapons, another enduring legacy of the Manhattan Project is what has come to be called Big Science, a term for research projects so large that they can only be managed and supported by the government. The three main scientific sites of the Manhattan Project (Oak Ridge, Tennessee; Hanford, Washington; and Los Alamos, New Mexico) are still sites of National Laboratories. Other examples of Big Science are the Human Genome Project and the National Aeronautics and Space Administration (NASA). Scientists and engineers at these sites and at universities and private labs across the country, all work to develop knowledge that can inform and enrich our understanding of the world.

NAME: **DATE:**



Aerial view of the Hanford Site of the Manhattan Project, where reactors produced uranium, August 15, 1945.
(Image: The National WWII Museum, 2012.019.567.)

1. What type of innovation—Adopt, Adapt, or Apply—was the development of nuclear power from the discovery of nuclear fission? Explain your thinking.

2. Do you think that government investment in Big Science research projects is a good idea? Explain your thinking.

3. Do you know of any other problems in history that have been solved by Big Science?

4. What is a big problem in the world today that might be solved with a Big Science approach? Describe the problem and how Big Science might be organized to solve it.

ACTIVITY

BUILD A TABLE

INTRODUCTION

The 1800s were an era in which human understanding of science advanced rapidly. One of the fastest developing fields of science at that time was chemistry. By 1863, chemists had identified 56 elements. An element was considered a fundamental substance in chemistry. Some chemists had noticed that there was a pattern to the elements if they were arranged by their mass. However, Dmitri Mendeleev, a Russian chemist, was the first to arrange elements into groups and to organize them in a table.

With his table, Mendeleev was even able to predict the existence of several elements that had not yet been discovered. Mendeleev's accomplishment was very impressive, given how little the scientists of his time knew about atomic structure. For example, the existence of electrons, neutrons, and protons—all packed into the atoms—was unknown.

In this activity, you will organize elements, just like Mendeleev did.

In the cards your teacher will give you, you will have all the information Mendeleev knew about the chemical elements.

Use these cards and the information in them to make your own table of elements. You will do this as a group. Your group must have come to consensus on the table's organization, and each member of your group must be able to explain why that structure was chosen and what data were used to make your choice.

Using the symbols on your cards, draw a diagram of how you organized the elements.

Se
Selenium
Gray or red solid
Atomic Mass 79

Br
Bromine
Very reactive reddish liquid
Atomic Mass 80

Rb
Rubidium
Reactive, soft gray metal
Atomic Mass 85

Sr
Strontium
Soft silvery metal
Atomic Mass 88

In
Indium
Soft silvery metal
Atomic Mass 115

Sn
Tin
Silvery-white metal
Atomic Mass 119

Sb
Antimony
Blue-white metallois, semiconductor
Atomic Mass 122

Te **Tellurium** Silver-white metalloid, semiconductor Atomic Mass 128	**I** **Iodine** Reactive, purple solid Atomic Mass 127	**B** **Boron** Gray metalloid, semiconductor Atomic Mass 11	**C** **Carbon** Black solid (graphite) or transparent (diamond) Atomic Mass 12
N **Nitrogen** Odorless gas, unreactive Atomic Mass 14	**H** **Hydrogen** Flammable odorless gas Atomic Mass 1	**Li** **Lithium** Soft metal, reactive Atomic Mass 7	**Be** **Beryllium** Grayish metal Atomic Mass 9
O **Oxygen** Flammable, reactive odorless gas Atomic Mass 16	**F** **Flourine** Very reactive yellowish gas Atomic Mass 14	**Na** **Sodium** Soft, highly reactive metal Atomic Mass 23	**Mg** **Magnesium** Flammable gray metal Atomic Mass 24
Al **Aluminum** Silvery metal Atomic Mass 27	**Si** **Silicon** Gray metalloid semiconductor Atomic Mass 28	**P** **Phosphorus** Spontaneously combustible solid of variable color Atomic Mass 31	**S** **Sulfur** Solid yellow powder Atomic Mass 32
Cl **Chlorine** Extremely reactive greenish gas Atomic Mass 35	**K** **Potassium** Reactive soft metal Atomic Mass 39	**Ca** **Calcium** Flammable silvery metal Atomic Mass 40	**As** **Arsenic** Gray metalloid Atomic Mass 74

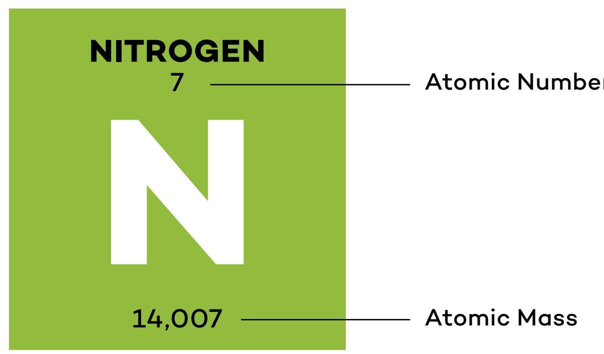
ACTIVITY
BUILD AN ATOM

INTRODUCTION

Use a periodic table to follow along with this explanation. You will need the table for the activity later in this lesson.

Each element is represented by one or two letters as an abbreviation for its name. This abbreviation is called the element's symbol. In the example to the right, the full name of the element is also included, but in many tables only the symbol is used. The symbol is often, but not always, similar to the full name. For example, the symbol for carbon is C. However, sometimes the table abbreviates the Latin names for the elements; thus, the symbol for lead is Pb and the symbol for copper is Cu.

The number above the symbol is the Atomic Number of the element. The Atomic Number represents the number of protons in the element's nucleus. Each element has a unique number of protons—if you change the number of protons, you change the element. The Atomic Number also represents the default number of electrons in the element. That means the element has no charge because the number of negative charges (electrons) is the same as the number of positive charges (protons). Those electrons orbit the nucleus. If an atom of an element has lost or gained an electron, it will carry a charge and is referred to as an ion. In their normal state, elements are not ions.



The nucleus can also hold another kind of particle—neutrons. Neutrons have no charge, but like protons they do have mass. Electrons have a negative charge and are so small that their mass is insignificant. To find the number of protons in the nucleus, you will subtract the Atomic Number from the Atomic Mass. The Atomic Mass is the number under the element's symbol. Atomic mass is rarely a whole number because it is an average of different forms of the element. Elements can have different numbers of neutrons. Round the number to the closest whole number to get the default number of protons in an element.

For example, Carbon (C) has an Atomic Number of 6 and an Atomic Mass of about 12. This means it has by default, 6 protons, 6 electrons, and 6 neutrons.

Here is another example: Aluminum (Al) has an Atomic Number of 13 and an Atomic Mass of about 27. So, it has 13 protons, 13 electrons, and 14 neutrons normally.

NAME: **DATE:**

Directions: Now, you are going to make your own atoms. Your teacher will give you three small containers and two kinds of beans.

1. Using your three containers and two beans, make models of the following elements: hydrogen, oxygen, and carbon. With masking tape and pen, label the three containers. Complete the table below to keep track of the data on your models of elements.

ELEMENT	PROTON	NEUTRON
Hydrogen		
Carbon		
Oxygen		

2. Now, using your periodic table, take the unknown elements your teacher gives you and identify them using their Atomic Number and Atomic Mass in the last rows of the table above.

ACTIVITY

BUILD AN ISOTOPE

INTRODUCTION

Isotopes are forms of elements with different numbers of neutrons. Scientists can use isotopes for many purposes, including to find out how old a bone is or how cold it was when a glacier was formed. An isotope is represented by the Atomic Symbol followed by the number of neutrons in the isotope. For example, U235 is the form of uranium scientists were trying to isolate in the Manhattan Project.

Your teacher will give you three containers representing models of three elements—hydrogen, carbon, and oxygen.

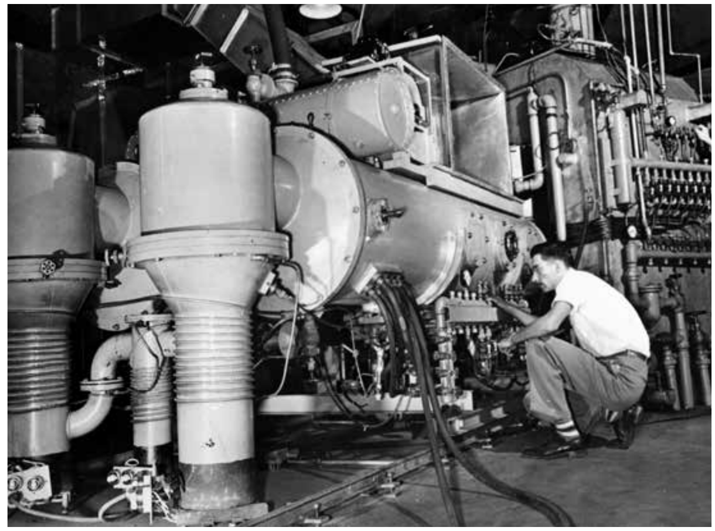
You are going to modify these models to make isotopes of each element. To make an isotope, you will change the number of neutrons in the model. Make the most common isotope of each element: for hydrogen, that is H2; for carbon, that is C14; and for oxygen, that is O16.

In the Manhattan Project, scientists were trying to isolate enough of the specific isotope of uranium they needed to construct what would be the first atomic bomb. The most common isotope of uranium is U238. The isotope needed in the Manhattan Project was U235. U235 is only 0.72 percent of all uranium.

At first, Manhattan Project scientists tried to get enough U235 by separating atoms by the difference in their mass. That, as you can imagine, is very hard, and some very special kinds of centrifuges had to be used. In the end, scientists made only enough U235 for one bomb.

Along the way, Manhattan Project scientists discovered that when U238 is hit by a fast neutron, it becomes a different element—plutonium. It was easier to make plutonium than to get U235, and it takes less plutonium than uranium to make a bomb. By the summer of 1945, Manhattan Project planners had made a large reactor that produced enough plutonium for the cores of three bombs. One of these plutonium bombs was used for testing in what would be called the Trinity Test. Another was used in the war against Japan. The third was used for research.

Your teacher will show you models of uranium and plutonium atoms.



Technicians working on a cyclotron built to create radioactive phosphorus, in St Louis, Missouri, in 1945.
(Image: The National WWII Museum, 2012.019.501.)

NAME: **DATE:**

1. **Just by looking, can you tell the difference between model C and O atoms? Does one model look like it has more beans (protons and neutrons) than the other? Do you think the models have different weights?**

2. **What about the difference between O16 and O18? Can you tell these models apart?**

3. **Your teacher will give you models of U238 and U235, and of plutonium.**

   Can you tell the difference between the model isotopes by looking at them?

   What about between plutonium and uranium?

4. **Is there another way you could find the difference between these isotopes? Without opening the models and counting? Brainstorm an idea and describe your method in the space below:**

LESSON PLANS, READINGS & ACTIVITIES

LIFE SCIENCE: BODY SYSTEMS

GRADE LEVEL: 6-8 | TIME REQUIREMENT: 4 HOURS

LIFE SCIENCE: BODY SYSTEMS

2 READINGS | 2 ACTIVITIES

INTRODUCTION

It can be challenging finding ways to teach the function of cells and body systems using a question- or phenomenon-driven approach. The resources in this section provide ways to teach about different cell types and body systems by starting with a story about WWII innovation.

There was a major effort in World War I to fight infections in the military of both sides and to stop the spread of disease. However, the basic science of medicine was not developed enough to make much headway. After World War I and the 1918 Flu Pandemic, scientists learned a great deal about the identity of the microbes and viruses that cause disease. They also learned much more about blood and how to treat trauma with blood products. Armed with more knowledge about human bodies, diseases, and bacteria, there were more possibilities to **apply** that knowledge and find treatments in World War II.

OBJECTIVE

These resources can be used individually or in tandem. Fungus Among Us and Antibiotic Targets can be used together to introduce or review cells, their organelles, and their specializations. Plasma for Trauma and Blood in a Bag can be used to introduce or review organs and organ systems. Together these resources provide experiences to understand body systems, and the research and problem solving of biologists studying body systems.

STANDARDS

NGSS DCI LS1.A
Structure and Function

NGSS DCI ETS1
Engineering Design

NGSS DCI ETS2
Links Among Engineering, Technology, Science, and Society

NGSS SEP
Developing and Using Models

NGSS SEP
Constructing Explanations and Designing Solutions

NGSS CCC
Cause and Effect

NGSS CCC
Systems and System Models

PERFORMANCE EXPECTATIONS

MS-LS1-1
Conduct an investigation to provide evidence that living things are made of cells, either one cell or many different numbers and types of cells.

MS-LS1-2
Develop and use a model to describe the function of a cell as a whole and ways the parts of cells contribute to the function.

MS-LS1-3
Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

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

READINGS (2)

1. FUNGUS AMONG US

Description
A reading for students on the history of penicillin, the fungal product that became the first antibiotic. It introduces the challenge and basic facts.

2. PLASMA FOR TRAUMA

Description
A reading describing the story of the development of blood plasma as a life-saving, innovative treatment. The reading also shows the role of Charles Drew in that development and asks students to connect the development of basic research to its application as a treatment.

ACTIVITIES (2)

1. ANTIBIOTIC TARGETS

Description
An activity that can be used with or without Fungus Among Us. This activity introduces different types of cells that can cause diseases, and their characteristics, asking students to identify antibiotic targets that could be used to treat diseases.

Supplies
The handout and any additional resources you might want students to use in their research.

Instructions
Have the students look at the table of types of organisms that cause diseases. Assign, or have them pick, one to research and brainstorm. You may want to have students work in groups to pick a target treatment to brainstorm. Use Kagan strategies or other cooperative group structures to support their productive talk. By providing other resources like a textbook you can give them practice at reading to find information and summarization.

2. BLOOD IN A BAG

Description
An activity that has students create and then identify the components of a model of blood. Blood is an organ, though most people don't think of it that way. This activity encourages consideration of the definition of an organ or an organ system.

Supplies (per group)
1 Quart-sized Ziploc bag
2 Cups vegetable oil
20 Skittles
10 Mentos
10 Tic Tacs
1 Tsp candy sprinkles

Instructions
You can use other similarly-sized candies to replace these if the ones listed are not available.

Students will place the oil and the candies in the bag, and then, using the table, determine what each candy is supposed to represent in the model. Because it asks students to identify the parts of the model, it is using a higher domain of knowledge.

ADDITIONAL RESOURCES

To learn more about the development of antibiotics, try these books:

+ *The Mold in Dr Florey's Coat* by Eric Lax, Henry Holt, 2005.
+ *The Demon Under the Microscope* by Thomas Hager, Three Rivers Press, 2006.

READING
FUNGUS AMONG US

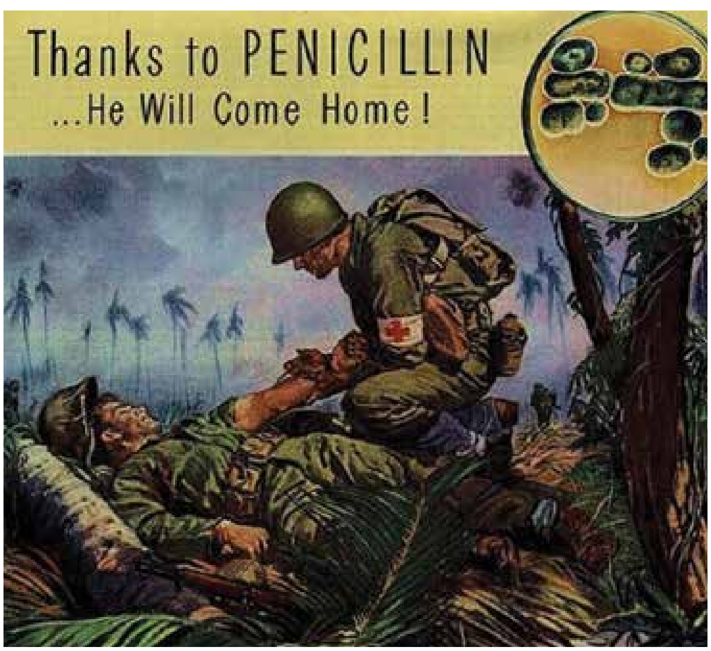
When most people think of fungi (plural of fungus), they often think of things like mold or mildew. However, fungi are also needed for things like getting bread to rise. Fungi are in beer, wine, and many cheeses. Fungi also have saved millions of lives over the last century.

The very first drugs to treat bacterial infections were sulfa drugs. In the years after World War II, many people were looking for ways to treat infections. During World War II, many soldiers died because of infections from what should have been treatable wounds. Infections can also cause deaths by diseases like pneumonia or cholera. German scientists had been experimenting with coal tar, a chemical from fossil fuel, to make synthetic dyes to replace ones that had previously come from plants and insects. These scientists also learned that some of these dyes worked well to make bacteria visible under a microscope by attaching molecules in their cell walls. This discovery inspired German researchers to begin looking for dyes that would attach to bacteria and kill them—they called the idea chemotherapy. By the 1930s, German chemical companies had developed drugs to treat diseases including malaria. In 1933, they discovered a sulfa drug that treated common infections, and by 1936, sulfa was being mass produced.

When World War II began, sulfa drugs were the only antibiotics available. Some scientists in England, led by Howard Florey at Oxford University, were trying to develop a fungus into an antibiotic. Florey knew that in 1928 Alexander Fleming had discovered that the fungus Penicillium killed bacteria. Florey's lab was growing Penicillium and pulling chemicals out of it that they believed could be used as an antibiotic. They first tested these chemicals to treat the infections in mice. The results were so successful that Florey knew he was on the right track.

However, Florey's work was happening while the Battle of Britain was raging in 1940. The cities, factories, and ports of Great Britain were being bombed. Resources were tight too. Florey communicated with the government of the United States and received permission to travel there and work with a US Department of Agriculture lab to develop an antibiotic. To make a long story short—a story involving moldy cantaloupe, giant incubation tanks, and lots of smelly fermentation—Florey's team developed penicillin into a usable drug in the spring of 1944. That was just in time for the D-Day invasion and also before many of the final battles of the Pacific.

A hundred years ago there were no antibiotics in use, and some scientists today say there might be too many. In the United States, antibiotics are commonly added to products like animal feed to prevent illness and promote growth. Antibiotics work against bacteria, not viruses, but often antibiotics are prescribed "just in case" a patient might have an infection. Since bacteria evolve quickly, there are many bacterial strains that are now immune to common antibiotics. Another problem is that pharmaceutical companies who make medicines and drugs aren't developing new antibiotics to replace the older ones that don't work well enough anymore because of antibiotic resistance. Drug development costs lots of money, and the profits from antibiotics are relatively small. Less than a century after the discovery of the first antibiotics, we are suffering a new bacterial challenge.



Detail from a WWII advertisement in *Life Magazine*.
(Image: The Education Collection of The National WWII Museum.)

NAME: **DATE:**

Entrance to the military hospital in New Caledonia.
(Image: The National WWII Museum, 2010.087.113.)

1. When was the last time that you took an antibiotic?

2. When was the last time you had a viral disease like the flu or a cold?

3. Dr. Florey took what he learned (that a fungus kills bacteria) and used it to make something useful (a drug to treat infections). Does this follow the pattern of Adoption, Adaptation, or Application? Why does this matter?

4. Since 1940, people have learned a lot about infections and about the viruses and bacteria that cause them. Think of any modern day disease caused by bacteria or viruses. What is something scientists have learned since World War II that you think might be able to be applied as a new way to prevent or cure these diseases?

READING

PLASMA FOR TRAUMA

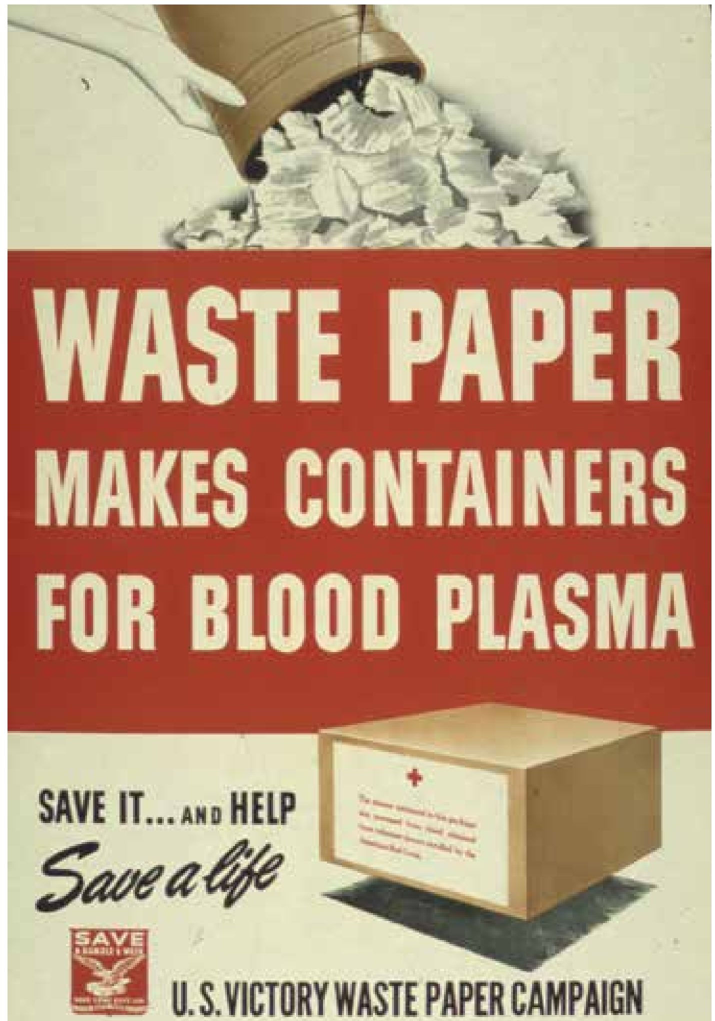
Charles Drew was studying to be a medical doctor and researcher at Columbia University, one of the best teaching hospitals in the world. With his advisor, John Scudder, Drew studied how to diagnose and treat shock. Shock, a result of trauma due to wounds or severe disease, affects the circulatory system. Drew was the first African American scientist Scudder had agreed to mentor, and his achievements impressed his advisor.

In the late 1930s, when Drew was doing his research, it was possible to preserve blood and set up blood banks. However, the process depended upon the region in which a blood bank was set up. Because of this, the quality of blood to treat patients often was different from place to place, sometimes even between different hospitals in the same city. Drew decided to develop a system to make sure that blood was collected and stored in the best way possible. He developed screenings for donors—the best ways to draw and store blood—and with his advisor, developed a new blood bank at their hospital.

The entry of the United States into World War II may have surprised some, but it did not surprise everyone. When the Germans invaded Poland in 1939, the National Research Council began an investigation into our country's ability to provide blood for injured soldiers. During the Battle of Britain the following year, the United States began a program called Blood for Britain. The plan to collect, store, and then send blood for transfusions was written by Drew and Scudder.

After writing the plan, Drew went to Howard University where he became a professor. Because he was African American, Howard was the only university that would hire him in the United States. Drew continued his research on treatments using blood. His research included separating plasma from blood and using it to treat shock and that finding had led him to develop a procedure to dry plasma.

Dried plasma could be stored without refrigeration and could be transported more easily than blood. Because of his success in leading the Blood for Britain program, Drew was recruited to lead a similar effort to mass produce dried plasma for the Red Cross in New York. Drew was again successful in setting up a program that saved thousands of lives from death after trauma. Blood plasma kits became widespread in Allied medical centers and field hospitals in Europe, Africa, and Asia.



A US government poster encouraging recycling.
(Image: The Education Collection of The National WWII Museum.)

Wounded Marine treated by medics on Guam.
(Image: The National WWII Museum, 2010.130.080.)

NAME: **DATE:**

One tragic part of history is that segregation affected all parts of life in the United States during World War II, including the blood program. In spite of its complete irrelevance, race was a factor in who received what blood and what plasma. Supplies were segregated just like bathrooms and dining rooms. In his acceptance speech in 1944 for a medical award recognizing his efforts, Drew said, "It is fundamentally wrong for any great nation to willfully discriminate against such a large group of its people. . . . One can say quite truthfully that on the battlefields nobody is very interested in where the plasma comes from when they are hurt. . . . It is unfortunate that such a worthwhile and scientific bit of work should have been hampered by such stupidity."

Once Drew had the system for plasma production established, he returned to Howard where his wife and young daughter were living. He said his most important ambition was to set up a great surgical education program at Howard. Sadly, Drew died young, at age 45, in 1950, of trauma from a car accident.

Do you know your blood type?

Do you know the blood types of your parents or siblings?

Do you know someone who has been treated with a blood transfusion or blood plasma?

Drew took his knowledge of medicine (how blood is made, and how it is involved in shock) and used it to develop something very necessary for World War II (blood banks, and kits to administer powdered plasma). **Does this follow the pattern of Adoption, Adaptation, or Application? Why is this important?**

People have learned a lot about blood since World War II: what's in it; what diseases are involved in it; and what can cause these diseases. **What have scientists learned since World War II that you think might be able to be applied as a way to prevent or cure one of these diseases of the blood or other parts of the body?**

A medic administers blood plasma to a wounded soldier.
(Image: The National WWII Museum, 2000.325.010.)

ACTIVITY

ANTIBIOTIC TARGETS

INTRODUCTION

Why do antibiotics affect bacteria and not human cells?

Why do antibiotics affect some bacteria and not others?

Why don't antibiotics work on viruses?

Why don't antibiotics work on diseases like malaria?

The answer to these questions is in the details of cells and how they are made. Examine this table describing single-celled organisms and their makeup:

CELL (TYPE)	CELL WALL	ORGANELLES	NOTES
Plasmodium (eukaryote, protozooan)	None (has protein coat)	Nucleus, mitochondria, ribosomes, microneme	Parasite that causes malaria
Gram positive bacteria (prokaryote)	Thick peptidoglycan wall	None	Streptococcus, Staphlococcus, (more succeptible to antibiotics)
Gram negative bacteria (prokaryote)	Thin peptidoglycan inside a membrane	None	E. coli, Pseudomonas (less succeptible to antibiotics)
Yeast (eukaryote, fungus)	Chitin	Nucleus, mitochondria, ribosomes	Candida (can cause infections)
Algae (eukaryote, plants)	Cellulose	Nucleus, mitochondria, ribosomes, chloroplasts	
Viruses (not really cells)	Protein Coat		Rhinovirus and Coronavirus (DNA and proteins inside)

NAME: **DATE:**

Directions: Use the table to answer the questions below. Before answering consider the following: Do you have enough information to fully answer the questions? What else would be helpful to know?

1. Why do antibiotics affect bacteria and not human cells? Why do they affect some bacteria and not others?

2.Why don't antibiotics work on viruses?

3. Why don't antibiotics work on diseases like malaria?

4. In a group, pick one of the disease-causing organisms in the table and propose a way to fight it. Use the organism's characteristics and its differences from the others in the table to guide your brainstorming.

ACTIVITY
BLOOD IN A BAG

INTRODUCTION

Even though it might not seem like it, our blood is an organ.

WHAT IS BLOOD MADE OF?

First, there's plasma, which is most of human blood by volume. Plasma is water with proteins, clotting factors, and antibodies suspended in it, and with ions dissolved in it.

Then there are blood cells, both white and red. Red blood cells bind oxygen and carry it through the body. Red blood cells have markers on their surface which determine which type of blood you have. White blood cells are part of the human immune system. There are many fewer white than red blood cells. Finally, there is another kind of cell called platelets, which help in healing and blood clotting. There are even fewer platelets than there are white blood cells.

An organ is defined as a bunch of different cells that work together for a function. By that definition blood is an organ.

When people are injured badly, they can go into shock. Shock is a bodily response to injury that helps conserve blood. One of the best ways to treat shock is to give the injured person a transfusion of blood.

However, blood combines lots of immune cells and can cause problems when one person receives another person's blood. A transfusion is like a transplant, and so it can only work if the blood types of the two people match. Blood also needs to be preserved at a low temperature (refrigerated) until it is used and also needs to be in a liquid form, which makes it difficult to transport.

In World War II, doctors learned how to use just blood plasma to treat shock. Because plasma doesn't have types and can be dried, it is easier to use in the field. Eventually the patient would need a blood transfusion, but until then plasma would help the injured person stay alive.

Your teacher will give your group the following:

- 1 Quart-sized Ziploc bag
- 2 Cups vegetable oil
- 20 Skittles
- 10 Mentos
- 10 Tic Tacs
- 1 Tsp candy sprinkles

NAME: **DATE:**

Directions: Put the ingredients together to make a model of blood. Use the proportions above in the description of blood to decide which candies to use for each role. Make sure the proportion and size of the blood components match between your model and the description of blood. Fill in the table below to show what each component in the model represents:

COMPONENT	REPRESENTED BY	FUNCTION
Plasma		
Red Blood Cells		
White Blood Cells		
Platelets		
Clotting Factor		
Antibodies		
Ions		

1. Which model components would an injured person receive in blood plasma?

2. Why doesn't plasma have blood types?

3. How might plasma prevent shock?

LESSON PLANS, READINGS & ACTIVITIES

EARTH AND SPACE SCIENCE: PLATE TECTONICS

GRADE LEVEL: 6-8 | TIME REQUIREMENT: 2 HOURS

EARTH AND SPACE SCIENCE: PLATE TECTONICS

1 READING | 1 ACTIVITY

INTRODUCTION

The vast Pacific Ocean and the islands scattered across it were almost as tough an enemy as the Japanese forces that controlled much of that territory during World War II. Those islands were formed by forces not fully understood by science until decades later. The "Ring of Fire" is a term used to describe a huge circle of volcanic activity that forms a ring around the Pacific, from New Zealand in the south to the Aleutians in the north. In the region where most of the US battles in the Pacific during World War II took place, there are many active volcanoes, and there were dozens of earthquakes during that time. The islands varied greatly in their physical geography—in a manner that was only understandable once the theory of plate tectonics was formalized in the late 1960s.

The many volcanoes of the western Pacific are formed through a process known as subduction where one continental plate moves under another and sinks into the earth's mantle; magma from the subducted crust then bubbles up to the surface.

Most of the islands in this Ring of Fire formed when undersea volcanoes emerged from the ocean. Over time, coral reefs formed around them, and the volcanoes eroded to form rich soils. The youngest islands have high elevation and active volcanoes. The oldest have only a ring of reefs remaining. These oldest islands are referred to as atolls.

OBJECTIVE

Use these two resources to show the pattern of volcanoes and earthquakes in the South Pacific and then learn and make diagrams about plate tectonics. These are reversed in order from most of our sets—we suggest you use the activity first and then the reading. You can supplement with physical maps from these areas, and even use maps of volcanoes and at other plate boundaries as an extension.

STANDARDS

NGSS DCI ESS2.B
Plate Tectonics and Large-Scale System Interactions

NGSS DCI ESS3.B
Natural Hazards

NGSS SEP
Analyzing and Interpreting Data

NGSS SEP
Engaging in Argument from Evidence

NGSS CCC
Patterns

NGSS CCC
Stability and Change

PERFORMANCE EXPECTATIONS

MS-ESS2-3
Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.

MS-ESS3-2
Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

READING (1)

1. GEOLOGY AND HISTORY

Description
This resource is a reading for students to understand how active geologic features like volcanoes and earthquakes shaped some of the events in World War II. It has descriptions of the geologic forces acting in a region, and asks students to make a diagram based on the descriptions.

Supplies
Paper and colored pencils
Physical maps of the Philippines and Italy (optional)

Instructions
Have the students read the handout, then discuss it in small groups or the whole class. Have them follow the instructions to make a geologic diagram. The optional maps may help them to understand the plate tectonic forces in the regions discussed.

ACTIVITY (1)

1. MAPPING DANGER

Description
This is an activity in which students map volcanoes and earthquakes using a table of data. Students will explore and explain the pattern as seen in the data that they map.

Supplies
Pencils or pens in contrasting colors
Map of the South Pacific (that includes latitude and longitude grids)

Instructions
Show students how to use the latitudes and longitudes to locate the spots on the map. Have them mark earthquakes in one color and volcanoes in a contrasting color. To lighten the work load you could divide the data up so that some groups only do some lines of the data, and then put them together to make the bigger picture. With small modifications you could use Google Maps to map the data. In this case you need to change all S latitudes to a negative value.

READING

GEOLOGY AND HISTORY

On September 1, 1923, at 11:58 a.m., an earthquake with a magnitude of 7.9 occurred in a bay just south of Tokyo, Japan. Tokyo and Yokohama, a relatively young port city with a strong international influence, were the closest large population centers. After the earthquake struck, a tsunami with an 11-meter-high crest hit Yokohama and surrounding areas. Fires spread throughout Tokyo and Yokohama, and with water mains broken by the quake, there was no way to fight them. The earthquake lifted the shoreline up two meters higher compared to sea level and made a crack in the earth that was 4.5 meters wide.

Even though the earthquake lasted only 14 seconds, there was a huge amount of energy released: 570,000 homes were destroyed and more than 140,000 people were killed. With telegraph technology connected to radio, news from Japan to the countries of the West moved rapidly. The United States and other countries mobilized support for victims of the earthquake within 24 hours. Japan had annexed Korea more than a decade earlier, and in the months before, what came to be called the Great Kanto Earthquake, a group working for the liberation of Korea had been conducting terrorist attacks. Rumors spread in the aftermath of the quake that Koreans were looting and starting fires. Violent attacks on Koreans and anyone thought to be Korean followed. The Japanese government tried to protect Koreans, but also covered up any attacks that occurred. This event, and Japan's dependence upon the West for support in recovery, fueled growing nationalism. This influenced Japanese imperialism and expansionism in the decades before World War II.

Vesuvius erupting in the background as a truck passes. Naples, Italy, March 1944. *(Image: The National WWII Museum, 2007.243.080.)*

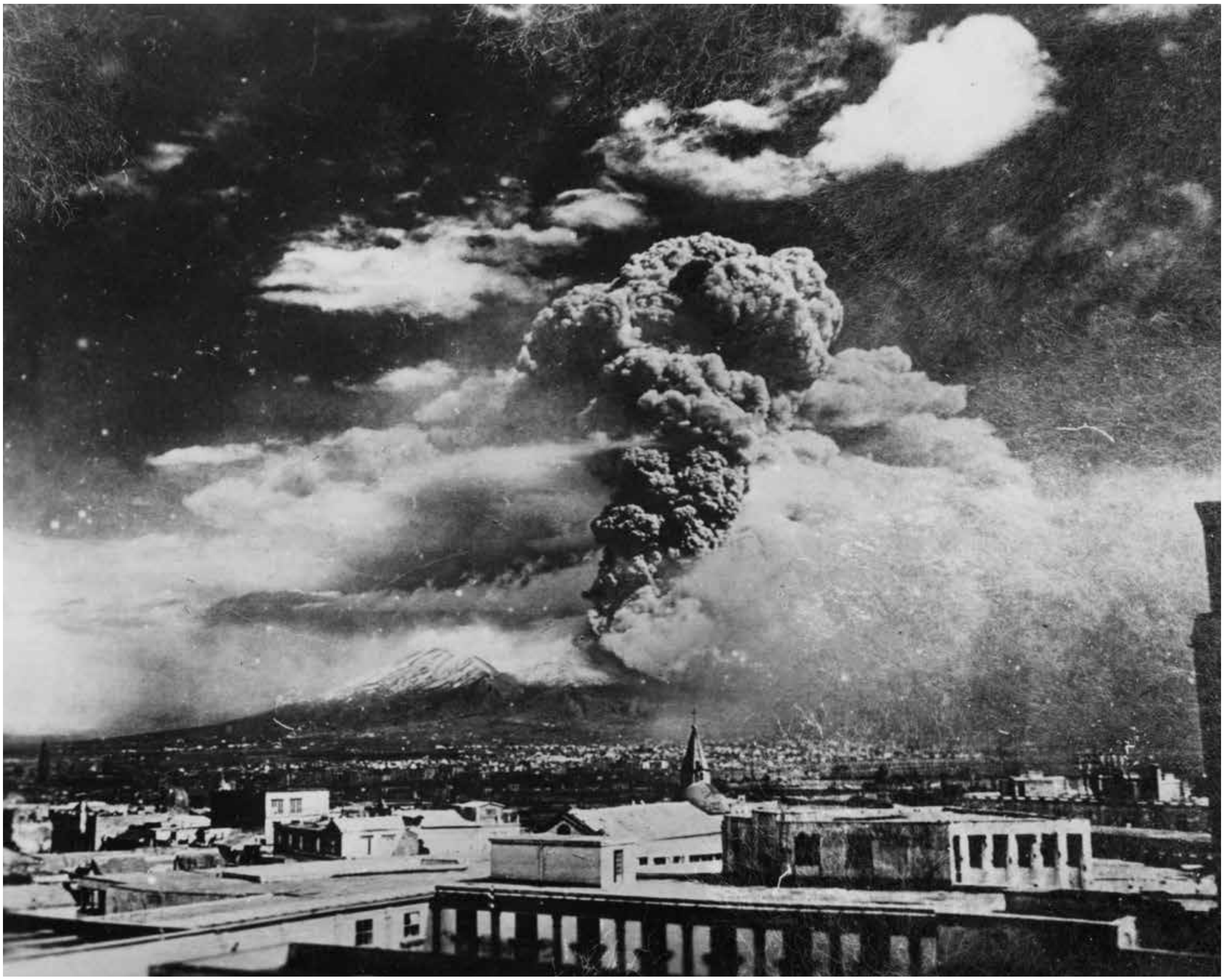
Earthquakes and volcanoes were, and still are, common in the Pacific. These geological factors shaped the Pacific islands, and when US troops fought there in World War II, these conditions shaped logistics and even the path of the war. There is a diamond-shaped continental plate—the Philippine plate—pinned between the much larger Pacific and Eurasian plates. The Pacific plate is moving slowly but relentlessly west, pushing the Philippine plate ahead of it. Where the plates meet, the Pacific sinks below both the Philippine and Eurasian plates, and the Philippine plate dives under the Eurasian plate. This pattern of plate convergence is called subduction and leads to earthquakes and volcanoes. Where the plates come together in the ocean, they form volcanoes, which can emerge from the ocean, slowly over time, creating islands. From New Guinea to the Marianas and Iwo Jima (on the east side between the Philippine and Pacific plates), from the Philippines to Okinawa and north (on the west side, between the Eurasian and Philippine plates), and to Japan (split by the Eurasian and Pacific plates), all of these islands were formed from volcanic activity. Some of those islands are very old, their volcanoes mostly dead. Coral reefs surround these islands (like Tinian or the Bikini atoll). Others are younger and form very high tropical peaks (like in the Philippines).

Iwo Jima, which in its original Japanese name means "sulfur island," was formed by slightly different volcanic activity that led to its peculiar geography. There is abundant groundwater on Iwo Jima, all of it very hot and enriched with minerals. The frequent volcanic activity there is mostly steam created by the interaction of groundwater and magma (molten rock).

The geological theory that explained volcanoes and earthquake patterns, called plate tectonics, wasn't solidified until the late 1960s. US troops went into this zone, where there were more than two dozen large earthquakes (> 6.0) between 1940 and 1946. Imagine the uncertainty this caused without any way to predict what was going on or without or any understanding of what each stop on the island-hopping path to Tokyo would bring.

Put together your knowledge of plate tectonics and the information in the passage you just read above. Draw a cross-section of the crust showing how the Pacific Plate, the Philippines Plate, and the Eurasian Plate interact. Indicate where volcanoes might form and earthquakes might occur.

NAME: **DATE:**



A huge plume of volcanic ash from Vesuvius in the background of an image taken of Naples, Italy, March 1944.
(Image: The National WWII Museum, 2009.046.219.)

Far, far away, in Europe, on March 17, 1944, Mount Vesuvius erupted. Mount Vesuvias is the volcano that destroyed Pompeii and other Roman cities in 79 CE. The volcano, which is in southern Italy near the western coast, is a very different kind of volcano than the ones you mapped in the Pacific.

Italy had surrendered to the Allies, but German forces still held the north of the country. A US air base was near Vesuvius, and the planes on the airstrip there were seriously damaged by the eruption.

Do some research and try to figure out why there is a volcano in Italy. Are there others in Italy? Are there others in the Mediterranean region? Can you use plate tectonics to explain their pattern?

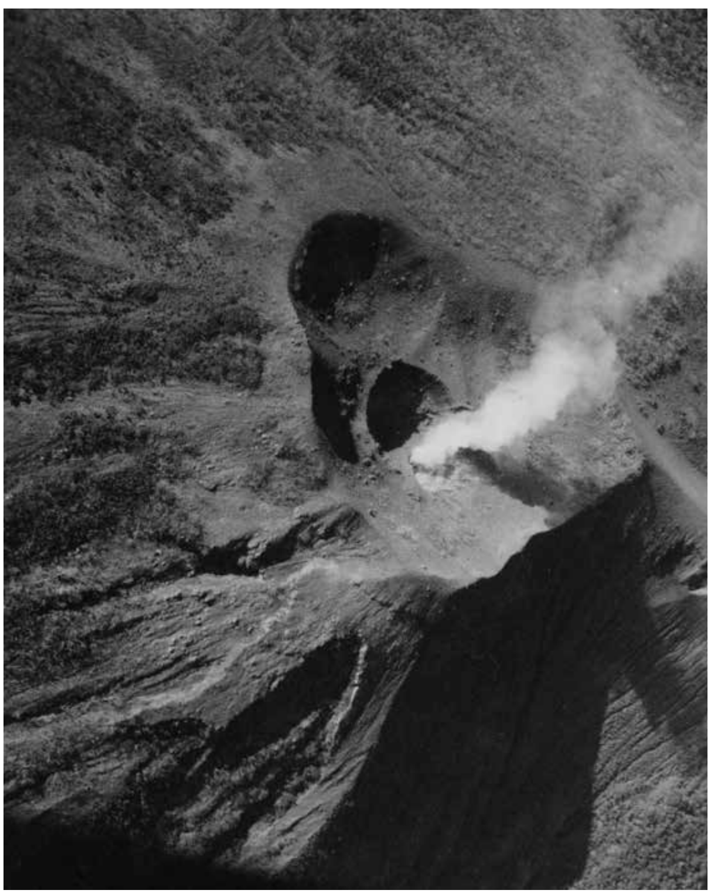
ACTIVITY

MAPPING DANGERS

INTRODUCTION

In World War II, our troops moved across the Pacific Ocean, exploring areas and islands that were very exotic. This area was known to be home to many volcanoes and frequent earthquakes. These natural hazards and the manner in which they shaped the landscape were very challenging in many ways to the soldiers and military planners and leaders. In those decades, there was really no understanding of why volcanoes occurred in these places or of what caused earthquakes.

On a map, place dots in one color for each location where there was an earthquake, and a use a different color to show every location where there was a volcano in this region during World War II.



Ash rising from a volcano in New Britain, the South Pacific, in August 1944.
(Image: The National WWII Museum, 2008.354.114.)

1. **What do you notice about the patterns of each type of hazard (earthquake or volcano) and of all the hazards together?**

2. **What could possibly be causing such a huge pattern on the surface of the Earth?**

3. **Imagine that the US commanders in World War II had understood what caused earthquakes and volcanoes. How do you think it would have changed their plans?**

NAME: **DATE:**

SELECT VOLCANOES IN THE PACIFIC THEATER

NAME	LATITUDE	LONGITUDE	LAST ERUPTION
Abu	34 N	131 E	9,000 ya
Adatara	37 N	140 E	1996
Agrigan	18 N	139 E	1990
Akagi	36 N	139 E	1938
Akan	43 N	144 E	1988
Akita Yakeyama	39 N	140 E	1997
Akuseki-Jima	29 N	129 E	?
Alamagan	17 N	145 E	1887
Ambrym	16 S	168 E	2015
Anathan	16 N	145 E	1993
Aso	32 N	131 E	1993
Bam	4 S	144 E	1960
Bamus	5 S	151 E	2006
Bulusan	12 N	124 E	1988
Canalaon	10 N	123 E	2016
Camiguin	9 N	124 E	1953
Dakatua	5 S	150 E	1895
Daisetsu	43 N	142 E	1739
Fuji	35 N	138 E	1708
Hibok-hibok	9 N	124 E	1953
Ioto (Iwo-jima)	24 N	141 E	2012
Iraya	20 N	122 E	1454
Kanlaon	10 N	123 E	2015
Kirishima	31 N	130 E	2011
Kamagatake	35 N	139 E	2015
Kusatsu-Shirane	36 N	138 E	1983
Lamington	9 S	148 E	1956
Loloru	6 S	155 E	1994
Long Island	5 S	147 E	1993
Lopevi	16 S	168 E	2007
Mayon	13 N	123 E	2014
Nikko-Shirane	36 N	139 E	1952
Ragang	7 N	124 E	1915
Suwanose-jima	29 N	129 E	2016
Yake-dake	36 N	137 E	1995

EARTHQUAKES IN THE PACIFIC THEATER

YEAR	LATITUDE	LONGITUDE	MAGNITUDE
1940	41 N	137.2	7.5
1940	4 S	152.8	7.1
1940	8 N	123.4	7
1941	32 N	130.2	7.7
1941	5 S	153.5	7.1
1941	4 S	151.6	7
1941	10 N	123.6	7
1942	12 N	121.2	7.4
1942	8 N	123.4	7.2
1943	8 N	124	7.8
1943	16 N	121	7.2
1943	40 N	143.1	7.2
1943	4 S	143	7.2
1943	35 N	134	7
1943	6 S	154.3	7
1944	32 N	138	8.1
1944	4 S	142	7.1
1944	2 S	152	7.1
1944	43 N	143.5	7
1945	5 S	149.8	7.8
1945	40 N	149.9	7.2
1945	24 N	141	7.2
1945	37 N	143.2	7.2
1945	43 N	147.2	7
1945	3.9 S	149	7

LESSON PLANS, READINGS & ACTIVITIES

EARTH AND SPACE SCIENCE: WATER CYCLE

GRADE LEVEL: 5-8 | TIME REQUIREMENT: 3 HOURS

EARTH AND SPACE SCIENCE: WATER CYCLE

1 READING | 2 ACTIVITIES

INTRODUCTION

Water is so ubiquitous that is easy to forget how important it is. Yet clean water was a very important part of logistics planning in World War II. Prior wars and the growth of urban areas had shown that deadly diseases like cholera can spread when clean water isn't available. Tropical diseases like malaria that are associated with stagnant water had killed millions in previous conflicts.

World War II covered territories from the deserts of North Africa, the arid Mediterranean, the mountains of the Alps, and the forests of Europe. The geography of the campaigns included the brutal ice of Greenland and the drenching rains of the tropical Pacific. In all these areas, troops needed clean water to drink and bathe to avoid disease.

OBJECTIVE

These resources focus on different aspects of the water cycle, framed by the challenge of finding potable water in the Pacific Theater during World War II. Testing water samples and building a solar still, students investigate the water cycle and the physical properties of water.

STANDARDS

NGSS DCI ESS2.C
The Roles of Water in Earth's Surface Processes

NGSS SEP
Developing and Using Models

NGSS SEP
Planning and Carrying Out Investigations

NGSS CCC
Systems and System Models

NGSS CCC
Scale, Proportion, and Quantity

PERFORMANCE EXPECTATIONS

NGSS 5-ESS2-2
Describe and graph the amounts of salt water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.

NGSS MS-ESS2-4
Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.

READING (1)

1. WATER EVERYWHERE

Description
This reading describes the Pacific Theater of World War II, which was dominated by expanses of ocean, drenched jungles, and wide rivers. In spite of all this water, finding clean water to drink and bathe in was a big challenge. You might use a diagram of the water cycle along with this reading. You could also perform a demonstration of the water distribution model. For this demonstration, start with a liter of water in a clear container so that students can watch. Remove the appropriate amounts of water, in sequence, into smaller and smaller containers, as outlined in the student handout. You could also have students make bar graphs of the relative amounts of water to practice their quantitative skills.

ACTIVITIES (2)

1. MEASURING WATER

Description
This is an activity that can be done in combination with Water Everywhere. This activity will require you or your students to collect samples of local water sources, on field trips, at school, or at home.

Supplies
Water Samples
pH paper
Thermometer
Other water quality tests (optional)

Instructions
You will need water samples that your students have collected. If that isn't possible, you could just make your own samples by adding dirt or other material to water or by taking it from a fish tank or other source. Recording temperature data only works if you are collecting water in the field. You will also need pH paper, which you can get inexpensively at a pet store or from a science materials supplier. You could easily add other water quality tests with some simple supplies. For example, pool and aquarium kits allow you to measure ammonium or salinity. Additionally, if you are in the field, you can use tools to measure how far into the water you can see or to record what animals and plants you see in the water.

2. SOLAR STILL

Description
This is an investigation activity that is perfect to follow the previous two. Please note that this activity is best done outside in groups on a warm, clear day. You can modify it to be done inside with heat lamps or an incandescent bulb.

Supplies
1 Small bucket
1 Small plastic cup
2 Cups of water, to which you have added some salt or dirt
Clear plastic (you may be able to use plastic wrap)
A small rock

Instructions
Have the students put the dirty water (or you can use salt water) in the bottom of the bucket. Then place the small cup upright in the middle of the bucket. Cover the bucket with the plastic, placing the weight on it in the middle so that the center of the plastic is lower than the edges. Then place the bucket in a warm spot outside. The water will slowly evaporate as it warms in the bucket, and some of it will condense on the plastic. Because the plastic is lower in the center of the bucket, the condensation will run down toward the center. If it is very warm and sunny outside, this will happen over a couple of hours. If it is cool, it may take longer.

To accelerate the process, you could add a heat lamp and keep it inside. When enough condensation builds up, it will drip into the cup. This is a model of the evaporation-condensation portion of the water cycle. This is also a rudimentary demonstration of a water purification method that was used by American servicemen during World War II.

READING

WATER EVERYWHERE, BUT NOT A DROP TO DRINK

Imagine that you are a pilot or a sailor during World War II, and you are sent to serve in the Pacific Ocean. You travel across the vast Pacific, dotted with islands, small and large. When you finally arrive at your base, by air or by sea, it's on an island, wet with soaking rains, green with lush plant life, and crossed by rivers and streams. But what can you drink? Can you drink the water from the ocean? Can you drink the water from the rivers and streams on the island, which might hold bacteria and protozoa that cause dysentery, cholera, and other illness? What can you drink?

During World War II, there were some water treatment plants that removed living things and contaminants from water so that it could be used by troops. There weren't very many places that had water treatment plants. Americans serving in World War II needed water to cook, to wash clothes and dishes, to drink, and to bathe. They conserved water by not bathing much. Sometimes they used water purification tablets to disinfect water in their canteens, but it was still extremely hard to get enough clean water.

The Earth is a water planet—most of its surface is covered by water, such as lakes, rivers, or oceans. Mountain ranges like the Himalayas and the Alps are covered in ice year-round. Antarctica in the Southern Hemisphere and Greenland and much of the Arctic in the Northern Hemisphere are covered in ice. Water flows through rocks underground on all the continents. But do we have enough water to drink? Let's look closer at all that water. Your teacher will demonstrate with a model.

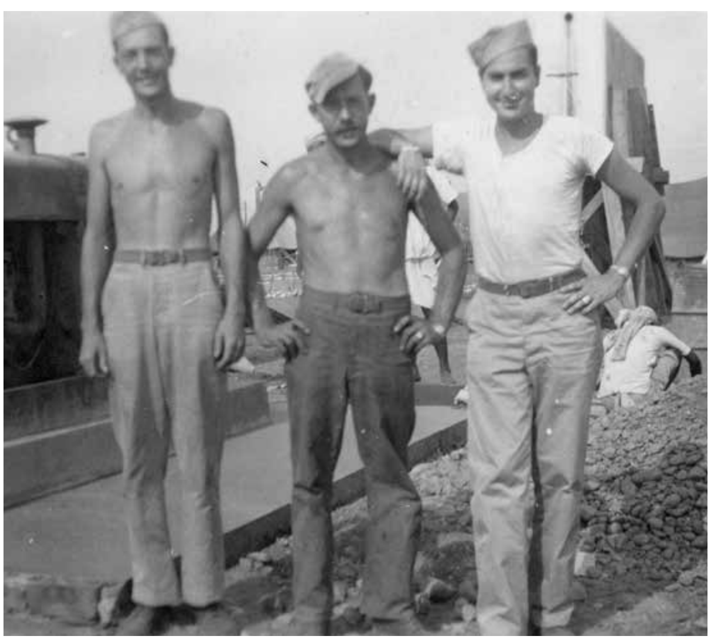
To make it easier to think about, we'll use one L of water to represent all the water on Earth. That's 1000 ml (milliliters) of water.

Ninety-seven percent of the Earth's water is saltwater in the oceans. Of this 1000 ml, how many ml are saltwater? How many ml are fresh?

Of the fresh water on Earth, 69 percent is frozen in glaciers and ice caps; 30 percent is groundwater flowing through rocks underground; and one percent is surface water.

Of our original 1000 ml, many ml are frozen, how many ml are underground, and how many ml are on the surface?

The water on Earth isn't static—it moves. Lakes flow into rivers, and rivers into the oceans. Water on the surface, including the oceans, evaporates into the atmosphere. Some of what evaporates forms clouds and falls back to the surface as snow or rain. When rain falls on land it either runs over the surface and then sinks into groundwater, or it flows into rivers and lakes. This is called the water cycle.



Three United States Army Air Force engineers standing in front of a water distilling pump and generator, probably India. *(Image: The National WWII Museum, 2011.407.015.)*

View of a glacier in Iceland, 1943.
(Image: The National WWII Museum, 2013.606.084.)

NAME: **DATE:**

1. Draw a diagram of the water cycle, showing the changing states of water and the locations of Earth's water:

2. All living creatures including humans need water to survive. How much fresh water is available and accessible to humans? Is that amount of fresh water significantly larger or significantly smaller than the amount of salt water?

3. Using what you know about the water cycle, brainstorm some ways that US troops in World War II could access clean water or to make water safe for use. Outline your best idea in the space below. If you are having trouble imagining that, pretend there is a natural disaster, and you need to get clean water. Brainstorm how you could collect water and clean it for your use.

ACTIVITY
MEASURING WATER

INTRODUCTION

Your class is going to learn about the characteristics of water from different sources in your community. Your teacher will give you specific instructions about how you will collect and test water.

If you can't see through your sample or if it has material still floating in it, leave it to sit undisturbed, and record how long it takes to settle.

TEMPERATURE	SECCHI DEPTH	DISSOLVED SOLIDS	pH

NAME: **DATE:**

1. Do you think the water from either of your samples is safe to drink? How could you know for sure?

2. If you answered no, how could you make it safe to drink?

3. Does water for different uses need to all be treated in the same way? For example, can water in a fishpond be the same as water to drink? Does water to drink have to be the same as water to irrigate crops?

ACTIVITY

SOLAR STILL

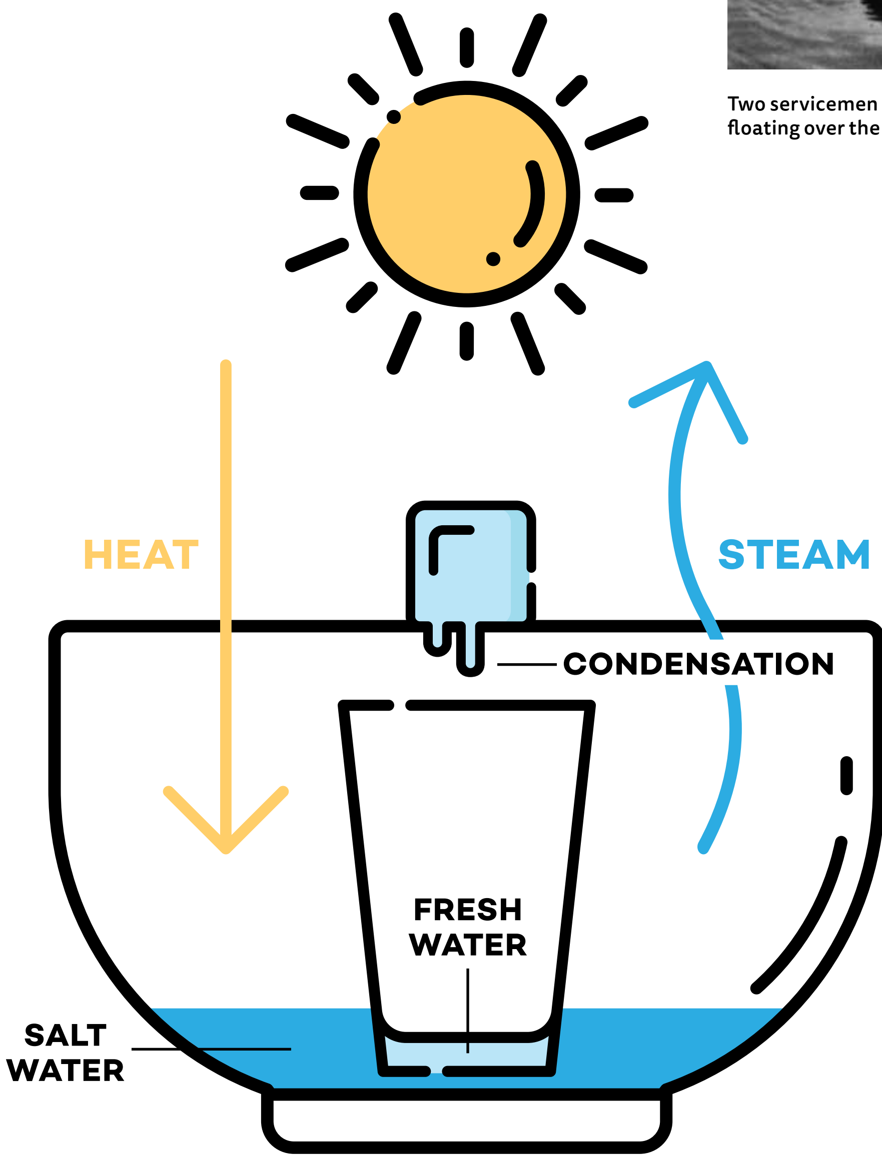
INTRODUCTION

In World War II, planes carried inflatable life rafts, flares, and solar stills. The solar still was used to make drinking water from sea water because crash survivors might be in the raft for a long time before being rescued.

In this activity you are going to making a solar still. It will use evaporation and condensation to remove the salt from sea water.

Your teacher will give you the materials to construct the device.

Two servicemen sitting in a raft on water, with emergency solar stills floating over the side. *(Image: The National WWII Museum, 2012.019.620.)*



NAME: **DATE:**

1. What might be in a sample of water before purification?

2. On the diagram of the solar still, show which parts correspond to the parts of the water cycle.

3. What might be dissolved in the water you collected from your solar still? Or is it pure water?

4. How long do you think it would take for you to collect enough water to survive using your solar still?

5. How could you make the solar still more efficient, collect clean water faster?

LESSON PLANS, READINGS & ACTIVITIES

EARTH AND SPACE SCIENCE: WEATHER

GRADE LEVEL: 5-8 | TIME REQUIREMENT: 2 HOURS

EARTH AND SPACE SCIENCE: WEATHER

1 READING | 1 ACTIVITY

INTRODUCTION

Weather is a core topic of upper elementary and middle school science. It also is a topic that allows you to revisit physical science concepts that underlie weather phenomena, such as the gas laws, solutions, and heat transfer.

Weather was certainly important to the military planners in World War II. For every invasion or large action in World War II, there were detailed weather forecasts made. Every flight crew went through detailed weather forecasts before taking off, and every ship had someone making or receiving forecasts of coming weather.

Weather is also something that students see and experience in their daily lives, which means that they can apply what they learn both immediately and constantly.

OBJECTIVE

The reading asks students to consider why and how we forecast weather. It introduces one of the most important weather forecasts in modern history—the forecast for D-Day in the English Channel and Normandy on June 6, 1944. The reading also asks them to apply skills of weather-map reading. Then students learn about and create simple versions of thermometers, barometers, and hygrometers. Each weather tool works in very unique ways due to the physical properties of materials.

STANDARDS

NGSS DCI PS1.A
Structure and Properties of Matter

NGSS DCI ESS2.D
Weather and Climate

NGSS SEP
Developing and Using Models

NGSS SEP
Constructing Explanations and Designing Solutions

NGSS CCC
Patterns

NGSS CCC
Energy and Matter

PERFORMANCE EXPECTATIONS

5-PS1-1
Develop a model to describe that matter is made of particles too small to be seen.

5-ESS2-1
Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.

MS-PS1-4
Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

MS-ESS2-5
Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

READINGS (1)

1. WHY WEATHER?

Description
This reading asks why weather is important and how it has made an impact on history. As students read ask: Why does weather matter? How can we predict the weather? What data do we need to predict the weather? Have students work in groups and use your preferred Kagan strategies or cooperative learning methods to organize productive student conversation.

ACTIVITIES (1)

1. WEATHER TOOLS

Description
This activity can be used in conjunction with the Why Weather reading as a way to introduce weather data collection. This lesson is a good example of how we can make measuring tools when we know the physical properties of materials. Students need to apply knowledge of what temperature, pressure, and humidity are; making the tools will help them remember.

Supplies
For all 3 tool-making activities, safety goggles or glasses are necessary

<u>Thermometer</u>
1 Clear small plastic bottle (too large and you'll use too much alcohol; a small 8-16 oz water bottle would work)
1 Clear plastic straw
1 Ruler
Rubbing alcohol, colored with food coloring
(can be only 50 percent)
Clay
Dropper

<u>Barometer</u>
1 Empty plastic bottle (an empty 16-20 oz bottle will work)
1 Length of plastic tubing (you can use aquarium tubing)
Water, colored with food coloring
Clay
Ruler

<u>Hygrometer</u>
1 Metal can (can be a bean or coffee can)
Water
Thermometer
Ice

Instructions
<u>Thermometer</u>
Have the students mark the straw in half-centimeter increments with the pen and ruler. Next, they will fill the bottle one-fourth full with alcohol, put the straw in the bottle, and seal the straw in the bottle's mouth with clay. The seal needs to be tight so that air can't get in or out of the bottle. The straw also needs to be straight and in the center of the bottle's mouth. Have the students fill the straw with alcohol so that the level in the straw is just a couple of centimeters above that in the bottle. This step is possible because the air in the bottle is trapped and pushing back against the added liquid in the straw.

Have the students hold the bottle in their hands or put the bottle in a sunny spot to see if the temperature changes. Finally, to calibrate the thermometer, have the students record the marks of the alcohol level at different temperatures.

<u>Barometer</u>
Have the students mark the tubing in half-centimeter increments with the pen and ruler. Then have them fill the bottle halfway up with water and put the tubing in the bottle. Students will need to make sure that the tubing is not pressed against the bottom of the bottle so that it will be able to suck the water up until it is a few centimeters above the level of water in the bottle. Finally they will seal the tube with clay.

Because the air pressure outside won't change quickly, students won't see changes in the barometer quickly. Students can watch how the level changes daily and correlate it with the weather.

<u>Hygrometer</u>
Have students fill the can about halfway up with water and place the thermometer in the can. They should watch the thermometer until it stabilizes (just a couple of minutes) and then observe if there is any condensation on the outside of the can. If not, add a couple of ice cubes to the water and stir it, watching until the temperature stabilizes. Is there any condensation on the outside of the can? Repeat as necessary until condensation is seen. The temperature where condensation occurs is the dew point.

Generally, the humidity will be below 50 percent in a well-regulated indoor environment. If the hygrometer is taken outside into a more humid place, it may produce better results.

READING
WHY WEATHER?

WHY ARE PEOPLE ALWAYS TALKING ABOUT THE WEATHER? DOES IT REALLY MATTER?

The weather forecast for a certain day in 1944 made a big difference and may have saved thousands of lives. That day is called D-Day. The Allies had to consider many variables when they were making plans to invade France and take it back from Germany in spring of 1944.

Because the Allies were landing most of the soldiers by boat, the tide had to be low so that they could see and avoid explosive mines and deadly obstacles. The Allies also planned to use paratroopers, so the moon had to be full so that the airplanes could navigate at night and the paratroopers would be able to see when they got to the ground. There would be only one week in early June where the tide was low and the moon full. If the invasion came much later, the Germans might notice, with spies and airplane reconnaissance, the large numbers of ships and troops that had assembled in southern England. If the invasion did not take place in early June, all could be lost.

In early June, the weather on the English Channel (the narrow strip of water that separates England from France and the rest of Europe) is often very stormy. Captain James Stagg was a British officer in the Royal Air Force. Stagg was in charge of assembling weather forecasts from all the different branches of service involved in the planning of the invasion, and Stagg had the responsibility to tell General Eisenhower, the US commander in charge of the operation, when the weather conditions would be favorable. Eisenhower and his team had initially chosen June 5 for D-Day. Allied troops were to be carried in landing craft from ships offshore to the beach. These landing craft were small, and rough seas and bad weather would have made it very hard for them to reach the shore. Many of them would have sunk if the weather were too stormy.

The Allies had weather stations in Canada, Greenland, and Iceland to collect data to support forecasts of weather. Since weather generally moves from West to East in the Northern Hemisphere, the open Atlantic is a challenge for gathering weather data. In the United States, for example, we can follow weather systems from the western to the eastern states easily. Since the Germans had many stations across Europe but very few in the Atlantic, they had an even harder time predicting weather. Today, satellites give us a huge amount of data that makes weather forecasting much more accurate.

Data from their weather stations told the Allies and their meteorologists that a series of low-pressure systems and fronts, each bringing stormy weather, were lined up across the Atlantic Ocean. One of these was arriving over England on June 3 and 4. US meteorologists were recommending that the invasion go ahead on June 5. However, British meteorologists insisted that the weather would be too severe on June 5 and that the invasion should be postponed. Some suggested that the earliest possible date would be around June 16. That option seemed too late for moon-tide alignment and for keeping the date secret. A few meteorologists from England suggested that there would be a short period of calm weather between the storms, and that June 6 could be the only window of opportunity for the next two weeks.

In his report to General Eisenhower, Captain Stagg recommended setting June 6 as D-Day, the launch day of the invasion. Eisenhower accepted that recommendation. He trusted that the British meteorologists, who had more experience predicting the weather coming across England from the Atlantic than the Americans, were making a more accurate forecast.

The Germans saw the storms in the Atlantic, but didn't have enough data on their size or exact location. Because of this lack of data, they thought it would be impossible for the Allies to invade before the middle of June. Based on this forecast, they actually moved some troops away from the coast of France and thus were less prepared for the invasion.

In the end, the weather on June 5 was terrible. The seas were rough and the winds high. Conditions were still a bit rough on June 6, but the landing craft were able to get through the waves to shore, and the planes were able to insert their airborne paratroopers from the sky. The Allies built a temporary floating port starting June 7. This port allowed them to put ashore many trucks, tanks, and supplies. Two weeks later, on the date that some officers suggested for the invasion, another large storm came through, and the temporary port was destroyed. Had the Allies not had Staggs' expert advice and good weather data, the effort might have failed.

A radio weatherman from the Weather Squadron in Italy, 1944.
(Image: The National WWII Museum, 2002.337.038.)

NAME: **DATE:**

1. Look at the WWII weather maps in the reading. What symbols represent low pressure systems?

2. What symbols represent weather fronts?

3. Do we use similar maps today? What is similar and what is different about how forecasts are presented today?

4. What data do you need to be able to forecast weather?

5. What innovations since World War II have improved our ability to forecast weather?

ACTIVITY
WEATHER TOOLS

INTRODUCTION

Knowing tomorrow's weather totally depends upon knowing what the weather was like in the past. Only by monitoring the weather can we understand its patterns and be able to predict what conditions will be like in the future. People have been collecting weather data for hundreds of years, and many of the tools they used in the past are similar to the ones we use today. These tools have of course been supplemented by modern technologies, and we now use computers to analyze weather data.

In this activity you will make three different weather tools. They won't be the most accurate tools you've ever used, but they WILL show you how the more accurate tools work and reveal some of science ideas behind these phenomena.

THERMOMETER

You will need the following from your teacher:

- **1 Clear plastic bottle**
- **1 Clear plastic straw**
- **1 Ruler**
- **Rubbing alcohol, colored with food coloring**
- **Clay**
- **Dropper**

1. Using a pen your teacher gives you, mark every half-centimeter increment on your straw.
2. Fill the bottle about 1/4 of the way up with alcohol.
3. Put the straw in the bottle and seal the top of the bottle with clay tightly. Make sure the straw is straight and goes through the middle of the clay lid.
4. With the dropper, add alcohol to the straw until the level is just a couple of inches above the level of the alcohol in the bottle.

Now you are ready to test your thermometer. Hold the bottle tightly in your hands to warm it up with your body heat. It may take a minute for it to absorb the heat from your hands, but watch the level of the alcohol in the straw. To test more extreme changes in temperature, try putting your thermometer in hot water or ice water. Calibrate your thermometer by indicating which line the alcohol level reaches at the different temperatures.

NAME: **DATE:**

BAROMETER

You will need the following from your teacher:

- **1 Empty plastic bottle**
- **1 Length of plastic tubing**
- **Water, colored with food coloring**
- **Clay**
- **1 Ruler**

1. Using a pen your teacher gives you, mark every half-centimeter increment on your tubing.
2. Fill the bottle about 1/2 of the way up with water.
3. Put the tubing in the bottle and secure it with tape so that the tubing doesn't touch the bottom of the bottle.
4. Now suck water up the tubing until it is halfway up the length of the bottle, and then seal the end of the tubing with the clay.

Changes in atmospheric air pressure are not immediate, so note where the water level in the tube is today and check it tomorrow. When the pressure goes up or down, do you notice a change in the weather? Air pressure changes in a place due to weather, but only by about 0.75 percent. Air pressure changes a lot by altitude—at the top of Mt. Everest the air pressure is only 1/3 of what it is at sea level.

HYGROMETER

You will need the following from your teacher:

- **1 Metal can**
- **Water**
- **Thermometer**
- **Ice**

1. First, put the water in the can, filling it about halfway up. Place the thermometer in the can.
2. Add a cube of ice to the water, and stir it as the temperature goes down and then stays constant.
3. Check to see if there is condensation on the outside of the can.
4. If there is condensation, record the temperature of the water in the can as the dew point. If not, repeat until there is condensation on the outside of the can.

It is usually not very humid inside, meaning that the dew point inside is very low. It may be easier to get a result if you go outside, unless you live in a part of the country that is very dry.

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