LEMELSON-MIT InvenTeams™

EDUCATOR GUIDE

ACTIVITY OVERVIEW

Introduction to JV InvenTeams P4
Summary and Meeting Synopses P12
Facilitation Materials for Educator
Facilitation Tips P14
    Self-Assessment (students complete at end of each meeting)... P16
    Problem Strips P17
    Shop Safety Rules P19

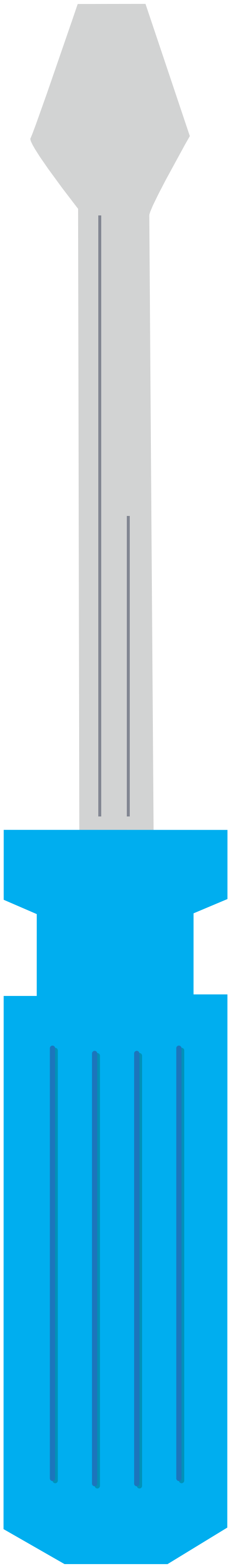
MEETINGS

1 Invention Introduction 1
2 What is Heat 9
3 Keep Your Cool 25
4 Removing Heat 37
5 Peltier Prototyping 51
6 Invention Extension 67

APPENDIX

Invention Worksheet 75
Certificate of Achievement 76
Word Wall Words 78
Educational Standards 103

INTRODUCTION TO JV INVENTEAMS



Welcome to JV InvenTeams, where students develop skills in science, technology, engineering, and math (STEM) through fun, invention-based design activities and challenges.

About Lemelson-MIT

The Lemelson-MIT Program (**https://lemelson.mit.edu**) is dedicated to honoring those who have helped improve our lives through invention. The Program was established in 1994 at the Massachusetts Institute of Technology (MIT), by one of the world's most prolific inventors, Jerome Lemelson (1923 -1997), and his wife, Dorothy. It is funded by The Lemelson Foundation and administered by MIT's School of Engineering. The Lemelson-MIT Program recognizes outstanding inventors, encourages sustainable new solutions to real-world problems, and enables and inspires young people to pursue creative lives and careers through invention.

The Lemelson-MIT Program encourages great inventors through various outreach programs such as InvenTeams (**https://lemelson.mit.edu/inventeams**), a national grants initiative for inventive high school students who have a strong foundation in scientific and technical skills. InvenTeams are teams of high school students, teachers, and mentors that receive grants of up to $10,000 to invent technological solutions to real-world problems. The Lemelson-MIT Program developed JV InvenTeams in order to reach slightly younger students and provide them an introduction to inventive thinking and doing.

About JV InvenTeams

The goal of JV InvenTeams is to cultivate new ways of thinking and develop technical skills for students with limited access to hands-on STEM enrichment opportunities. Through prescribed activities, students will add to their own "toolkits" of minds-on knowledge and hands-on skills while having fun!

Students will learn how to identify a need in their lives or in the world around them and develop their own invention after completing the main activity in each unit. They will pull from their expanding toolkit to come up with solutions.

JV InvenTeams Activity Guide Components

Each unit of JV InvenTeams activities is presented in the same format. The Educator Guide includes specific notes and segments, while the student version is more streamlined and includes working space for the students. The educator may decide how much of the information should be shared with the students and in what manner—e.g., read out loud or read individually. Each meeting within the unit is estimated to take between 1.5 and 2 hours to complete.

Each group of young people will be different, so the pace of each unit is up to the educator. Know that there are numerous resources to balance the unit to meet your needs. Some may find that breaking meetings into a couple of sessions will allow the think-time needed for your group. Others may want to streamline items and skip some of the videos.

INVENTOR'S TOOLKIT

HANDS-ON

- General shop safety

MINDS-ON

- Biomechanics
- Biomimicry

KEY TERM(S)

Insole (n): The fixed inner layer of a shoe.

Isometric Drawing (n): Visually representing a 3D object in two dimensions on paper.

Each unit has the following in the first pages:

- Title page with summary of the unit and learning objectives
- Summary of each meeting within the unit
- Master consumable materials and tools lists

Each meeting within the unit includes the following:

- "Toolkit" of hands-on and minds-on skills to be learned
- List of tools and materials
- Agenda
- Key terms
- Safety message(s)
- Video clips
- Instructions with step-by-step procedural notes
- Pop-outs that include any of the following: Historical Connections, Inventor and Invention Spotlights, Related Patents, Extend the Learning, High School Connections and College Connections
- Student Self-Assessments that serve as exit slips
- Indicators of a successful meeting

SAFETY

Wear protective gloves and safety glasses for this activity. Avoid breathing in the release agent spray. Use it in a well ventilated room or outdoors.

INVENTOR SPOTLIGHT

In 1902, mechanical engineer Willis Carrier patented the air conditioner, a device he originally invented to solve a problem facing a paper printing plant in Brooklyn, New York. Read more about his invention—and how the invention of air conditioning helped expand Southern cities such as Houston and Atlanta.

Students may ask, “Why should I invent?” Here are some of the reasons you can share during the first meeting. Invention…

- solves world problems;
- helps people;
- allows people to explore a creative process that often involves teamwork;
- provides fulfilling careers: inventors are often scientists and engineers who improve areas of health, energy, food and transportation;
- can also lead to a high-paying career with many job opportunities as an engineer or scientist; and
- is fun!

Group Size

JV InvenTeams is recommended for approximately 20 students in Grades 7-10. Most activities require students to work in teams of four.

Partnerships

The Lemelson-MIT Program encourages participating schools to seek community partnerships to sustain JV InvenTeams. Partnership opportunities include:

- Science and technology museums, to provide direct mentoring;
- Local technology and engineering companies, to provide funding for future extension ideas, materials, or mentors;
- Local universities or colleges, to provide collegiate mentors; and
- Hardware stores, to provide tools or materials.

Flexibility

The JV InvenTeams has built flexibility into the program to meet the needs of educators, school systems, and grants-based clubs and organizations. Following are some examples:

- Each unit is designed to stand on its own. Educators can lead one unit, a few units, or all of the units.
- The program can be held in any educational setting with a science or technology educator facilitating the activities.
- Each unit has approximately 6 meetings of 1.5–2 hours duration.
- Meetings can take place multiple times a week or once a week.

Inventive Thinking

Both educators and students will develop an understanding of the invention process as you navigate through JV InvenTeams. This new way of thinking, part of the minds-on toolkit, may take some time to adopt since learning within the school day increasingly focuses on standardized tests of academic knowledge.

Invention is a variable, non-linear process. JV InvenTeams introduces the curiosity and creativity of recognizing problems and addressing them with novel solutions. You will not need to worry about knowing the "right" answer since there are countless possibilities. Experiencing failure is part of the invention process.

Inventing is creating something new that is useful or helpful, by means of one's own investigation, experimentation, and thinking. An invention is the product of the inventing process. It can be a device, a material, a system, and even a plant. Invention refers to a new physical thing made possible by technology. Inventive thinking challenges what people come to expect or anticipate. Revolutionary inventions, known as macro- inventions, make a huge impact on the way we live. Examples include the internal-combustion engine for the automobile and the integrated circuit for consumer electronics. Most inventions are micro-inventions, or adaptations that grow from larger-scale inventions. This means making an existing product faster, stronger, cheaper, easier, safer, more efficient, or more useful.

User-Centric

The key to inventing is to make sure the invention is user-centric. This means that students need to think about and understand problems affecting real people and their specific needs. Researching the unique characteristics and needs of the user is essential to coming up with an effective design – as is working directly with them! Students will develop empathy for the beneficiary during the process.

An example of this would be a student noticing that his or her grandmother has difficulty moving around the house in her slippers, due to slippery floors.

The student should investigate by first asking his or her grandmother:

- Do you wish your slippers had a better grip?
- What parts of the slipper do you like? What parts would you change? Why?

After learning from the user, the student can further investigate. Questions he or she might ask include the following:

- Does the solution lie in changing the floors or the footwear?
- How can I change her slippers to make the grip better?
- Is there another product on the market that provides the ease and comfort of slippers with the safety features of shoes with more grip?

These questions will inform research and allow the student to develop meaningful solutions.

Deciding on a Good Problem to Solve

Identifying a good problem to solve can be challenging, but it is just like any other skill: it becomes easier with practice. Therefore, at the beginning of each unit in JV InvenTeams, students will be given a problem or scenario that requires devising an original solution. Coming up with solutions to problems can be difficult at first, but students will gain confidence in generating new ideas over time. One way to accomplish this is through transgressive thinking – applying flexible or "out of the box" thinking in one area to another. The SCAMPER technique is a good technique to start with because it provides a framework to come up with solutions.

Scamper

The SCAMPER brainstorming technique was developed by Bob Eberle and published in a book by the same title. SCAMPER is based on the notion that something new can be modified from something that already exists. Each letter in the acronym represents a different way you can mentally view the characteristics of the challenge. It's a "mash-up" of disparate things to conceive something new.

S = **Substitute** *(playing basketball with a softball)*

C = **Combine** *(toothbrush combined with a pencil to create a new product)*

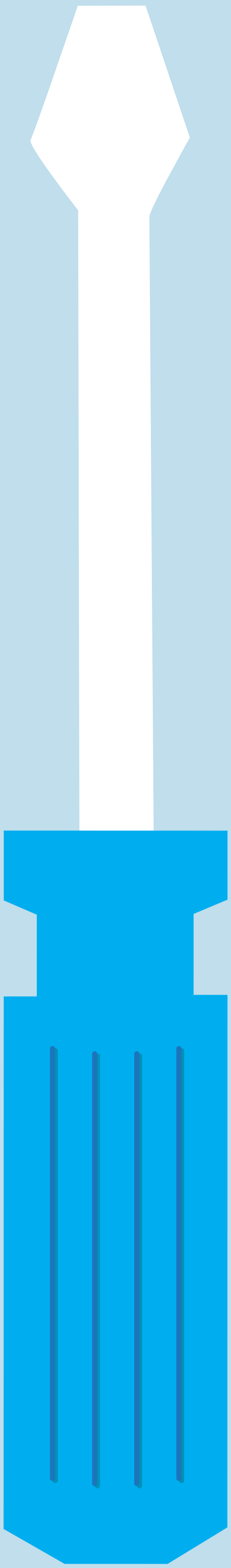
A = **Adapt** *(how would you eat your spaghetti without a utensil?)*

M = **Magnify** *(how would your chair function if its legs were wider and longer?)*

P = **Put to Other Uses** *(could your fork be used as a comb?)*

E = **Eliminate** *(could you play tennis without a racket?)*

R = **Rearrange** *(what if the laces of a shoe were placed on the bottom and not the top?)*



The SCAMPER technique involves the students first stating the problem they would like to solve, which defines the challenge. Then it's a matter of asking questions, using SCAMPER to guide the students. No idea is a "good" or "bad" idea at this point. There can certainly be good ideas!

Documentation

Students should be encouraged to document their progress along the way. This includes saving sketches, designs, research data, graphs, images, and early prototypes. Most of this work, with the exception of the actual prototypes, can be compiled in the Student Guides. Students should routinely review their guide, adapting what they have learned and experienced to new challenges.

Patents

Since this program is all about invention, it is important that educators and students familiarize themselves with the United States laws that protect the intellectual property of inventors.

A patent is one type of intellectual property that can be legally protected through the U.S. Patent and Trademark Office (USPTO). The other types of intellectual property are trademarks and copyrights. A trademark includes any word, name, or symbol used to distinguish one manufacturer from another (e.g., brand name). Copyrights are recorded with the U.S. Copyright Office in the Library of Congress for original authored works like books and music.

According to the U.S. Patent and Trademark Office, patents provide legal protection to inventors' intellectual property by excluding others from profiting from their property in the U.S. for a specific amount of time, in exchange for the inventors' disclosure of their idea according to the criteria for granting a patent. There are three different types of patents. Utility patents are granted to inventors who discover a new and useful process, machine, article of manufacture, or a new and useful improvement. Design patents are granted to those who invent a new, original, and ornamental design for an article of manufacture. Finally, a plant patent is granted to an inventor who invents a new variety of plant. The basic components of a U.S. patent are: patent number, title, inventors, assignee (optional transfer of intellectual property to a company or other individual), abstract (short overview of invention), drawings, description (technical details), and claims (legal information). To learn more about the patent process, visit: **http://www.uspto.gov/.**

Students will be required to search patents to ensure that their idea is unique. Patent searches can be done through Google Patents and Free Patents Online. Both have easier search functions than the U.S. Patent and Trademark Office.

Jerome Lemelson, founder of The Lemelson Foundation, had a productive life as an inventor, holding more than 600 patents. He was awarded his first patent in 1953 for a toy cap, and spent the next 45 years coming up with inventions that led to products such as bar code readers, automatic teller machines, cordless phones, cassette players, fax machines, machine vision and personal computers.

It is important to keep in mind that not all inventions are patented. Some inventors purposefully do not seek a patent with the idea that their inventions are immediately and widely available. An example is open source software, which allows anyone to use the software without paying a fee.

This openness can spur further invention since anyone can access it and make adaptations. In spite of the changes in patent law through the Innovation Act of 2013, students should adopt the habit of recording and dating their work, including early sketches and research. This practice will be useful for future science exploration and invention. To learn more, visit: **https://govtrack.us/congress/bills/113/hr3309**.

UNIT SUMMARY FOR EDUCATOR

UNIT SUMMARY

Students will design and build a lunchbox cooled with a thermoelectric tile and heat sink fans in this unit. Students will learn about heat and heat transfer, and explore how engineers and inventors apply these concepts in fields ranging from food safety and transportation to green design to public health. Focusing on the idea of keeping foods and beverages at an ideal temperature, students will consider the design of currently available coolers, lunchboxes, and other food transportation and storage devices. They also will consider new designs for improving these devices and new users of them, ultimately designing and prototyping a thermoelectrically cooled lunchbox using Peltier tiles.

Students will first learn about heat and heat transfer through readings and hands-on activities demonstrating convection, conduction, and radiation. They also will experiment with materials with a variety of thermally conductive and insulating properties as they explore some of the coolers and lunchboxes they may already be familiar with. Students will learn about methods for removing heat from systems, and will build a Peltier cooling unit using a Peltier tile and two heat sink fans. Finally, they will build a prototype of a lunchbox that uses a Peltier cooling unit to keep one side cool and the other side warm. They will test the performance of their prototype and brainstorm ways to improve it.

Students will gain both minds-on and hands-on skills in this unit. Minds-on skills include understanding heat and heat transfer, recording data and calculating differences and rates of change, learning about biomimicry, and practicing the prototyping process. Hands-on skills include using a utility knife to cut cardboard, cutting and stripping wire, sketching and drawing, and building with cardboard. They will consider how to incorporate their new skills into a new invention in Meeting 6. Students will learn what it means to be inventive thinkers and practice inventive thinking as they progress through the unit.

LEARNING PRINCIPLES

- Heat transfer
- Heat and energy
- Electricity and circuits
- Prototyping

MEETING SYNOPSES

1 Invention Introduction

Students do warm-up activities and discuss invention. Students play “Four Corners” to help the educator assign diverse teams.

2 What is Heat?

Students do hands-on activities that demonstrate convection, conduction, and radiation, and begin to discuss problem solving and invention in the context of food safety and transportation.

3 Keep Your Cool

Students explore the thermal properties of various materials, then design and build a simple device that will both keep a cold item from warming up and a warm item from cooling down.

4 Removing Heat

Students learn about evaporation and evaporative cooling. They also learn about the thermoelectric effect, experiment with Peltier tiles, and brainstorm ways they might use these devices in their invention.

5 Peltier Prototyping

Students build a Peltier cooling unit, made of a Peltier tile sandwiched between two heat sink fans. They compare how the tiles function, with and without being attached to a heat sink. Then they design and build a lunchbox prototype out of cardboard and a Peltier cooling unit. Finally, they test out their lunchboxes and provide feedback to other teams.

6 Invention Extension

Students conceptualize a purposeful invention that uses their new minds-on and hands-on skills.

FACILITATION TIPS

Word Wall

Consider using the Key Terms to construct a Word Wall. Use the Word Wall to help young inventors review what was covered in the previous session, reinforce concepts that may need some review, and reinforce the use of new words to promote vocabulary growth.

Idea Board

Consider creating an Idea Board out of poster board that serves as a repository for new ideas and questions. Students can post new invention ideas here, which can be referenced for the development of their inventions at the end of the unit.

Teamwork

Students will be working in teams throughout this program. Consider inviting a coach from one of your school's sports programs to talk about how important teamwork is on and off the field.

Facilitating Redesign

Teams test their first lens prototypes and think about ways to improve them. You may find that your students would like to design a second prototype and test again. If you have the time and resources to facilitate a second round of designing and testing, follow these tips to help you engage your students in engineering practices as they work:

Encourage students to improve only what needs to be improved. It is a natural impulse to want to throw away an entire design idea because one element of it needs improvement. Encourage students to think hard about what elements of their design work well and what elements do not. Help them narrow their focus so they are truly improving specific elements of their original design, as opposed to starting from scratch.

Have students link their improvement ideas to particular results from their first test and from peer feedback they received. Make sure students use evidence from their test results and specific ideas from peers to justify each improvement. This helps students stay grounded in their actual design.

Encourage students to learn from the work of others before implementing improvements. Engineers and inventors always learn from the work other people have done! Have students do some more research on lenses before deciding on their improvements. Encourage students to link their improvement ideas to specific information they learned in their research.

Have students predict how their results might change based on the improvements they made before testing. Students will likely have lots of ideas about how their second prototype will perform, as compared to their first prototype. Allow students to explain what they think will happen and why. Encourage students to apply their understanding of lens properties and focal length to the design process.

Have students reflect on the strengths and weaknesses of their second prototype after testing. Encourage students to identify what worked well and what did not in their second design. Have students brainstorm further improvements and justify their ideas with evidence from their previous tests. Tell students that inventors often repeat this process of prototyping and testing many, many times before releasing a final design!

JV INVENTEAMS SELF-ASSESSMENT: U CONTROL

Inventors need to be confident and know their own strengths and weaknesses. Use this table to think about how likely you are to complete these skills with confidence. Check the response that best describes your confidence right now.

I CAN...	PROBABLY	MAYBE WITH HELP	PROBABLY NOT
make something useful out of material like cardboard, wood, fabric, or foam insulation board.			
use tools such as thermometers and utility knives.			
work as part of a team.			
test the thermal insulating and conducting properties of various materials.			
demonstrate heat transfer.			
build a portable cooling device.			
identify a real-world need.			

TODAY

Which skill was the most challenging?

____

Which skill was the most enjoyable?

____

IN THE FUTURE

What will YOU invent?

____

How is it unique?

____

How is it useful?

____

PROBLEM STRIPS (INVENTION INTRODUCTION)

Copy and cut out these Problem Strips prior to leading the Invention Introduction with students.

You want to eat soup but you don't have a spoon.

You need to walk across a hot concrete parking lot after going to the beach, but you don't have any shoes.

You hit a baseball over a barbed-wire fence and need to get it back.

A fly is buzzing in your room and the noise it makes is bothering you.

You lost an item under your heavy dresser and want to get it back.

GENERAL SHOP SAFETY RULES

Discussing shop safety helps set the tone to introduce inventing with electronics in the classroom. It introduces safe practices and helps students understand why these practices are used. Asking your students to help develop the rules may help with the ownership and understanding of the lab safety rules. You may also choose to set the rules. Either way, make sure students understand these rules and why they are necessary. You may ask students to create posters for display in the room throughout the year to emphasize safety and remind students of the specific safety rules. Keep these safety rules posted throughout the unit.

SAFETY

1. **Wear safety glasses.**
2. **If you are in doubt about how to use a tool, ask!**
3. **Have a plan for what you are going to do with the tool.**
4. **Be mindful of others who might enter into your workspace accidentally.**
5. **Secure the workpiece.**
6. **Have a balanced stance while using a tool.**
7. **Remove all jewelry, watches, and loose clothing before working with machinery.**
8. **Pin up long hair and wear closed-toe footwear.**
9. **Never work when you are tired or unfocused.**
10. **Leave the workspace cleaner than you found it.**

CHILL OUT
MEETING 1: INVENTION INTRODUCTION

KEY TERMS

Engineering (n): Using science and technology to design and improve objects and systems to solve a problem or meet a need.

Invention (n): A unique and useful device or process.

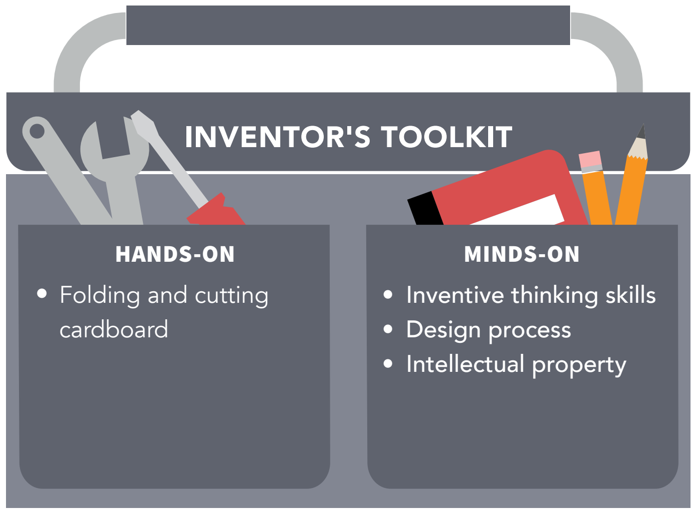
Iteration (n): A version of a design in a series of designs.

Modification (n): The act of making small or partial changes.

Patent (n): An intellectual property right issued by the U.S. **Patent** and Trademark Office, excluding others from making or selling the **invention** in the U.S. for a specified period of time in exchange for disclosing the **invention**.

PhD (n): A postgraduate academic degree awarded by universities.

Prototype (n): A model of something built to test a concept. Many **iterations** are created before the final design is determined.



Tools & Electronics

- Writing utensils
- Utility knives or sharp scissors
- Projector and computer to show video

Materials & Shop Supplies

- Student guide
- Shipping tape
- Cardstock
- Cardboard and scrap materials from the recycling bin
- Problem strips
- Self-Assessment

Procedure

- Distribute Guides and Introduce JV InvenTeams
- Introduction to **Invention** and Problem Solving
- Design a Cell Phone Stand
- Watch Some **Invention** Videos
- Research an **Invention**
- Discuss Improvements to an **Invention**
- Investigate Real-World Improvements
- Watch Videos about the Design Process
- Set Rules and Develop Teams
- Self-Assessment

DISTRIBUTE GUIDES AND INTRODUCE JV INVENTEAMS

1. Let students know that today they will learn about the basics of **invention**. Get everyone thinking about **invention** by asking:
   - How would you define "**invention**?"
   - Why do you think people invent things?
2. Distribute one JV InvenTeams guide to each student. Tell students that their **invention** guides will be a portfolio of their work. Explain that the grid paper and blank paper at the end of each meeting can be used to sketch, brainstorm, and document ideas.
3. Explain that items written in **bold underline** represent links to be clicked.

INTRODUCTION TO INVENTION AND PROBLEM SOLVING

1. Tell students that we all run into challenges on a daily basis. They will now get a taste of what being an inventor means by coming up with ideas to address some of these problems.
2. Divide the class into teams of 3 or 4 and give each team one of the Problem Strips you prepared.

Early prototypes of the Polaroid camera from the MIT Museum collection

3. Have teams devise a quick **invention** that solves their problem by using materials from the recycle bin.
4. Bring everyone back together and have teams take turns sharing their solutions. To facilitate sharing, students can ask the following:
   - What else would you do if you had more time?
   - What would you add or change if you had more expensive supplies?
5. Explain that inventors often use inexpensive, everyday materials to create **prototypes** of their **inventions**. That's because they don't want to waste expensive materials in the early stages of designing. Failure and mistakes are common and part of the process.

EDUCATOR NOTE

Consider constructing a Word Wall with these Key Terms to help young inventors review what was covered in the previous session, reinforce concepts that may need some review, and reinforce the use of new words to promote vocabulary growth.

EDUCATOR NOTE

The cell phone activity could take even longer if students get invested. Consider breaking this meeting into two sessions if you want to take your time.

Hands-On and Minds-On

MIT's motto is Mens et Manus, which translates to Mind and Hand. Inventors are resourceful and use many tools. Some "tools" are based on learned knowledge stored in our minds from science and math classes. Other "tools" are practiced – hands-on skills like drawing and building things.

EDUCATOR NOTE

After Cell Phone Stand

It is beneficial for students to conduct some peer evaluation if you have extra time. Have students leave their finished cell phone holders on their table tops. Leave a blank piece of paper and pen next to each stand. Students can walk around the room and anonymously leave some constructive feedback. A few students can share their feedback and explain how they would improve their project.

DESIGN A CELL PHONE STAND

1. Ask students if they ever get annoyed by phones not being able to stand up on their own. Explain that inventors think outside of the box and often create **prototypes** of their ideas using everyday materials.

2. Tell students that their challenge is to invent a low- cost cell phone stand using recycled materials like cardboard and tape.

3. Before students start, have them watch **Josh Ramos' Cardboard Videos** to learn some cardboard cutting tips and tricks. Josh earned his **PhD** in Mechanical **Engineering** from MIT in 2018.

4. If students are having difficulty coming up with their own design, they can check out **Josh Ramos' Cardboard Phone Stand.**

5. When finished, have students respond to the follow-up questions (below) in their guides.
   a. What do you like about the stand you made?
   b. How would you change your design if you wanted to watch a video in the landscape format (sideways)?
   c. Where are the speakers on your phone? How might you use the placement of the cardboard or other materials to improve the sound?

6. Have students share their design with another student.

7. Ask students how they would incorporate their peer's comments and their own in their next design? Tell them to describe this next design **iteration** in words or pictures in their Student Guide.

8. Tell students that during the JV InvenTeams initiative, they will learn about new tools and materials through **invention** activities like this one. They will think of **iterations** to improve or change their designs, after successfully meeting challenges these activities present.

Cellphone stand example

Students folding cardboard

WATCH SOME INVENTION VIDEOS

1. Explain that each year, teams of undergraduate and graduate students apply for the Lemelson-MIT Student Prize. Have students check out some cool videos from previous winners and finalists on the **Lemelson-MIT Program's** website.

- **Alice Chen's Inventions Make Our Lives Healthier** (2:27)
- **Ben Peters' Inventions Make Our Lives More Engaging** (1:57)
- **Eduardo Torrealba's Inventions Make Our Lives Easier** (first 9 min)

2. Explain that all good **inventions**, including the ones presented in these videos, stem from a real problem or need. Most **inventions** do not produce radical change in society, but rather build upon previous **inventions** to make aspects of life easier, safer, more comfortable, more engaging, and/or healthier.

PATENT PROFILE

MIT alumna Alison Wong invented **Keyprop**, a simple solution to the problem of keeping your smartphone propped up.

MEETING 1

EDUCATOR NOTE

After Videos: Debrief

Engage students in a discussion about the videos. Students should be asked to think and converse about the common themes, the inventors' approach, and why failure during the process is okay.

EDUCATOR NOTE

Extend the Learning

An additional resource that may inspire **invention** research is a video called **Extend the Learning: InvenTeens**. Produced by the Museum of Science in Boston.

EDUCATOR NOTE

Before Product Discussion

Ask students in small teams or as a class to devise a list of problems or things that don't work quite right in their daily lives. Give them a few examples to help them get started, such as a grandparent slips walking in socks, their laptop computer wires get tangled up, and they can't wake up to an alarm.

EDUCATOR NOTE

Before Real-World Examples

Explain to the students that **invention** follows a process of identifying needs, brainstorming ideas, sketching, building a **prototype**, testing, modifying, and re-testing. Potential users are consulted for feedback throughout the process.

RESEARCH AN INVENTION

1. Have students identify an object in the room. Ideas include a specific type of desk, piece of technology, chair, tool, writing utensil, or article of clothing.

2. Explain that we often take the daily products and tools in our world for granted. Each of these items has a history of evolution. Scientists, engineers, and designers made **modifications** over time that produced the modern product you see today.

3. Tell students that they will conduct research on **inventions** using **Google Patent Search**. Explain that Google **Patents** list U.S. **patents** as well as international **patents**. **Patents** are sequentially numbered; for example, search for "student desk" and look at the images for US7571959B2.

4. Give students a few minutes to conduct research on the product they identified.
   - How can this product continue to improve?
   - What information can you gather from the technical drawings?
   - Why are detailed images such an important part of a **patent**?

DISCUSS IMPROVEMENTS TO AN INVENTION

1. Tell students they will learn to carefully observe the world around them in search of problems that can be addressed with a technological solution.

2. Have students work in small groups to brainstorm how they could improve one product or process they use during a typical day. Students will respond to the following prompts in their guides:
   - How might you go about making the improvement? Describe your process.
   - What might be some challenges to meeting this need?
   - Thinking further, do you notice anyone in your family or community who struggles to complete a certain task? What **invention** might improve this aspect of their life?

INVESTIGATE REAL-WORLD IMPROVEMENTS

- **Sesame Ring**: Several MIT undergraduate students were having difficulty locating their reusable train tickets upon entering the train station. Their solution is a wearable reader in the form of a customizable ring.

- **Tile**: Do you ever have difficulty finding your keys or wallet in your home? The solution is a small piece of plastic with a chip that connects to an app on your smartphone.

- **uBeam**: Meredith Perry, a graduate of the University of Pennsylvania, was sick of long electrical wires for laptop computers. She started a company, uBeam, that is working on a wireless charger.

WATCH VIDEOS ABOUT THE DESIGN PROCESS

1. Have students watch the **MIT Design Process Videos**. The videos cover: Design Introduction, Observation, Brainstorming, Idea Selection, and Prototyping.

2. Give students time to outline the design process in their guides.

SET RULES AND DEVELOP TEAMS

1. Tell students that JV InvenTeams is all about hands-on fun. To make this possible, here are a few important rules to follow:

Allison Wong, Illustrator

   - Safety is the number one priority! Watch tutorial videos before using new tools and materials.
   - Ask for help. Don't guess, especially about how a tool works.
   - Consider all ideas. No idea is "dumb." As an inventor, focus on the ideas with the most potential when developing a **prototype**.
   - Embrace failure. Failure is a part of the **invention** process.
   - Value your team. Everyone brings different skill sets and knowledge to the table.

2. Explain that most of the projects require working in small teams. Diverse teams are successful teams.

3. Use the directions on the next page to play "Four Corners." This game will help you place students into diverse teams.

EXTEND THE LEARNING

You can continue exploring invention by researching well-known inventors in your community. How? Go to Free Patents Online. The login is free. Click on the SEARCH tab, then use the "Quick Search" feature to enter your location under "Inventor Fields." You may want to search chronologically by the last 20 years.

MEETING 1

EDUCATOR NOTE

After Design Process Videos

Ask a volunteer to recap the steps of the design process. Have them draw a visual outline to include on the Idea Board. Survey the students to see if they have any questions before proceeding.

Steps of the design process are:

- identifying needs,
- brainstorming ideas,
- sketching,
- building a **prototype**,
- testing,
- modifying, and
- re-testing.

EDUCATOR NOTE

Before Setting Rules

You can create a bold list of these rules to place on the Idea Board or somewhere else that is visible in the classroom.

SELF-ASSESSMENT

Collect the completed self-assessments as exit slips when students leave.

INDICATORS OF A SUCCESSFUL MEETING

Students can build a cardboard cell phone stand. They can demonstrate how to think like an inventor, and they understand how the design process works.

FOUR CORNERS GAME

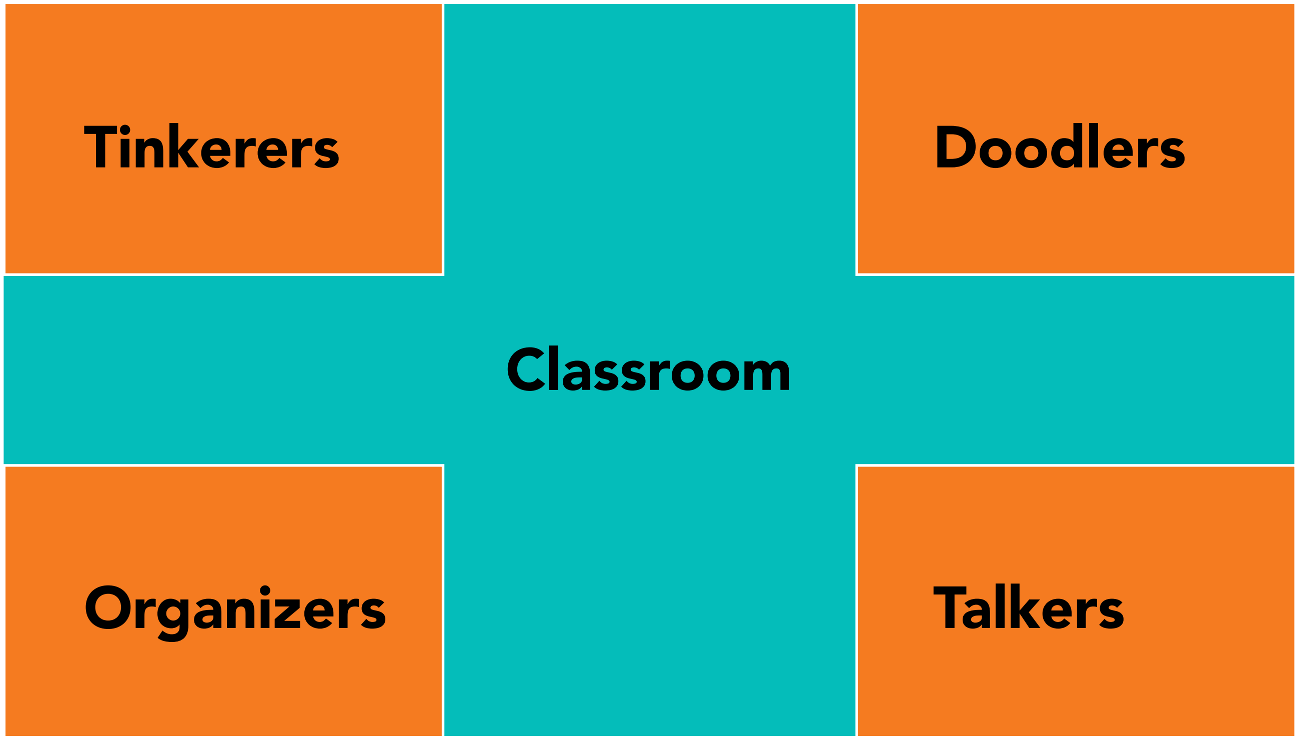
Teams of inventors include people with different interests and skills. Ask students to think about their own interests and skills to help you organize the class into diverse teams. Have students draw a line from each type of team member on the left to the best-matching description on the right.

The corners of your classroom will be marked with the four types of team members. Students will decide which corner best matches their interests and skills.

Ask students to go to their respective corners based on their "sounds most like me" description. The corners will have an equal number of students in an ideal world. If they don't, mention to the students that equal numbers are needed in order to make well-balanced teams. Have students in the larger group(s) look at their "sounds almost like me" description and compare with the corners needing students. Ask students to consider rearranging.

Types of Team Members	Your Interests and Skills
Tinkerer: I like to take things apart and build things.	Sounds most like me
Talker: I like to talk to people and I enjoy public speaking.	Sounds almost like me
Doodler: I like to draw things and express my thoughts through drawing.	Sounds a little like me
Organizer: I like to organize people and things.	Sounds least like me

Have students count off within their corners once each has a nearly equal number of students. Finally, have all 1s, 2s, 3s, and 4s come together to form their **invention** teams. Write down the names and teams in your notes. These teams will come into action when students start designing.



MY NOTES

CHILL OUT

MEETING 2: WHAT IS HEAT?

KEY TERMS

Cold (n): The absence of heat energy.

Conduction (n): The transfer of heat between objects in contact with each other.

Convection (n): The transfer of heat by the movement of the heated parts of a liquid or gas.

Electromagnetic waves (n): Waves that carry energy from a source like the sun.

Input effort (n): The effort or force exerted on an object.

Energy (n): The ability to do work; thermal energy is energy associated with the motion of molecules.

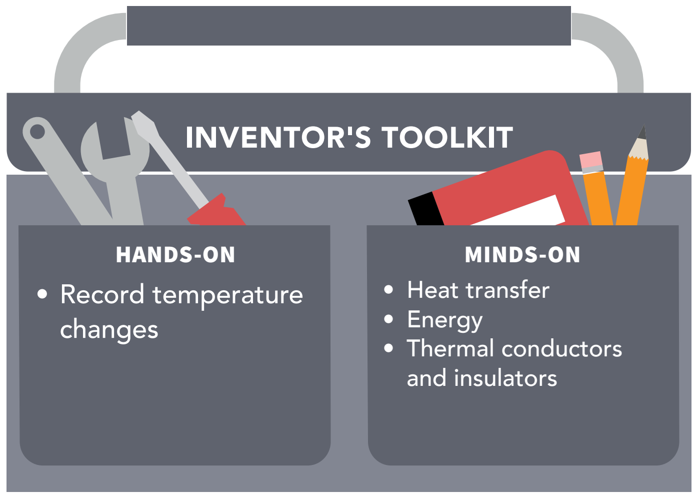
Heat (n): A form of energy associated with the motion of molecules.

Heat transfer (n): The exchange of thermal energy between physical systems.

Kinetic energy (n): The energy of a body as a result of being in motion.

Radiation (n): The emission of energy as electromagnetic waves.

Temperature (n): A measurement of heat energy.



Tools

- Writing utensils
- Computer and projector to show videos
- Thermometers (showing both °F and °C), two per pair of students

Materials

- Student Guides
- Shop safety rules
- Safety glasses
- Electric tea kettle
- Funnel
- Aluminum foil
- Ice cubes or a small bag of ice (ice will need to be stored in a freezer or cooler)
- 2 metal lunchboxes
- 2 nylon-insulated lunchboxes
- 2 neoprene lunch bags or neoprene beverage sleeves
- 2 glass measuring cups, 4-cup capacity
- 4 6-quart clear plastic bins (shoebox size)
- 4 16-ounce insulated cups, such as a foam cup or insulated travel coffee cup*
- 4 7.5-ounce soda cans*
- 20 2-ounce plastic bottles*
- 2 different colors of liquid food coloring
- Gooseneck lamp with an incandescent bulb
- Chocolate bar
- 10 plastic or paper plates
- Self-Assessments

* These items may be found in the recycling bin. Check there first!

Procedure

- Introduction to Shop Safety
- Introduction to Machines
- Watch a Video About Simple Machines
- Six Simple Machines
- Systems in Engineering
- Investigate Mechanical Door Openers
- Identify Users and Their Needs
- Taking a Closer Look: **CAD** Drawings (optional)
- Self-Assessment

INTRODUCTION TO SHOP SAFETY

1. Tell students that shop safety is of the utmost importance so that nobody gets hurt. They will be using hand tools such as utility knives. Tools should always be used in the way they were designed to be used. Have students watch a general **shop safety** video (10 min).

2. Review the general shop safety rules:

- Wear safety glasses.
- If you are in doubt about how to use a tool, ask!
- Have a plan for what you are going to do with the tool.
- Be mindful of others who might enter into your working space accidentally.
- Secure the workpiece.
- Have a balanced stance while using a tool.
- Remove all jewelry, watches, and loose clothing before working with machinery.
- Pin up long hair and wear closed-toe footwear.
- Never work when you are tired or not focused.
- Leave the workspace cleaner than you found it.

KEY TERMS (CONT'D)

Thermal conductor (n): Material that allows the transfer of thermal energy or heat.

Thermal insulator (n): Material of relatively low heat conductivity.

EDUCATOR NOTE

This meeting requires a sink with hot and **cold** running water in the classroom.

EDUCATOR NOTE

You will need access to a sink for this meeting. Pour approximately 5 cups of water into the electric kettle before students arrive; plug it in, turn it on and allow for the water to warm – but not boil. Fill each of the two measuring cups with 2 1/2 cups of heated water before students arrive. Place a thermometer in the water and monitor to ensure you do not heat the water beyond 40°C (102°F). Fill the four 6-quart plastic bins with cool water.

EDUCATOR NOTE

You will need to prepare three stations where pairs of students can rotate through in the "Exploring Heat Transfer" section. Follow the notes below for each station's set-up.

Convection: Move the four 6-quart bins filled with cool water to this station. Place two 2-oz. plastic bottles with caps next to each bin. Leave the food coloring, funnel, and two glass measuring cups with hot water at this station. Please note that water may need to be re-heated in the electric tea kettle as time passes. Also, students will need to refill the clear plastic bin with fresh water each time the pairs rotate.

Conduction: Place the 16-oz. insulated or foam cups, empty soda cans, and thermometers at this station.

Radiation: Plug in a gooseneck lamp and leave it on a tabletop. Leave a chocolate bar on the table beside it, along with a stack of 10 plastic or paper plates. Assign students to pairs or have them choose their own partners. There should be 3-4 pairs of students at each station if you have a class of 20. Announce "rotation time" as students wrap up at each station.

WHAT IS HEAT?

Read the following paragraphs about **temperature** and **heat**:

Have you ever eaten frozen ice cream or hot-out-of-the-oven pizza? Have you enjoyed iced tea or hot chocolate? If so, you've benefited from inventions and technologies that make and keep foods and beverages at the "right" **temperature** for us to enjoy them. When **heat** is transferred to or from a substance (like food or drink), **energy** is added to or taken away, which changes its **temperature**.

The terms "**temperature**" and "heat" are sometimes used to mean the same thing, but they are different. The **temperature** of a substance increases as **heat** is added and decreases as it is removed. A thermometer measures **temperature**, not **heat**. The amount of **heat** necessary to change the **temperature** of a substance a given amount is a property of the substance. This is called **heat** capacity. Think about a pot of water on the stove. **Heat** from the burner can be applied to the pot to increase the water's **temperature**. When the burner is turned "off," the water's **temperature** will decrease because the **heat** is transferred to the lower **temperature** surrounding surfaces and air surrounding the pot.

If two bodies at different **temperatures** are placed in contact, **heat** will flow from the initially higher **temperature** body to the lower **temperature** body. The result is that the **temperature** of the high-**temperature** body decreases and that of the low-**temperature** body increases. **Heat** flows until the two bodies come to the same **temperature**.

Lunchboxes, coolers, and vacuum flasks (think of a Thermos®) are inventions meant to help keep foods and drinks at the "right," or desirable, **temperature**. You want your hot chocolate or soup to stay at a high **temperature** while it sits in your lunchbox all morning at school. Similarly, you want your ham-and-cheese sandwich to stay at a low **temperature**. So, how do lunchboxes, coolers, and vacuum flasks keep **heat** from transferring between substances at lower or higher **temperatures**? Do the materials these products are made from affect how well they work?

You and your team will design and build a type of cooler in this unit to keep food at a desirable **temperature**. You will come up with a way to cool the interior of the device – or, more precisely, transfer **heat** from it. First, let's take a step back and think about some of the terms we've just used.

1. Ask students the following questions:
   - What is **temperature**? Where does the **cold** go when a glass of juice "warms up"?
   - What happens to the **heat** when a hot bowl of soup "cools down"?
   - How might learning about **heat** help you design a product that will help keep beverages cool?
2. Have students watch the following: **The Science of Keeping Cool**. This is a five-minute video about an invention designed to help soldiers stay cool in extremely hot desert environments. Tell them that the video explores how the U.S. military is researching, design-ing, and testing clothing that helps keep soldiers from overheating during long days in extremely hot environments. Have students take notes about **heat**, **temperature**, and **cold** as they watch.
3. Do a quick check-in to assess student understanding of key concepts after the video. Ask:
   - What is **heat**?
   - What is **temperature**?
   - What is **cold**?
   - Is "hot" a real thing? How do you know if something is **cold** or hot?
   - What does Dr. Castellani mean when he says, "There is no such thing as **cold**"?
   - What invention is Dr. Castellani testing, and what problem is it meant to address? Who are the users he identified for this invention?
   - How does the invention address the problem?
   - How do you think this video relates to the challenges of keeping foods hot or **cold**?

EXTEND THE LEARNING

Heat regulation is an important fact of life for animals all around the globe. The fennec, for example, is a small fox that lives in the Sahara Desert. It has enormous ears that radiate heat away from its body, helping to keep its body from heating to dangerous levels. Learn more here

Credit: Wikimedia Commons

EDUCATOR NOTE

Reinforce with students that temperature and heat are not the same. Temperature is a measurement, whereas heat is applied, which increases the total energy of all atoms and molecules in a substance.

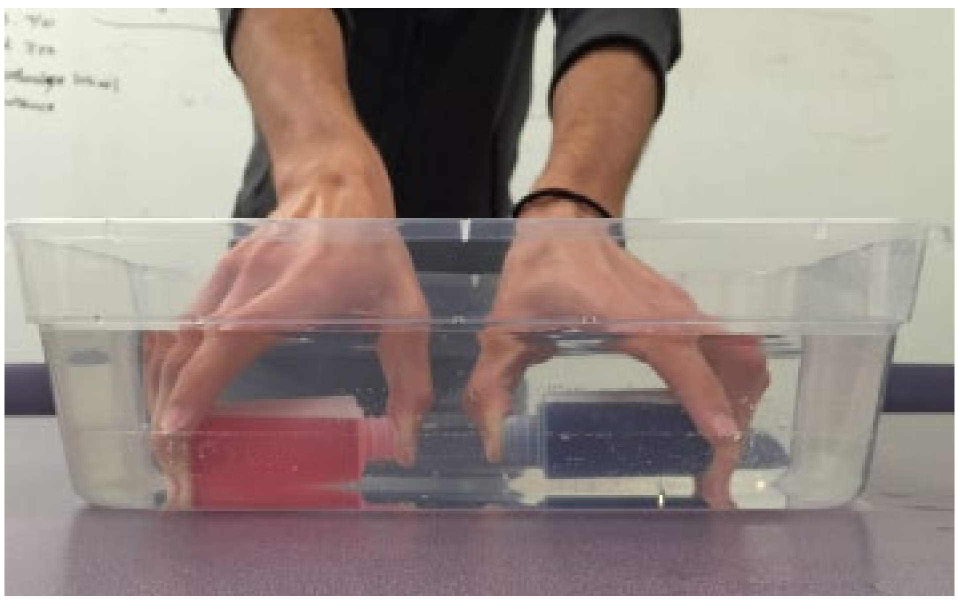
EXPLORING HEAT TRANSFER

Tell students that they will work in pairs to complete the activities at each of the three stations. They will explore the three processes through which **heat transfer** occurs—**conduction**, **convection**, and **radiation**—as they rotate through the stations.

Convection

1. Ask students: What do you think will happen to a hot drink left to sit in a **cold** room? Have them write predictions in their guides.

2. Review the instructions for this activity with students. Then, have them do the activity with a partner and address the questions that are in their guides.

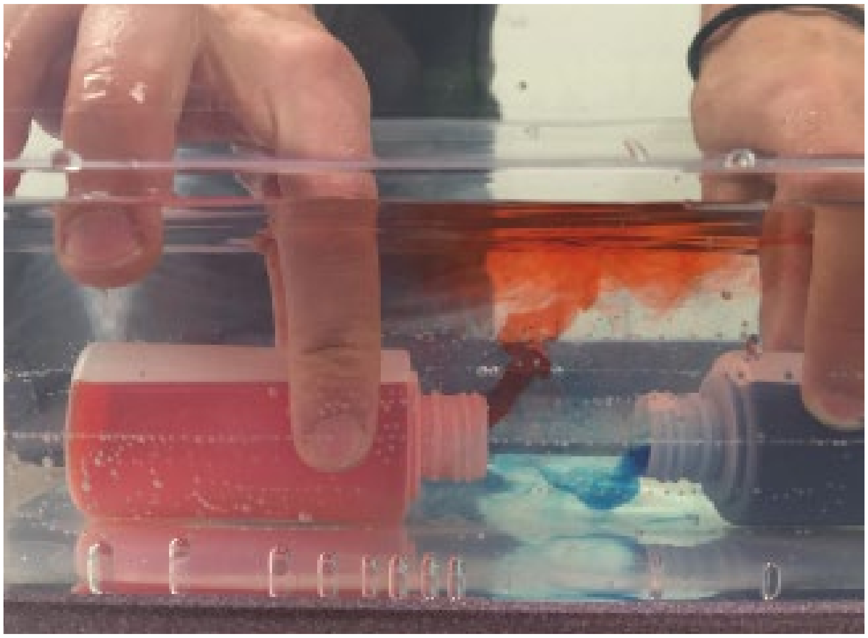


Credit: Jennifer Cutraro

What do you expect to happen to the water in each bottle when this student removes his thumbs?

- Fill one two-ounce plastic bottle with water that feels very warm to the touch. Use the funnel to carefully pour water from the glass measuring cup into the bottle. Add several drops of red food coloring and gently shake to distribute the color evenly throughout the liquid.
- Fill the other two-ounce plastic bottle with cool water. Add several drops of blue food coloring and shake.
- Place a finger over the opening of one bottle and gently place it on its side inside the large container that's filled with water. Have your partner do the same with the other bottle.

- Kneel or sit so that you are eye level with the bottom of the large plastic container.
- Next, gently remove your finger from the bottle at the same time your partner does. Observe what happens.
- Record your observations in your guide, using sketches and descriptions.



Credit: Jennifer Cutraro

Heated water, which is red, rises to the top, while cold water, which is blue, sinks to the bottom.

- Pour the water from the large container and the two small bottles down the sink.
- Prepare for the next rotation of students: fill the large container with clean water and place two more small bottles next to it.

3. Discuss these questions as a class when students finish the activity:

- What happened to the colored water?
- Can you describe how it moved?
- Why do you think it moved in this way?

4. Tell students to think about the temperature of the water in each container in terms of **kinetic energy**—or the **energy** of the molecules in the system—which they learned about in the video. Read the following, or have them read it independently in their guides: Hot water has more **kinetic energy** than cool water. That is, its molecules are

HIGH SCHOOL CONNECTION

The 2013 Ella T. Grasso Southeastern Technical High School InvenTeam from Groton, Connecticut invented a water heater powered by compost units that provides continuous hot water. The invention can be used to heat small greenhouses and rooms in rural areas. It can also preheat water as it reduces energy costs associated with boiling water. [Learn more here](#).

EDUCATOR NOTE

Start the interactive "Heat Transfer: Conduction, Radiation, Convection," and **click here** to see how convection works.

moving more quickly than the molecules in the cool water. You can see this in the way that the hot colored water escapes more quickly from its bottle.

You also observed a type of **heat transfer** called **convection**. **Heat transfer** is the movement of heat from one substance to another. **Heat** always moves from substances with higher **kinetic energy** (**temperature**) to substances with lower **kinetic energy**, a phenomenon known as the second law of thermodynamics.

You just saw the hot water rise to the top of the container as it left the bottle. Hot water has less density—or particles per unit volume—than cool water. Because of this, the hot water in this experiment rises. Along the way, the hot water exchanges some of its heat with the cooler water it is mixing with.

5. Ask the students, "How would you now explain what you expect to happen to a hot drink left to sit in a **cold** room?" Be sure students can explain that the **heat energy** in the drink would move, via **convection**, into the cooler surrounding air, which contains less **heat energy**.

Conduction

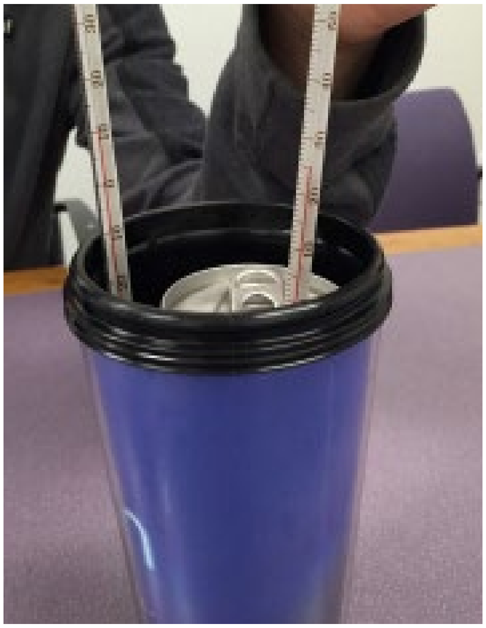
Ask students to think about the kinds of containers and packaging materials we use for foods. Do they think cardboard is the best material for keeping pizza hot? Are paperboard containers for ice cream ideal for keeping ice cream **cold**? Why or why not? Encourage them to consider these questions as they complete the next activity.

Credit: Jennifer Cutraro

This thermometer shows an initial temperature of 5°C (41°F).

1. Review with students the instructions for this activity, which are also in their guides. Then, have them complete the activity below:

- Fill the 16-ounce insulated cup halfway with cold water from the faucet. Place a thermometer in the cup. Observe the thermometer for several seconds. When the indicator line stops moving, record the temperature in the table on page 17 in the row “0 seconds (initial temperature).”
- Carefully fill the 7.5-ounce metal soda can halfway with hot water from the sink. Place a thermometer in the can. When the indicator line stops moving, record the temperature in the table in the row “0 seconds (initial temperature).”
- Place the metal can in the foam cup. Observe each thermometer, recording the temperature of each one every 30 seconds for two minutes. Record these data in the table in your guide.



Credit: Jennifer Cutraro

What happens to the temperature of the water in each container?

Credit: Jennifer Cutraro

This thermometer shows a final temperature of 34°C (93°F).

MEETING 2

Time	Temperature Inside Cup	Temperature Inside Can
0 Seconds (initial) (T1)		
30 Seconds (T2)		
1 Minute (T3)		
1.5 Minutes (T4)		
2 Minutes (final temperature) (T5)		
Difference between initial and final temperature		

- Dump the water from the containers into the sink to prepare for the next rotation of students.

2. Discuss these questions as a class when students finish the activity:

- What happened to the **temperature** of the liquid in the metal can over time?
- What happened to the **temperature** of the liquid in the cup over time?
- Can you explain your observations in the context of **heat transfer**, or where and how **heat** was moving?
- How do these observations help explain why "there is no such thing as **cold**"?

3. Explain the following, or have students read it independently in their guides:

- You should have seen the **temperature** of the water in the metal can dropping as the **temperature** of the water in the foam cup rose.
- This is an example of another type of **heat transfer** called **conduction**,

or the transfer of **heat** between two parts of a system in physical contact. In this demonstration, **heat** moved from the hot water inside the can across the metal and into the water in the foam cup. This means it's more accurate to say that heat was removed from the water in the can than to say the water "cooled down."

We all experience **conduction** as we go about our daily activities. Any time you touch an object, **heat** will transfer between you and that object! When you sit on a metal park bench or bleacher seat on a **cold** day, for example, **heat** from your body transfers to the much colder metal surface. Your body interprets this **heat transfer**—the act of **heat** leaving your body—as the bench or seat feeling **cold**.

Radiation

1. Review with students the instructions for this activity, which are also in their guides. Then have them complete the activity below:

  - Break off a square of chocolate from the chocolate bar.
  - Place it on a plate directly under the gooseneck lamp.
  - Turn on the lamp so that the bulb shines directly on the chocolate.
  - Observe the effect of the lamp on the chocolate.
  - Clean up the station when you are finished.

2. When students finish the activity, discuss these questions as a class:

  - What happened to the piece of chocolate?
  - Can you explain what happened using the terms **heat** and **heat transfer**?

3. Explain that this demonstration showed the students still another type of **heat transfer** called **radiation**. **Radiation** is the transfer of **heat** with **electromagnetic waves**, or waves that carry **energy** from a source such as the sun. You can feel this form of **heat transfer** when the sun shines on you on a sunny day. Sunlight is solar **radiation**— **electromagnetic waves** that carry the sun's **energy**.

MEETING 2

EDUCATOR NOTE

Start the interactive "Heat Transfer: Conduction, Radiation, Convection," and **click on the sun** to see an animation of radiation.

Credit: Wikimedia Commons

EXTEND THE LEARNING

The video "Misconceptions About Heat," talks about commonly held, but incorrect ideas about heat. Ask yourself which is hotter: a cake coming out of the oven or the metal pan holding the cake? Then, watch this video. Would you change your answer after watching the video? Why or why not? As the video explains, it's a trick question: neither is hotter than the other. However, metal is a much more efficient conductor of heat than cake. For this reason, you're more likely to burn yourself by touching the pan.

HEAT TRANSFER IN THE REAL WORLD

1. Read the following, or have students read it independently in their guides:

What do all these examples of **heat transfer** have to do with designing and building lunchboxes? The main goal of a lunchbox, vacuum flask, or other food or beverage container should be to minimize **heat transfer**. When you place your hot chocolate in a vacuum flask, you don't want the heat of the hot chocolate to transfer to the cooler air on the outside. You also don't want **heat transfer**ring to your **cold** ham sandwich. So what are some things you can do to prevent **heat transfer** from taking place?

You probably already use materials that minimize **heat transfer** every single day. You just never thought about them in those terms. Have you ever used oven mitts to remove a hot tray from the oven? The oven mitts act as **thermal insulators**, minimizing the transfer of heat from the tray to your hand. Have you ever used a foam sleeve to keep a soda can cool on a hot day? Then you've used an invention that minimizes the transfer of heat from the air surrounding the can to the cool beverage.

2. Tell the class you're going to look at some of the materials that lunchboxes, vacuum flasks, and coolers are made from. Divide the class into two groups and assign one group to each table. Have students examine the items on the tables and make a sketch of each item. They should work with a partner to answer the following questions about each item in their guides:

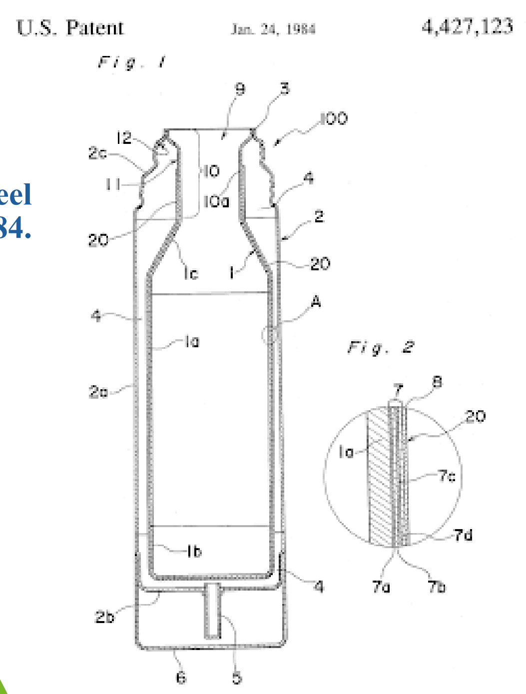
- What kind of material is it made from?
- What do you think the item would look like in cross-section? Make a sketch.
- Why do you think the engineers who designed it chose to use those particular materials?
- Do any of the items contain liquids or gels? What do you think these materials do?
- How do the items keep hot things hot? How do they keep **cold** things cold?
- What other things do you notice about the coolers, lunchboxes, and beverage containers?

EDUCATOR NOTE

Set up two tables, each with a nylon-insulated lunchbox, a neoprene lunch bag, a metal lunchbox, a small foam cooler, and a metal vacuum flask. Retrieve the bag of ice from the freezer to use in this activity. Students will be split into two groups.

Reconvene as a class after students have completed their exploration and discuss the questions. Tell students it's okay if they don't have all the answers! They will gain more experience with testing these and other materials in subsequent meetings.

3. Finally, place one ice cube in each container. Ask your students to rank the insulating efficiency of each item by predicting which ice cube will melt first, second, etc. Note the time, and check on the ice cubes in 15 minutes (more if needed). You will move on to the next activity while the ice cubes begin to melt.



USPTO drawing of stainless steel thermos bottle from 1984.

Credit: Wikipedia Commons

One of the most familiar consumer products that minimizes heat transfer is the metal vacuum flask. It was invented (but not patented) by the Scottish chemist and physicist, Sir James Dewar, in 1893. A vacuum flask is often called a thermos, which is now a "genericized" trademark because it has been used so widely. The Thermos Company was founded in 1904 to manufacture and sell vacuum flasks to eliminate all three forms of heat transfer between the inside of the container and the outside environment.

INVENTION SPOTLIGHT

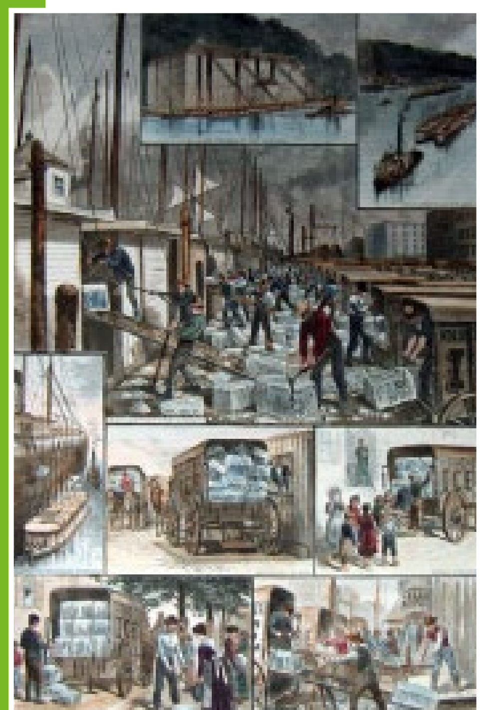
Credit: Jennifer Cutraro

Samples of lunchboxes and other materials designed to keep foods and beverages at the right temperature.

4. When the time is up, have students observe each ice cube. Which item performed the best? Which performed the worst? Ask students to compare these results and their predictions. What does this tell them about the materials that would be good candidates for minimizing **heat transfer** in a lunchbox? You should expect to see the ice cubes melting within about 15 minutes. The cube in the metal box will melt the fastest, melting completely into a puddle within about 30 minutes. The other containers will likely still contain solid—but smaller—cubes.

HISTORY

People kept food and drinks cold with iceboxes and ice-houses before the invention of electricity and refrigeration. Thomas Jefferson, third president of the United States, built an icehouse on his Virginia property, Monticello. It could keep foods chilled from December, when he filled the house with ice, until the middle of the following October. But where did his ice come from? The ice likely came from towns around Boston, Massachusetts. Read more about the history of keeping food cool—and how the New England ice trade laid the groundwork for the food industry we all benefit from today.


Credit: Wikimedia Commons from Harper's Weekly, 30 August 1884

MEETING 2

IDENTIFY USERS AND THEIR NEEDS

1. Wrap up this meeting with an open-ended discussion about invention and problem solving. Explain that identifying users and their needs is one of the first steps of the design process, a process that inventors follow in their pursuit of new products. This process starts with identifying a problem or need (e.g., a portable device for keeping foods and drinks cool), researching, brainstorming, and formulating ideas.

2. Ask students to think about transporting foods or drinks long distances and maintaining a specific temperature in their environment. Why might it be important to keep food products at a specific temperature? One very important reason is food safety, as harmful bacteria can grow in some foods and beverages.

3. Tell students to work with a partner to brainstorm users or scenarios in which keeping things cool might be especially important. Some ideas include:

- People who spend all day on the road, such as taxi, bus, or truck drivers; or, who spend all day in the sun, such as landscapers
- Camping or other outdoor activities
- Athletes or spectators at athletic fields
- Healthcare personnel who need to store medications in places that lack electricity
- Food vendors at outdoor events

Have students use the problem/ solution graphic organizer in their guides to organize their brainstorm.

EXTEND THE LEARNING

The Tesla Engineering Charter School InvenTeam from Appleton, Wisconsin, invented a refrigerator for northern climates. It takes advantage of cold outdoor air temperatures in the winter to lower the energy consumption of a standard household refriger-ator. The students describe their invention and the motivation behind it in this video from Lemelson-MIT's annual EurekaFest.

User	Problem	Need	Possible Solution
Person who drives a bus	Has no access to a refrigerator, microwave or stove	A container that reduces heat transfer through conduction or convection	A vacuum flask
High school soccer player	Wants to keep water bottle cool on the field during long practices on hot days	A container for the bottle that reduces heat transfer through radiation and conduction	A shiny bottle with a reflective surface; solar cells?

4. Ask students to conduct research to address any or all of the following:

- Find images and stories about other technologies and inventions that either limit or facilitate **heat** exchange. For example, how do cars keep from overheating? What about computers?
- Think of ways in which these technologies can be used in novel ways to address other problems.
- Identify other potential users.
- Research food storage and safety systems, and why **temperature** regulation is so important to food safety. Identify other industries where **temperature** regulation is essential.

WRAP UP

Wrap up with a short discussion that allows students to talk with classmates to share their ideas, propose solutions, and get feedback.

SELF ASSESSMENT

Collect the completed self-assessments as exit slips when students leave.

INDICATORS OF A SUCCESSFUL MEETING

Students demonstrate an understanding of **heat** and **heat transfer**. They can define **heat**, **cold**, and **energy**. They can identify the uses of insulation and **conduction** materials and have identified some common users. Teams have begun researching inventions.

NOTES

CHILL OUT
MEETING 3: KEEP YOUR COOL

KEY TERMS

Biomimicry (n): The design of new products or materials inspired by living things.

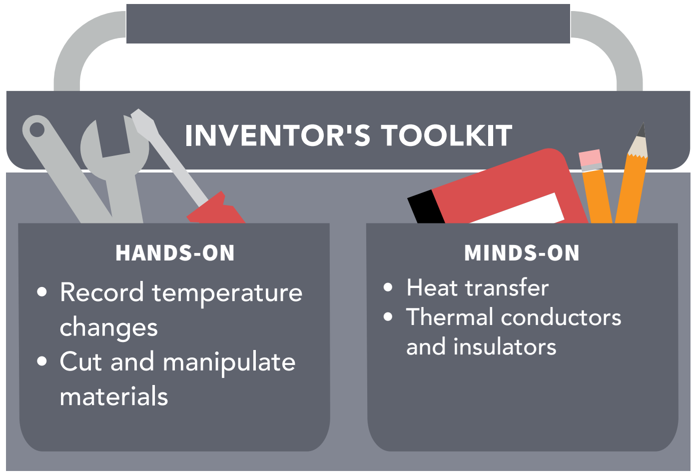
Non-renewable resource (n): Any natural resource from the Earth that exists in limited supply and cannot be replaced if it is used up.

Photon (n): A particle of light energy.

Sustainable design (n): An approach to building and construction that aims to minimize waste and produce healthy environments.

Thermal mass (n): The measure of a material's ability to absorb and store heat energy.

Wavelength (n): The distance between the peaks of two successive waves.



Tools

- Writing utensils
- Computer and projector to show videos
- Spoons
- Rulers
- Thermometers (showing both °C and °F)
- Scissors

Materials

- Student Guides
- Shop safety rules
- Safety glasses
- Electric tea kettle
- Glass measuring cup, 4-cup capacity
- Funnel
- Ice (ice will need to be stored in a freezer or cooler; a bag of ice from the grocery store will work)
- Supply of water (if you don't have a sink in the room)
- Vegetable shortening, 4 cans
- Paper or cloth towels (for drying hands)
- Packing "peanuts" (preferably recycled)
- Feathers
- Aluminum foil
- Paper
- Scrap cloth or squares of colored felt
- Plastic wrap
- Wax paper
- Cardboard or paperboard, such as broken-down cereal boxes (recycled)
- Masking tape
- Plastic or paper plates
- String
- 2 6-quart clear plastic bins (reuse from Meeting 2)
- Per Pair
- 2 gallon-size plastic reclosable bags
- 2 two-ounce clear plastic bottles (reuse some from Meeting 2)

Procedure

- Color, Light, and Heat
- Insulators
- Emperor Penguins
- Conductors
- Keep the Heat Out and Keep the Heat In
- Sharing Inventions
- Wrap-up
- Self-Assessment

COLOR, LIGHT, AND HEAT

1. Read the following text aloud, or have students read it in their guides:

How would you decide on materials and colors if you were to design an outdoor playground? Would you use dark or light colors? Would you use metal, wood, or plastic for the equipment and surface material? You will try to choose materials made from lighter colors if you want to keep cool on the playground—just as you probably try to wear lighter-colored clothing on hot, sunny days. That's because the sun emits energy in the form of solar radiation, which we observe as light and heat. Dark colors absorb this light and heat, while light colors and reflective materials deflect it, absorbing the heat more slowly.

Light coming from the sun includes **wavelengths** of light in the full visible spectrum—all of the colors of the rainbow. Black items absorb all of these colors; white items reflect them. Dark colors also absorb more **photons** than light ones.

2. Ask students: How might the property of materials to absorb light affect the choices engineers and designers make in designing new products?

3. Introduce the term **sustainable design**: an approach to building and construction that aims to reduce the use of non-renewable resources, minimize waste, and produce healthy environments. Ask students how the choice of color for a building's roof or walls might play a role in **sustainable design**.

EDUCATOR NOTE

Heat 4 cups of water to approximately 32°C (90°F) before students arrive, using the electric tea kettle. Alternatively, if you have a hot water supply in your classroom, you may simply fill the measuring cup with water that feels hot to the touch, but not scalding. You also should fill two 6-quart clear plastic bins halfway with tap water, and then add enough ice to bring the water level to within two inches from the top. Place these on two separate tables, where students will be able to gather around them later in this meeting.

EDUCATOR NOTE

Reinforce with students that temperature and heat are not the same. Temperature is a measurement, whereas heat is applied, which increases the total energy of all atoms and molecules in a substance.

4. Continue reading, either aloud or independently:

The ability of materials to differentially absorb light is one factor that engineers and architects who work in **sustainable design** consider when they are planning a new building or other development. For example, the roofs of most buildings receive a substantial amount of sunlight every day. This presents both an opportunity and a challenge: Absorbing that heat and sunlight in the winter may help to offset heating costs—but in the summer, absorbing that heat increases demand for air conditioning or other means to remove excess heat. Many buildings today have dark-colored roofs, but what if a material existed that could absorb heat in the winter and deflect it in the summer?

A team of MIT students took on this question as a challenge and invented roofing tiles that change color depending on the air temperature: They are black at cold temperatures, and turn white when the weather is warm.

Read more about the students and their invention **here**. A material's ability to absorb or reflect heat from the sun is just one property related to heat transfer that designers and engineers consider when envisioning a new product.

HIGH SCHOOL CONNECTION

The 2013 Ann Richards School for Young Women Leaders InvenTeam from Austin, Texas invented a non-electric cooling pressurized container to preserve food or medicine for those without electricity. Unlike current refrigeration systems, it uses no chemicals, and is small and transportable, weighing less than 30 lb. This low-cost invention can be used in developing countries or for use during camping trips, for food trucks, etc. Learn more here.

INSULATION AND CONDUCTION

1. Read the following text aloud, or have students read it in their guides:

Today you will experiment with different methods to prevent heat transfer from taking place. Work with a partner to answer the following questions in your guides:

- What is heat transfer and what are some examples of it?
- What are some reasons that you might want to prevent heat transfer?
- What do you think are some challenges to preventing heat transfer?
- What are some reasons that you might want to encourage heat transfer?

Recall that you observed in the last meeting some of the materials food storage containers are made from: metal, plastic, foam, and neoprene. Today you are going to build a device to test the ability of each material either to keep an ice cube from melting, or to keep a bottle of heated water from cooling down. But first, let's do some review.

Some of the items you explored in the last meeting were made of **thermal insulators**, or materials that minimize heat transfer. In what situations might it be important to minimize heat transfer? Homes are insulated to prevent heat loss during the cold winter months. Insulation also helps prevent homes from heating up during the summer. You wear layers of clothing in the winter to keep your body from losing heat to the outdoor air.

INSULATORS

1. Review with students the instructions for this activity, which are also in their guides. Then, have them work in pairs to complete the activity below.

Many marine mammals—especially those in polar environments, such as polar bears and walruses—have a thick layer of a type of fat called blubber beneath their skin. Like all fats, blubber is an effective thermal insulator. In this activity, experience how fats help to retain heat.

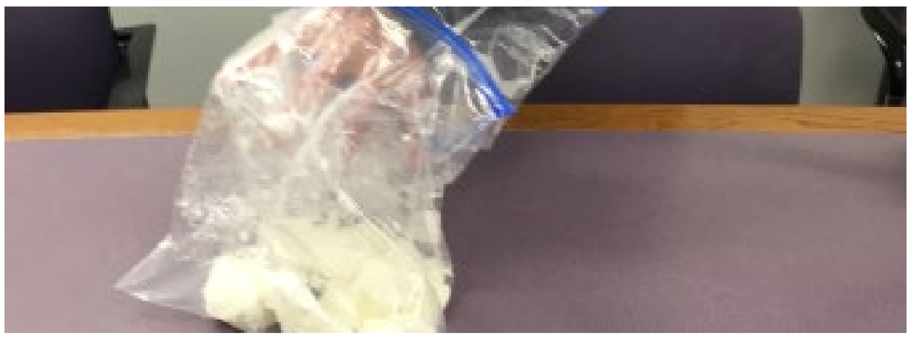
- What is heat transfer and what are some examples of it?
- What are some reasons that you might want to prevent heat transfer?
- What do you think are some challenges to preventing heat transfer?
- What are some reasons that you might want to encourage heat transfer?

EDUCATOR NOTE

Students will work in pairs on an insulation activity. Create two stations at different tables. Place half of the reclosable plastic bags, spoons, and cans of vegetable shortening at one station, next to the container of ice water that you prepared earlier. Do the same with the other half of the materials and the second container of ice water. Have paper towels on hand for students to dry their hands. Five pairs of students will work at one station, and five pairs at the other.

- Fill one reclosable bag halfway with shortening.

- Using a spoon, fill one of the reclosable bags about halfway with vegetable shortening.
- Cover your hand with a reclosable bag, and place this hand inside the bag filled with shortening.



- Turn the other reclosable bag inside out. Place a hand into this bag. Stick this hand into the bag filled with shortening.

- Move your hand around to spread the shortening evenly around the space between the two bags.
- Remove the bags from your hand and seal them together so the shortening will not leak out the top. This is your “shortening mitt.”

- Next, submerge one of your bare hands in the container of ice water. Your partner may do the same.
- Can you withstand the cold for 10 seconds? How does it feel?

- Put one hand inside your shortening mitt and submerge in ice water. Be sure that you do not allow water to pour over the top of the mitt.
- Remove and dry your hands. Then place one hand inside the shortening mitt.
- Place this hand into the ice water. Is it easier to withstand the cold? Why might that be?
- Remove your hand, and allow your partner to take a turn.

2. Have students answer the following questions in their guides:

- How did the water temperature feel to your bare hand, compared with the hand in the shortening mitt?
- Can you explain what happened, using the terms heat, heat transfer, and conduction?

SUSTAINABLE SOLUTIONS

Have you ever noticed, at the end of a sunny day, how bricks, pavement, and asphalt still feel warm even after the sun has gone down? That's because these materials have high thermal mass, the measure of a material's ability to absorb and store heat energy. One component of sustainable solutions is incorporating materials that can store the sun's heat energy during the day and then release it during cooler evening hours. Read more about thermal mass.

EMPEROR PENGUINS

1. Read the following text aloud, or have students read it in their guides:

Many marine mammals, such as whales, seals, and dolphins, have a thick layer of a fatty tissue called blubber beneath their skin. Blubber insulates their bodies by minimizing the amount of heat their bodies lose to cool ocean water. Penguins, which spend much time in the ocean, share this feature.

2. Play the video "Animals of the Ice: Emperor Penguins".

3. Have students name three body features or behaviors that help emperor penguins survive in the extreme cold of the Antarctic. Ask for volunteers to offer answers.

4. Next, have them read "**Feathers Trap Air to Provide Warmth: Emperor Penguin**," an informational text about the structure of penguin feathers and why engineers are looking to penguin feathers as inspiration for new insulating materials.

Credit: Wikimedia Commons

5. Ask students to answer the following questions in their guides:

- How do a penguin's outer feathers act as a barrier against water and wind?
- How are a penguin's inner feathers different from its outer feathers?
- How does trapping air close to the body help insulate penguins from the cold?
- What is **biomimicry**? How is the research described in this story an example of **biomimicry**?
- How could you use the properties of penguin feathers in designing a product that helps to insulate a building or a person? What about keeping a person or a building dry during a heavy rain?

EDUCATOR NOTE

Prepare for the **conduction** activity by passing around the roll of aluminum foil and a stack of paper. Each student can rip off a sheet of foil about the size of a piece of paper and take one piece of paper.

CONDUCTORS

1. Review the activity below with students. Then have them complete the activity using the instructions in their guide.

   - Place a piece of paper and a piece of aluminum foil side by side on the table or countertop. Place one hand on each. Does one feel cooler to the touch than the other? Explain why this might be.
   - Discuss these questions as a class:
     - What did you notice when you put your hand on the aluminum foil? On the paper?
     - Do you think both materials are the same temperature? Why or why not?
     - Can you explain what happened, using the terms heat and heat transfer?

2. Explain to students that when they placed their hands on the foil, the foil quickly conducted heat away from their hands to the countertop, which has less thermal energy than their hands. Paper is not as thermally conductive, so it doesn't feel as cool to the touch. Because both materials are sitting in the same environment, they both have the same surface temperature. The foil does not have a cooler temperature, but the body perceives it this way because it is losing heat to the foil.

3. Ask for a volunteer to explain in which direction heat moves in this demonstration. Heat moves from the hand to the piece of foil, and from the hand to the piece of paper. There is less heat in both the paper and the aluminum foil than in the hand.

4. Discuss with students how they might use information about thermal conductors and insulators to design a variety of products. For example, what kind of material would they use in a cooler to keep ice cream cool while they drive home from the grocery store?

KEEP THE HEAT OUT AND KEEP THE HEAT IN

1. Remind students of the lunchboxes they observed during the last meeting. In which one did the ice cube melt the fastest? Can they explain why?

2. Read the following, or have students read it independently:

You placed ice cubes in several different kinds of lunchboxes to see what would happen to them during the last meeting. From what kinds

EDUCATOR NOTE

Prepare for this activity by gathering the following materials on a central table:

- Packing "peanuts"
- Feathers
- Vegetable shortening
- Aluminum foil
- Colored paper
- Scrap cloth in different colors or squares of felt in different colors
- Plastic wrap
- Wax paper
- Cardboard or paperboard such as broken-down cereal boxes
- Masking tape
- Plastic or paper plates

Have students brainstorm the design of their containers while you use the funnel to fill the 2 oz. bottles with hot water from the electric tea kettle or sink. Remove the bag of ice from the freezer or cooler. Pass out two thermometers to each pair of students.

of materials were the lunchboxes made? What happened to the ice cube in each?

You most likely observed that the ice cube in the metal lunchbox was the first one to melt. That's because metals are very good thermal conductors, and the metal lunchbox transferred heat from the room into the ice cube.

EXTEND THE LEARNING

A common misconception about insulators and conductors is that aluminum foil is a good thermal insulator. This is because hot foods such as hot dogs and burgers are sometimes wrapped in foil at sports arenas or fast-food restaurants. The opposite, in fact, is true. The choice of wrappers for hot foods also includes criteria such as durability, malleability, and cost. For more information on the variety of materials used in wrapping foods, visit "Packaging Materials Defined."

Credit: Wikimedia Commons

Today, your challenge is to design and build a container that will keep an ice cube inside a metal lunchbox from melting, and will also keep a bottle of heated water from cooling down. Work with a partner and follow the instructions below:

- Spend a few minutes brainstorming what properties this container should have. Should it facilitate heat transfer, block it, or do both? Why? What kind of materials do you know of that have these properties?
- Think about what you have learned about **biomimicry**. Can you apply the thinking behind **biomimicry** to the design of your container? How might nature inspire your design?

3. Have students work in pairs to discuss which materials they will use to build their containers. Have them examine the materials on the central table. Encourage them to think about some of the examples of **biomimicry** they learned about in the previous meeting, and in this one as well. How might they also apply their new understanding of the role of color in insulation and conduction?

- Observe the materials on the table and, before selecting any, work with your partner to identify which materials you would like to use for your container. You also should look around the room for other materials you might use.
- Make a sketch of the container you will build. What size and shape will it have, what kinds of materials will it be made from, and how will these materials contribute to the container's ability to keep ice from melting? To keep a bottle of heated water from cooling down?
- Gather the materials you identified, and work together to build your device.
- Ask your instructor for two ice cubes and two bottles of heated water. Note the time, water temperature (°F) in each bottle, and the dimensions of each the ice cube (length, width, and height in inches). Write the measurements in the table. Can you think of a reason you are also observing the ice cube on the plate and recording the temperature of both water bottles?
- Set a timer for 15 minutes. Record temperatures and measure the ice cubes again after 15 minutes.

4. Ask students: Why are we leaving one ice cube and one bottle of water on a plate of heated water? They serve as controls to help students determine whether their inventions kept ice from melting and heated water from cooling longer than if they had simply been placed at room temperature.

Beginning Time:	End Time:
Water Temperature Bottle 1	Water Temperature Bottle 1
Water Temperature Bottle 2	Water Temperature Bottle 2
Ice Cube Bottle 1 Length Width Height	Ice Cube Bottle 1 Length Width Height
Ice Cube on Plate Length Width Height	Ice Cube on Plate Length Width Height

SHARING INVENTIONS

Have student pairs share their inventions with the class. Be sure each pair can explain the following prompts below. They also should write answers in their guides.

When you have finished both activities, answer the fol-lowing questions in your guides, and be prepared to talk about them as a class.

- Describe the container you built. What materials did you use? Did you use different materials for the ice cube and the water bottle? Why or why not?
- How well did your container perform? Did the ice cube inside the container last longer than the control cube? Why or why not?
- Did the bottle of heated water inside the container retain more heat than the control bottle? Why or why not?
- What changes might you make to improve on your design?

WRAP UP

Have students brainstorm ways they might incorporate the technologies they learned about today into a portable cooler or lunchbox. What, for example, are some ideal insulating materials, and how could they use them in the design of a cooler?

SELF ASSESSMENT

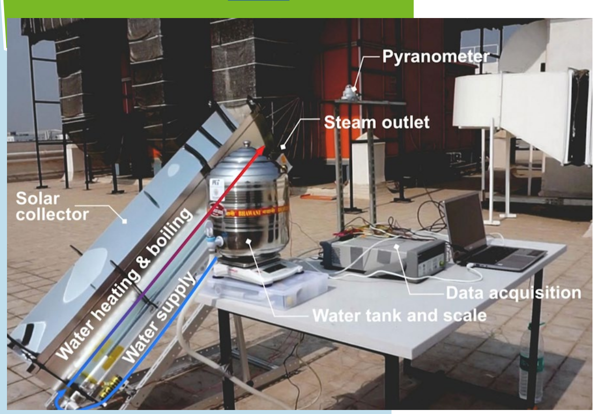
Collect the completed self-assessments as exit slips when stu-dents leave.

INDICATORS OF A SUCCESSFUL MEETING

Students demonstrate an understanding of thermal insulators and conductors, and can explain how a material's color affects its ability to absorb or reflect light and heat. They applied this understanding by designing and build-ing devices to keep ice from melting and/or warm water from cooling down.

SUSTAINABLE SOLUTIONS

Autoclaves, the devices used to sterilize medical equipment, need a steady supply of hot steam at 125 degrees Celsius. This typically requires electrical or fuel- based boilers. However, in developing countries electricity can be unreliable and fuel is very expensive. Researchers from MIT and the Indian Institute of Technology have successfully used the power of sunlight to generate the steam needed. The system works with the combination of a copper plate with mirrors to direct extra sunlight plus a new lightweight transparent foam for thermal insulation. With water pipes flowing under the device, hot steam can be produced. Learn more about this significant advance [here](#).



Credit: MIT News

NOTES

KEY TERMS

Evaporation (n): The process of changing from a liquid to a gas.

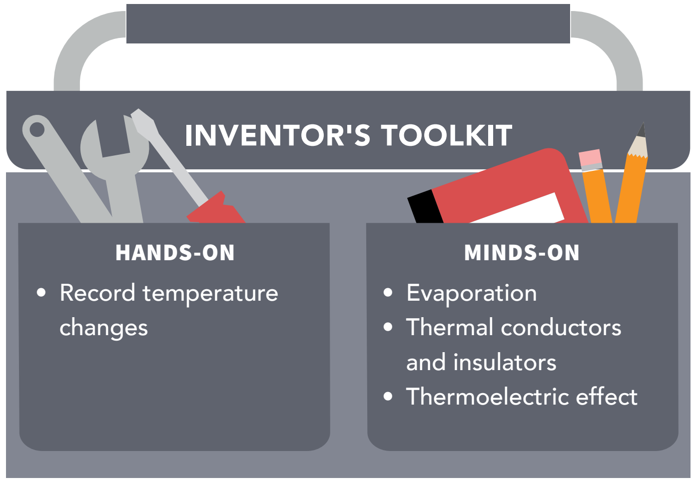
Evaporative cooling (n): The process of removing heat from a system through the evaporation of a liquid.

Heat wave (n): A period of abnormally hot and unusually humid weather.

Humidity (n): The amount of water vapor in the air.

Infrared radiation (n): A form of electromagnetic radiation that we feel as heat.

Metabolism (n): Chemical reactions that take place in the body's cells, such as breaking down food and building muscles.



Tools

- Writing utensils
- Computer
- Projector to show videos (optional)
- Infrared thermometer (2 to share with class)

Materials

Per Team

- Plastic spray bottle
- Thermometer (optional)
- AA battery holder
- 4 AA batteries
- D-battery holder
- 4 D batteries
- Peltier tile

Whole Group

- Shop safety rules
- Safety glasses
- Sand (optional)
- 20-inch terracotta pot (optional)
- 12-inch terracotta pot (optional)
- Duct tape (optional)
- Wet, light-colored cloth (optional)
- 2 empty plastic water bottles from recycling (optional)

Procedure

- Beat the Heat
- Explore Evaporation
- Cool Down
- Heat and the Human Body
- The Desert Cooler
- Build a Pot-in-Pot Cooler (optional)
- Keeping Hot, Keeping Cool
- Heat Transfer and Electricity
- Peltier Brainstorming
- Wrap up
- Self-Assessment

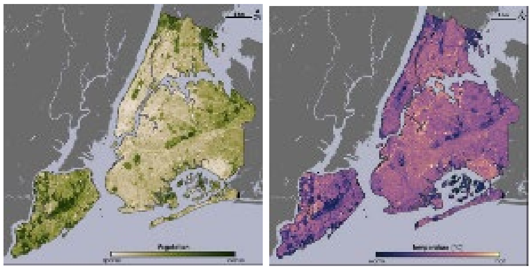
BEAT THE HEAT

1. Ask students if they have ever heard of or experienced a **heat wave**. Ask for a few volunteers to describe what it was like if students experienced one.

2. Either read the following aloud, or have students read it independently:

In the summer of 1995, the city of Chicago faced a **heat wave**, a stretch of five days of unusually high temperatures and relative **humidity**. **Humidity** is a measure of the moisture content in the air. Hundreds of people died as a result of the extremely hot weather. The combination of high temperatures and high **humidity** can be dangerous for people—especially the elderly— because these conditions make it difficult, and in some cases impossible, for the body to rid itself of excess heat.

One factor that made this **heat wave** particularly harmful in the city is a phenomenon called the urban heat island effect. An urban heat island is a densely built-up area in a city that experiences hotter daytime temperatures than nearby suburban and rural areas. Meteorologists have noticed this phenomenon for close to two centuries. Many factors contribute to the urban heat island effect. Dark-colored surfaces, such as the asphalt on road surfaces and the tar and shingles on the roofs of buildings, absorb solar radiation throughout the day and release it through the night. The loss of naturally cooling trees and vegetation as cities develop also con-tributes to this effect, as the images below illustrate.



These satellite images of New York City show the relationship between vegetation cover and the urban heat island effect. The image on the right shows a gradient from little to no vegetative cover, in white, to dense vegetation, in dark green. The image on the right shows a range in surface tem-peratures, with the coolest temperatures in dark purple and the hottest in light yellow.

Credit: Robert Simmon/NASA Earth Observatory & Landsat

Since the **heat wave** of 1995, leaders in the city of Chicago have been looking for ways to cool the city in the summer and minimize the urban heat island effect. They've turned to scientists, engineers, and architects to envision new approaches to urban development, from using building materials that are less likely to absorb and store heat to planting grasses and even trees on roofs across the city.

KEY TERMS (CONT'D)

Permeable (adj): Having openings through which liquids and gases can pass.

Porous (adj): Having small holes through which air or water can pass.

Thermoelectric (adj): Having the ability to convert temperature differences to electricity and vice versa.

Urban heat island effect (n): When cities experience higher summer temperatures than suburban and rural areas.

EDUCATOR NOTE

Fill the spray bottles with water. Gather the infra-red thermometers, a few sheets of paper, and a few pens. Place all materials on a table.

1. Have students explore Urban Heat Islands on Wikipedia. Look at the thermal images of New York City via infrared satellite imagery.

2. Ask for a volunteer to explain what kind of information is contained in the pictures. What story can they tell by seeing these pictures and knowing what the different colors represent? Can they find where Central Park is? How does vegetation affect the temperature of the area?

Credit: Tony the Tiger from Wikimedia Commons

Green roofs, such as the one on Chicago's City Hall, are one solution to keeping the city from heating up in the summer.

3. Watch the video **Urban Heat Islands Lighten Up to Cool Down**. Have a short discussion about green roofs and urban heat islands with students. Are there green roofs in your community?

- What problem are city leaders in Chicago addressing?
- What solutions have they proposed?
- How do innovations such as green roofs and permeable paving materials help minimize the urban heat island effect? What other benefits do they provide?
- How do you think the color of roofing materials affect a building's internal temperature? The choice of material itself? The temperature of the surrounding environment?

EXPLORE EVAPORATION

Tell students that today they will be exploring different methods for removing heat from a system. Ask students:

- How is removing heat different from preventing heat transfer from taking place?
- What devices do you know of that remove heat? If students struggle with this, give them a hint: What happens to a room-temperature apple when you place it in the refrigerator? An ice cube tray of water when you place it in the freezer?
- Remind students of the devices they built during the last meeting to keep an ice cube from melting. How did they prevent heat from transferring? How would their performance change if they also had the ability to remove heat from the inside of those devices?
- Explain that today they will learn about a technology that removes heat from systems. They'll also brainstorm and sketch ideas for using this technology to improve on the design of a traditional cooler or lunchbox.

COOL DOWN

1. Review with students the instructions for this activity, which are also in their guides. Split the class into teams of five to complete the activity below. Two students in each team should demo the activity for their group. Teams will have to share the limited number of infrared thermometers.

- In the last meeting, you built a device to keep an ice cube from melting. This device relied on materials called thermal insulators, which help prevent heat transfer. By preventing heat from entering the inside of the device, they slowed the rate at which your ice cube melted. Today, you are going to design and sketch a device, such as a cooler or lunchbox, that not only prevents heat transfer, but also removes heat from the system.
- Try the short activity below to experience how **evaporation** removes heat from a system.
- Make a small mark on your forearm with a pen. Measure the temperature of your forearm near this mark using the infrared thermometer. To do so, aim the thermometer straight at the mark on your arm. Hold the thermometer no more than 12 inches from your arm, pull the trigger, and note the temperature. A team member should record this number.

EXTEND THE LEARNING

Read more about the factors that create urban heat islands in the video "Urban Heat Island." Then, view a gallery of thermal images of New York City by photographer Nickolay Lamm.

EDUCATOR NOTE

Reinforce with students that temperature and heat are not the same. Temperature is a measurement, whereas heat is applied, which increases the total energy of all atoms and molecules in a substance.

- Next, spray your arm three times with water near this mark. A team member should record the temperature of your arm immediately after you spray.
- Have a team member record the temperature of the wet area of your arm every minute for five minutes, or until your arm dries completely.
- Repeat. This time fan your arm with a folded sheet of paper.
- Switch roles and repeat the activity.

2. Have the students answer the following questions in their guides:

- Describe the pattern you observed in your first test.
- How did using a fan affect results in the second?
- What does this tell you about the relationship between heat and **evaporation**?

HEAT AND THE HUMAN BODY

What is it about the human body that makes it susceptible to periods of excessive heat? Your body is constantly producing heat as a byproduct of **metabolism**. **Metabolism** is the many different reactions that take place in your body's cells to break down food, convert it to energy, and build new cells. **Metabolism** is one factor that determines normal body temperature, which for most people is 37°C (98.6°F). Heat in your body travels to your skin by conduction, where it is removed by convection as air or water currents move over your skin, and by radiation, as heat leaves your body through **infrared radiation**. **Evaporation**, or the change from a liquid to a gas, also removes heat from your body when you sweat.

THE DESERT COOLER

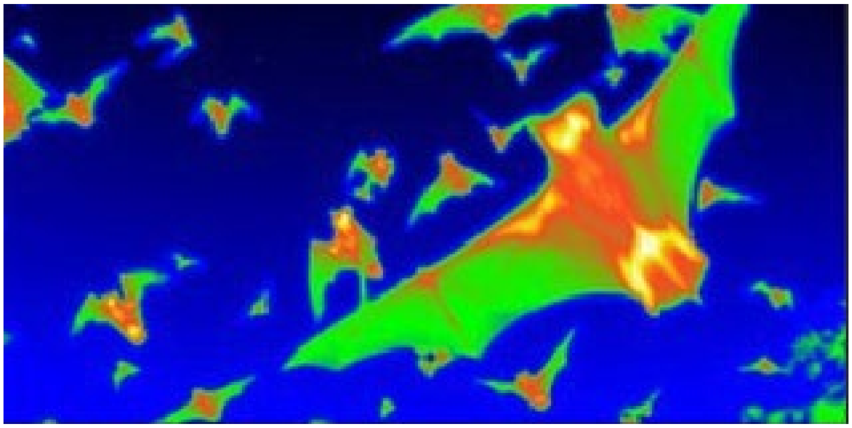
1. Read aloud the text below, or have students read it independently. **Evaporation** doesn't just help keep your body from overheating. Mohammed Bah Abba, a schoolteacher in rural Nigeria, saw a problem in the early 1990s that many of his neighbors shared. Access to electricity was scarce, and without refrigeration, it was difficult to keep foods from spoiling.

Bah Abba grew up in a family of clay pot makers and, having studied science in school, was familiar with the process of **evaporation** and its ability to remove heat from a system. He knew that clay is porous, meaning it has tiny holes through which air and water can escape. He began to wonder: Could he harness the power of **evaporation** to help keep perishable foods cool?

2. Watch the nine-minute video "**Mohammed Bah Abba, Rolex Laureate 2000**."

3. Have students address the following questions in their guides, and then discuss them as a group:

- How does this story show the design process?
- How has this invention helped Mohammed Bah Abba?



Credit: Nickolay Hristov, Tom Kunz and Margrit Betke, Boston University

The image above was taken with a thermal camera, a device that detects the infrared radiation that different objects emit. This image of bats in flight shows areas of relatively high temperatures in yellow and red, and cooler temperatures in green and blue. You can see how bats' bodies are the warmest at their core, where primary organs such as the stomach, lungs, and heart are located, whereas the wings remain relatively cool.

Learn more about heat and how too much of it affects the human body in the back-ground essay under the Support Materials of "The Science of Keeping Cool."

EDUCATOR NOTE

The pot-in-pot activity is best done outside in a sunny location on a hot day with low relative humidity. If you choose to do this activity, bring the supplies— terracotta pots, sand, container of water, duct tape, and empty plastic bottles—outdoors on a cart. The pots become very heavy when filled with sand and water. This activity is not recommended in a cool and/or humid climate: you would likely not see much of a temperature differential.

BUILD A POT-IN-POT COOLER (OPTIONAL)

1. Review the activity below with students. Then, have them complete the activity using the instructions in their guides.

- Cover the hole in the bottom of each pot with a small piece of duct tape.

Covering the drainage holes in each pot keeps water from leaking through the bottom.

Pot-in-pot coolers, like the one above, can keep vegetables cool in hot, dry climates through the process of evaporative cooling.

Credit: Peter Rinker | Wikimedia Commons

Credit: MIT News

INVENTION SPOTLIGHT

Researchers at MIT have come up with a system for keeping things cool in hot environments without the need of a power source. Camels have thick fur in spite of living in the scorching hot desert. Their thick coat can help reduce the loss of moisture while allowing sweat evaporation to provide a cooling effect. MIT engineers created a two-layer material to achieve a similar result. The bottom layer of hydrogel mimics sweat glands from which water can easily evaporate. The top layer of aerogel imitates fur by keeping out external heat and letting vapor pass through. Learn more about this camel-inspired invention here.

Credit: Wiki Commons

- Scoop enough sand into the large terracotta pot to cover the bottom to a depth of approximately two inches, or about the length of your thumb.
- Place the small terracotta pot inside the large one.
- Record the temperature of the outer surface of the large pot and the inner surface of the small one using the infrared thermometer.
  - The temperature of the surface of the outer pot is:
  - The temperature of the surface of the inner pot is:
- Fill the space between the two with sand until the sand reaches to within 1 to 2 inches of the top of the smaller pot.
- Pour room-temperature water onto the sand until it is saturated. You may need to pour a quantity of water, wait for it to seep through the sand, and then pour another quantity of water. Wait five minutes. Again, record the temperature of the outer surface of the large pot and the inner surface of the small one with the infrared thermometer.
  - The temperature of the surface of the outer pot is:
  - The temperature of the surface of the inner pot is:
- Fill two non-insulated plastic bottles, such as plastic drink bottles from the recycling bin, with room-temperature water.

Credit for all photos: Jennifer Cutraro

- Place one bottle inside the inner pot and the other beside it. Record the temperature of the water in each bottle using a thermometer.

- The temperature of the water in the bottle inside the clay pot is:
- The temperature of the water in the other bottle is:
- Cover the entire pot-in-pot cooler (with plastic bottle inside) with a light-colored wet cloth. Keep the other bottle beside the pot, uncovered.
- Return indoors, and revisit the pot at the end of the meeting, or after 45 minutes. At this time, record:
  - The temperature of the water in the bottle inside the clay pot is:
  - The temperature of the water in the other bottle is:
  - The temperature of the surface of the outer pot is:
  - The temperature of the surface of the inner pot is:

Compare this data with the initial data:

- Did the temperature of the water in the bottle inside the pot change between then and now?
- How does the temperature of this water compare with the bottle left in the sun?
- How can you explain this data?

KEEPING HOT, KEEPING COOL

1. Have students meet with their partners from the last meeting, when they built a container that not only kept a cold item cold but also kept a hot item hot.

2. In their pairs, have students take notes in their guides to address the questions below. Tell them they should be able to answer these questions well enough to explain them to a person unfamiliar with their design.

- What worked well? How?
- What didn't work as planned?
- How might you change the product to improve its performance?

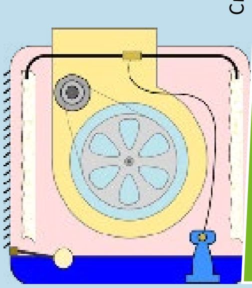
3. Have students reconvene with the teams of four they identified during the first meeting. Each student should take a turn talking about the device he or she built during the last meeting. They should show teammates sketches and the item itself, explaining why the chosen materials were used, and how they performed.

INVENTION SPOTLIGHT

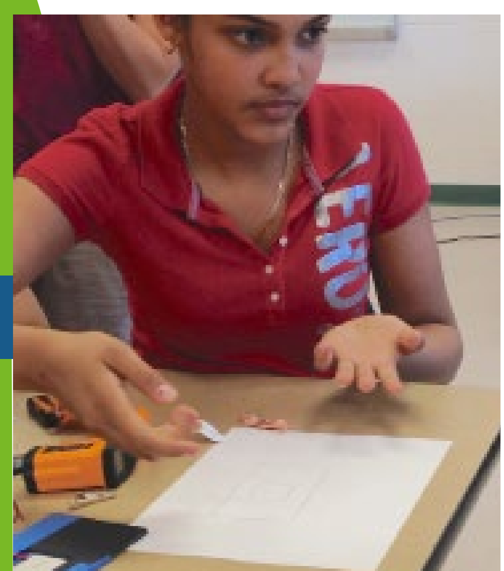
MIT student Quang Truong invented a cooler that takes evaporative cooling one step further by incorporating lighter-weight materials and more efficient heat conductors. Pot-in-pot coolers, when filled with wet sand, can be extremely heavy. The use of these lighter-weight materials makes it easier to transport perishable goods without refrigeration. Truong co-founded a company called, Evaptainers, to provide affordable refrigeration in developing countries. The company's website explains the science of how evaporative cooling works.

EXTEND THE LEARNING

Many people in arid, or dry, climates of the western United States, such as Utah, Colorado, and parts of California, rely on evaporative cooling to cool their homes in the summer. Evaporative coolers, sometimes called "swamp coolers," are devices that pass air across a material that's saturated with water. As the air passes through this material, some of the water evaporates, cooling the air that is then blown with a fan, into a home.



Credit: Wiki Commons



Part of the invention process is talking with teammates about what worked and what didn't.

Credit: Sophie Landay

HEAT TRANSFER AND ELECTRICITY

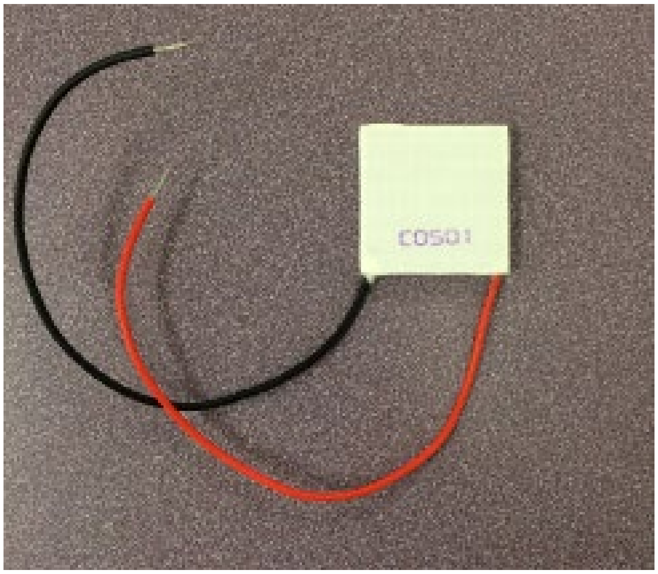
1. Read the following to your students, or have them read it independently.

Three European physicists were separately exploring different aspects of electricity in the mid-1800s. Each independently discovered and described parts of a phenomenon often called the thermoelectric effect. The thermoelectric effect happens when electricity runs through a material, creating a temperature differential across its two sides. One side becomes hot and the other side becomes cold. Conversely, electricity can be generated from this temperature differential.

Harnessing the thermoelectric effect for use in consumer products is an emerging field of research. So is using the thermoelectric effect to convert waste heat, such as the heat generated by engines, to produce electricity. Small devices called Peltier tiles take advantage of this effect. These devices are named for Jean Charles Athanase Peltier, the French physicist who described the thermoelectric effect. Today, you are going to experiment with Peltier tiles. How quickly do they heat up? What temperatures do they reach on each side?

2. Have students answer the questions below in their guides, then have a short discussion centered on these questions. Explain that today they will begin to explore Peltier tiles in their teams of four.

- How might you use a material that gets hot on one side and cold on the other in new products?
- What problem could materials like these help you solve?



Credit: Jennifer Cutraro

Example of a Peltier tile. The white square tile gets hot on one side and cold on the other when the red and black wires are connected to a battery.

MEETING 4

EDUCATOR NOTE

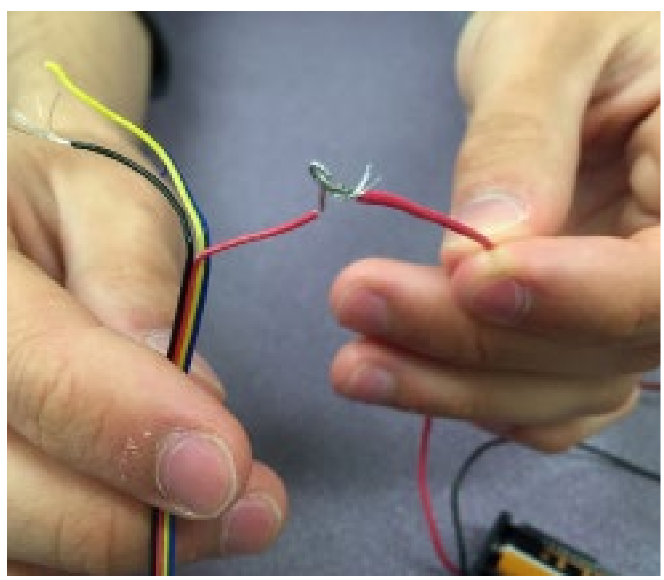
Consider splitting the meeting here if you are running out of time. Gather the AA battery holders, AA batteries, D-battery holders, D batteries, Peltier tiles, and infrared thermometers to distribute to teams.

3. Have students gather with their teams, and give each team:
    - one AA battery holder
    - one D-battery holder
    - four AA batteries
    - four D batteries
    - one Peltier tile

Teams will share the classroom's two infrared thermometers.

Have students follow the steps below, which are also in their guides:

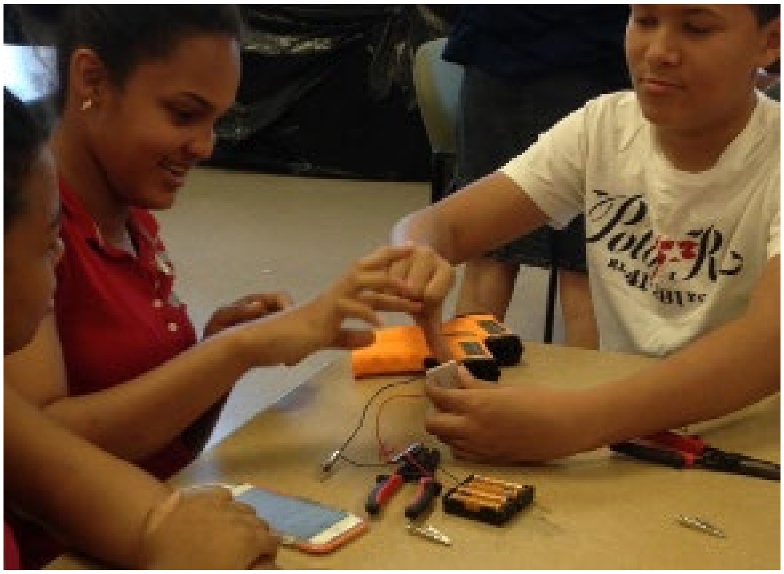
- Put on your safety glasses.
- Touch the Peltier tile and note what its temperature feels like. Does its temperature feel the same on each side?
- Have one member of the team use the infrared thermometer to measure the temperature of one side of the tile. Another team member should measure the temperature of the other side. A third team member should measure the temperature of the surface of the desk.
- Record these data in your guide.
- Have the fourth group member connect the wires on the tile to the wires on the AA battery holder. Be sure to connect red to red and black to black. To do so, twist the metal part of the wires together, as you can see in the photo below.
- Place the AA batteries inside the battery holder.



Credit: Jennifer Cutraro

Twist together the exposed metal part of each lead to connect two devices, such as a battery holder and Peltier tile. Be sure you only connect wires of the SAME color.

- Have each team member feel both surfaces of the tile. How do the sides differ?
- Record the temperature of the two sides again after one minute. Compare with the initial readings.


Credit: Sophie Landay

You should quickly feel a temperature differential when you connect the Peltier tile to the battery holder.

- Repeat after five minutes. How do the temperatures compare now?
- Remove the batteries from the battery holder and then disconnect the wires.

PELTIER BRAINSTORMING

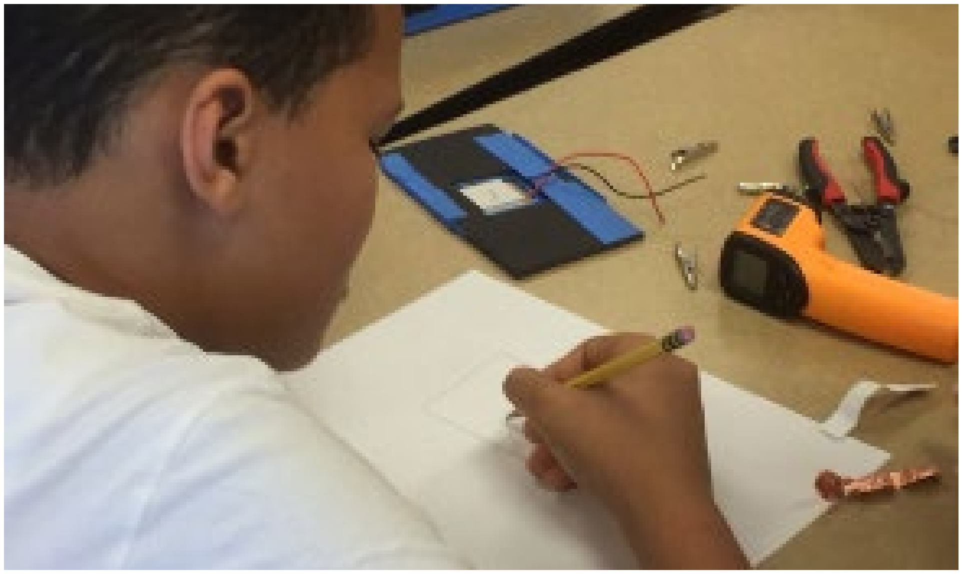
- Return to the questions you answered earlier, in the section
- “Keeping Hot, Keeping Cool.” What were some of the ideas you proposed for improving your product?
- Review some of the technologies and inventions you have learned about that help to remove heat from systems.
- Think about some of the challenges in keeping foods and beverages cool, especially on a hot day. What are some mechanisms you can think of for removing heat from a system?
- A Peltier tile can act as a heat pump, or a device that moves heat from one side of the device to the other. Talk with your team about how you might use this property of a Peltier tile in a lunchbox or cooler.
- Write about and sketch some ways in which you might design a portable cooler that uses a Peltier tile in an innovative way. You will build upon these ideas in your next meeting.

EDUCATOR NOTE

The students will likely observe that after a few minutes, the cold side of the tile begins to warm up again. Peltier tiles only maintain a pronounced temperature differential if the heat moving from one side to the other has somewhere to go.

WRAP UP

Have students work in their teams to answer the questions below. They should talk about their answers and record their ideas in their guides.



Sometimes it helps to write and sketch ideas independently and then share them with the members of your team.

This image shows an early prototype of the temperature-regulating bracelet invented by a team of MIT students.

Credit: Franklin Hobbs

- Revisit your list of potential users from Meeting 2. Are there other users or unmet needs you can think of that you might add to this list?
- How do you think a cooler using Peltier tiles might help meet some of the unmet needs for this user, or others you think of?

SELF ASSESSMENT

Collect the completed self-assessments as exit slips when students leave.

INDICATORS OF A SUCCESSFUL MEETING

Students have a basic understanding of **evaporation** and other means of removing heat from systems. They understand how and why too much heat can be harmful to people, and what solutions city leaders have proposed to keep urban areas from getting too hot in the summer. They also have learned about Peltier tiles and practiced connecting them to battery holders.

EXTEND THE LEARNING

A team of MIT students took home first prize at the MIT and Dow Materials Engineering Contest (MADMEC), a materials science design competition held at MIT each year. They invented a bracelet that helps people maintain an ideal body temperature. It relies on a thermoelectric tile that transfers heat from one side to the other when you apply a current to it. As a result, one side feels cold to the touch; the other feels warm. Read more about this cool invention—Wristify.

NOTES

CHILL OUT

MEETING 5: PELTIER PROTOTYPING

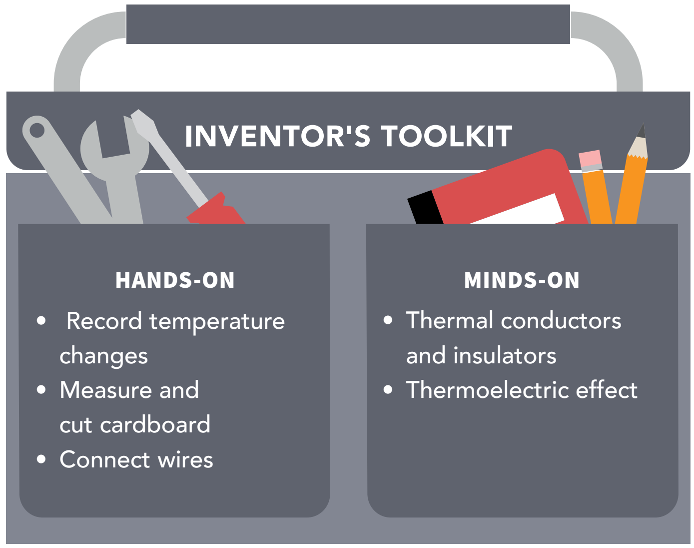
KEY TERMS

Alternator (n): A device that converts mechanical energy into electrical energy.

Ambient (adj): Of the surrounding environment.

Condensation (n): The process by which water vapor in the air changes into a liquid.

Heat sink (n): A device or material that absorbs or stores excess heat.



Tools

Whole Group

- Student Guides
- Computer and projector to show videos
- Infrared thermometers (2 to share among teams)

Per Team

- Writing utensils
- Indoor/outdoor digital thermometers with wired temperature probe
- Clock, watch, cell phone, or other device for recording time
- Safety glasses
- Ruler
- Masonite board
- Wire cutter/stripper
- Utility knife

Materials

Entire Class

- Masking tape

Per Team

- 2 empty 16-ounce plastic bottles (check the recycling bins)
- Battery pack for four D-cell batteries
- 4 D-cell batteries
- 2 20-inch x 20-inch sheets of cardboard
- 2 Arctic Alpine 11 Plus CPU fans
- Peltier tile
- Alligator clamps (optional)

Procedure

- Build a Simple Circuit
- Controlling the Motion of a Motor
- Build a Circuit to Control a Motor
- Self-Assessment

MEETING 5

Procedure

- Building a Better Lunchbox
- Product Development and Prototyping
- Building a Peltier Cooling Unit
- Designing and Building the Lunchbox
- Testing the Peltier Cooling Unit
- Assembling the Lunchbox
- Prototyping with Peltier Tiles
- Wrap Up
- Self Assessment

BUILDING A BETTER LUNCH BOX

Read the following aloud or have students read it independently.

Look back to the end of the last meeting. You might have noticed that your Peltier tile (when connected to the battery holder) initially got cold on one side and hot on the other. However, after several minutes, the cold side began to warm back up. Why might that be?

Think back to what you have already learned about heat transfer. Heat moves from areas where there is more heat to areas where there is less. A Peltier tile works as a heat pump, using electricity to help move heat from one side to the other. But, this only works over time if the heat is somehow removed from the hot side.

Today, you are going to explore how to remove the heat from a Peltier tile and then use what you learn to build a cooling device that you can place inside of a lunchbox. This will not just keep things cool, but also remove the heat that enters the system. You will also explore whether it is feasible to use the heat removed from the tile to keep other things warm.

PRODUCT DEVELOPMENT AND PROTOTYPING

Read the following aloud or have students read it independently.

Today you will build a two-compartment lunchbox in your teams. You will test whether you can use a Peltier tile to cool one compartment below **ambient** room temperature and use the heat removed from the tile to warm another compartment. You will build a prototype of a lunchbox out of cardboard. You will build a prototype of a Peltier cooling unit—a device made from a Peltier tile and two **heat sink** cooling fans—and test its performance in the prototype lunchbox.

EDUCATOR NOTE

Reinforce with students that temperature and heat are not the same. Temperature is a measurement, whereas heat is applied, which increases the total energy of all atoms and molecules in a substance.

BUILDING A PELTIER COOLING UNIT

Have students read the instructions below and review them as a class. They will make a Peltier cooling unit—a unit composed of a Peltier tile sandwiched between two **heat sink** fans. These types of fans are used inside of computers (the CPU in the materials list stands for "central processing unit"). They help to remove the heat generated by the processor inside of a computer. The computer may shut down unexpectedly, and parts of the computer may even become damaged, if the processor overheats.

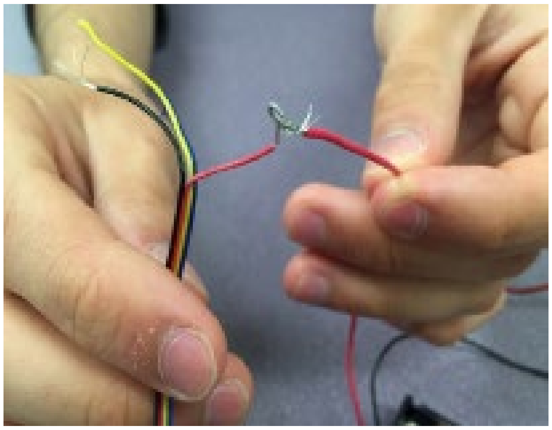
EDUCATOR NOTE

Have students wear safety glasses while they connect wires and cut cardboard.

Watch the five-minute video "**What Is a Heat Sink, as Fast as Possible?**"

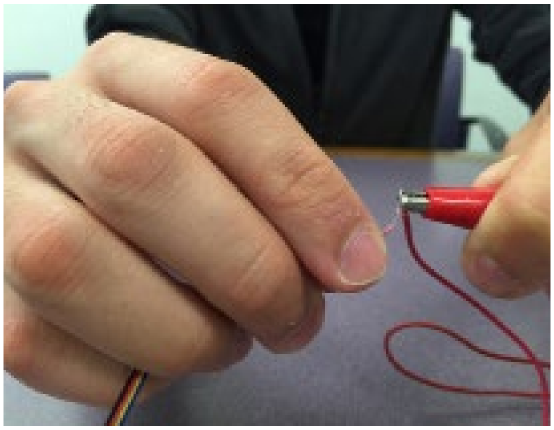
PELTIER TILES

- Put on your safety glasses.
- Place the batteries inside the battery holder. Connect the wires (also called leads) on the battery holder to those on the Peltier tile by twisting the metal part of the leads together, as you see in the photo below. You can also connect the leads with small alligator clamps, as shown in the second photo. Be sure to connect red to red and black to black.
- Feel both sides of the tile after a few seconds. Write "cold" on the cold side and "hot" on the hot side.



Credit: Jennifer Cutraro

Twist together the exposed metal part of each lead. Be sure you only connect leads of the SAME color.



Credit: Jennifer Cutraro

You also may connect the devices by placing the metal parts of each lead inside of a small alligator clamp.

The tiles quickly become cold on one side and hot on the other.

- Disconnect the wires and allow the tile to return to room temperature.

HEAT SINKS

- Open both boxes containing the cooling fans. Remove the fans and place them fan-side-down on the table.
- Pull on the plastic connector (the plastic cap with holes in it) with one hand while holding onto the thick black wire with the other. You will see that inside there are four narrow wires in four different colors.
- Your fan may have one of two types of wiring scheme. Please see the table below to identify the wiring scheme for your fan.

Credit: Sophie Landay

This student has placed her heat sink fan fan-side-down on the table. The gray square in the middle of the flat surface of the fan is adhesive material.

Credit: Jennifer Cutraro

Pulling on the connector exposes the wires inside.

Type 1	Type 2	Function
Black	Black	Ground
Red	Yellow	VDC+12V
Yellow	Green	RPM Signal
Blue	Blue	PWM Signal

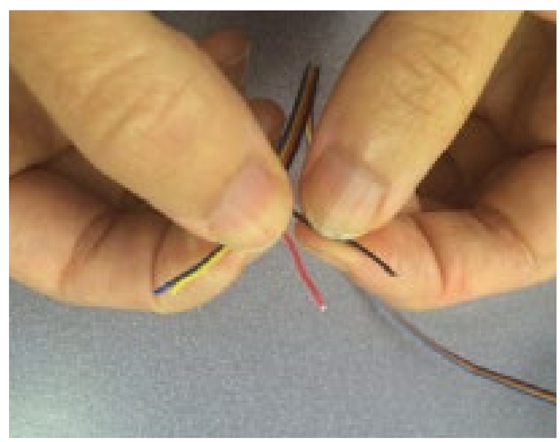
EDUCATOR NOTE

Each team should have the following materials distributed to them or left on tables at the start of this activity: D batteries, D battery holder, alligator clamps (optional), Peltier tile, two heat sinks, wire cutters/strippers, and infrared thermometers (to share among teams).

- Use wire cutters to cut off the plastic connector, working with a partner.
- Pull gently on the outer coating that covers the wires. It should pull off in one piece, exposing the four colored wires.
- Separate the red and black wires from the blue and yellow ones by inserting a thumbnail between them and gently pulling apart. Then, separate the red from the black in the same manner. You will not need to use the yellow or blue wires in this project.
- Strip, or remove, about one inch (about half the length of your thumb) of the insulating plastic coating from both the red and the black wires. To do this, place the wire inside the opening of the wire cutter that fits snugly. Squeeze the handle of the wire cutters, and pull the wire directly away from

These teammates are working together to expose the colored wires and cut off the cap.

Removing the connector exposes the four colored wires inside. The outer covering should pull off in one piece with a gentle tug.

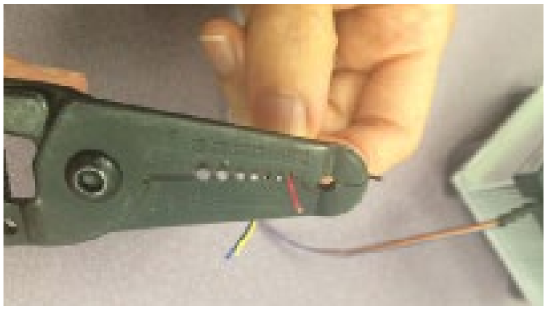


Credit for all photos: Jennifer Cutraro

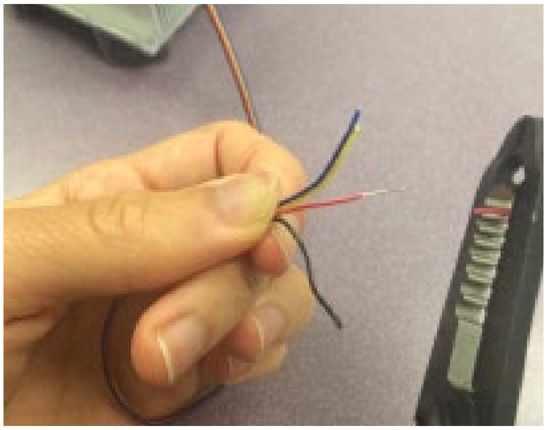
The colored wires can easily be separated with a fingernail.

the wire strippers (don’t bend the wire up or down as you pull it away). The wire stripper should cut through the plastic insulation and the insulation should pull off the wire. You might want to practice a few times with an extra piece of wire.

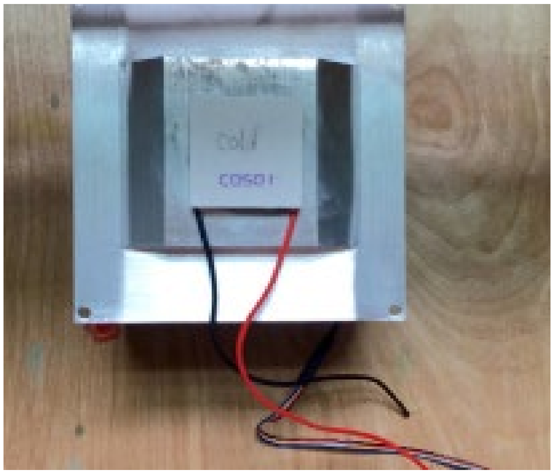
- Place the Peltier tile on the flat surface of the fan with the hot side down. Align it so that the wires coming from the tile are pointed in the same direction as the wires coming from the fan; this makes it easier to connect all of the components to the battery holder. The fan has a small patch of adhesive on its flat surface; press the tile firmly to attach to the flat surface of the fan, and then rotate the fan onto its side.
- Connect the wires from the tile and the wires from the fan to the battery holder. Remember to connect the red wire to the red wire and the black to the black by twisting



Wire strippers should snugly enclose the wire without nicking the wire.



Stripping the colored insulation exposes the wire interior.



The Peltier tile has been placed on top of the heat sink fan with its wires facing the same direction as the wires coming from the fan.

PATENT SPOTLIGHT

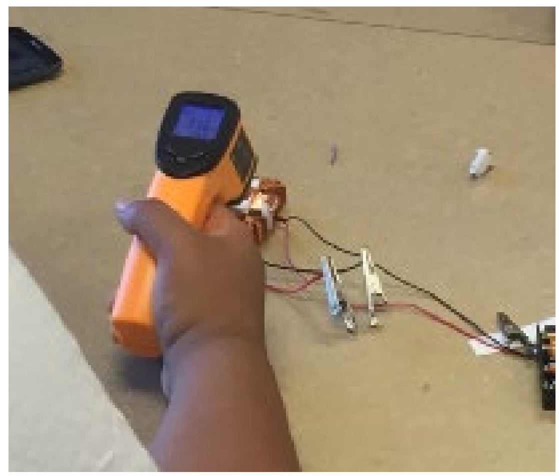
Why does your heat sink fan have four different colored wires? Heat sink fans are typically used to cool components inside of a computer. They are powered by the computer and also communicate with the computer to provide feedback about the fan’s operation. The red and black wires connect to the computer’s power supply, giving power to the fan. The yellow wire is called the “tacho,” and it communicates with the computer to let it know how quickly the fan is spinning. The blue wire is called the PWM control; this wire governs the fan’s operation. Read more about PC fans here.

together the exposed metal wires, or by connecting them with an alligator clamp. The cold side of the tile should immediately begin to feel cool, and the fan should begin spinning.

- Shine the beam from the infrared thermometer directly onto the Peltier tile on top of the **heat sink** fan to record its temperature. Note the time on a clock, cell phone, or watch. Record the data below:
  - Tile temperature: °C
  - **Heat sink** temperature: °C
  - Time: min sec
- Record both temperatures again after one minute. Record the data below:
  - Tile temperature: °C
  - **Heat sink** temperature: °C
- Time: min sec

Credit: Liza Goldstein

Power the fan by connecting the red leads on the fan and the battery holder, and connecting the black leads on the fan and battery holder. This creates a closed circuit.

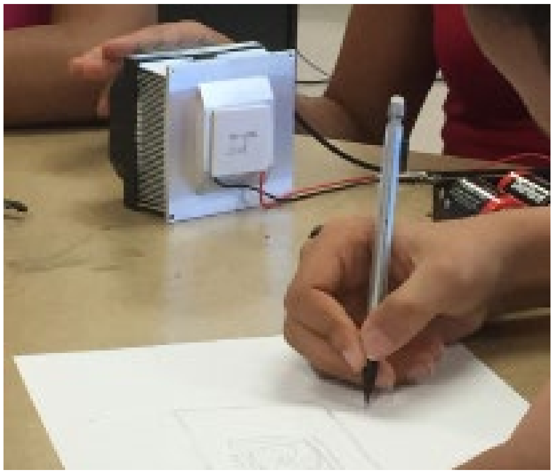


Credit: Ross Bloomfield

Shine the beam from the infrared thermometer directly onto the Peltier tile atop the heat sink fan to record its temperature.

MEETING 5

- Leave the cooling unit connected to the battery holder, but remove one of the batteries from the battery holder to turn off the fan and cooling unit. You will return to this setup later in this meeting.



Credit: Ross Bloomfield

Sketching the components of an invention is one part of the process.

EXTEND THE LEARNING

The electricity that cars and other vehicles use to power the lights, radio, power windows, and instrument panels comes from the vehicle's battery, which is recharged by a component called an alternator. The motion from the vehicle's engine—which uses gas—spins the alternator, which creates electricity to recharge the vehicle's battery.

MIT professor Gang Chen's invention has paved the way for vehicles to produce electricity from the engine's waste heat—bypassing the need for the alternator all together, and possibly boosting the vehicle's fuel efficiency. [Read more](#) about his invention.

DESIGNING AND BUILDING A LUNCHBOX

How to Cut Cardboard with a Utility Knife

[Watch a video on MIT's Josh Ramos](#) as he shows you how to cut cardboard.

EDUCATOR NOTE

Distribute cardboard sheets, masonite boards, and masking tape to teams. Explain that students need to be very careful when using the knives.

SAFETY

- Wear safety glasses.
- Always cut cardboard on top of masonite board in order to protect the tables.
- Hold the utility knife with thumb near the front, and pinky near the back.
- Stand up to get better leverage on your work when cutting.
- Keep your other hand on the material to stabilize it, but above and away from where you're going to cut. Don't cut toward your hand.

EDUCATOR NOTE

Have students watch the following video from **MIT's Design Online**, a resource for learning about design and prototyping. Review the safety notes before students begin. Have students practice cutting with scrap pieces of cardboard before they begin building.

- Make a shallow cut first along the line, slowly and easily.
- Make a few more cuts along the same line until you cut all the way through.
- Cut against a ruler for precision.
- Close the blade when not in use.

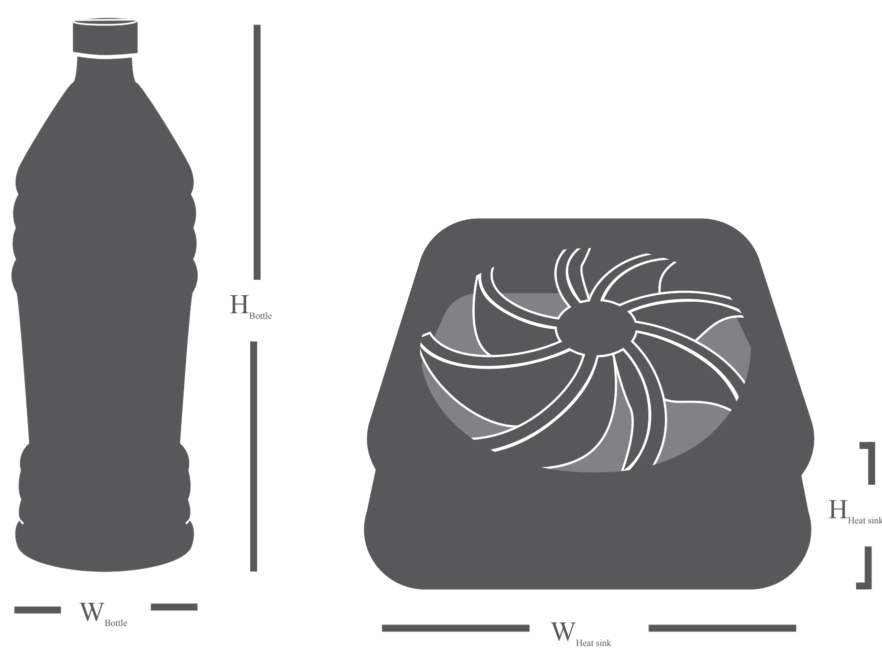
1. Tell students they will be making a prototype for a lunchbox that will keep a non-insulated bottle of water cold. Their finished lunchbox probably won't be pretty, but it will provide insulation. Let students experiment with variables such as how large to make the cooling compartment and how best to fit the Peltier cooling unit into the lunchbox.

2. Review the instructions below with students. These are also in their guides.

- Roughly measure the height and width of the bottle that you want to keep cool (or warm). A typical water bottle is about nine inches high and three inches wide. Enter those values below:

H (bottle) =

W (bottle) =



Roughly measure the height and width of your **heat sinks**. The Alpine 11 Plus fan is about three inches high and four inches wide.

H (**heat sink**) = ___________ W (**heat sink**) = ____________

- Determine the height of your box. The bottle will need to lie on its side in the box. The box also will contain the **heat sink** fans, standing on their sides. Thus, the box needs to be at least as high as the larger of either the width of the **heat sink** fan or the width of the bottle. Determine the largest of W (bottle) or W (**heat sink**) from above, and add 1 inch or more.

H (box) = [largest of W (bottle) or W (**heat sink**)] + 1 inch

H (box) = _______________

- Determine the width (long side) of the box. The box is going to have two sides of equal size, and each should be able to fit a **heat sink** and a bottle. We'll add two inches on each side to make sure you have room.

W (box) = 2 x [W (bottle) + H (**heat sink**) + 2 inches]

W (box) = _______________

- Calculate the depth of the box. The box will need to be deep enough for the water bottle to lie down in. Use the height of the water bottle and add two inches.

D (box) = H (bottle) + 2 inches D (box) = _____________

- Make the sides and middle divider by measuring and then cutting three pieces of cardboard with the dimensions H (box) x D (box). Fill in the blanks below with the measurements you will use, based on the size of your water bottle.

D (box) = _____________ H (box) = _____________

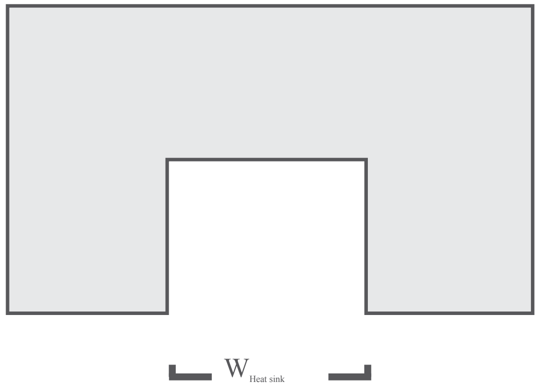
- Make the front and back by measuring and cutting two pieces of cardboard of dimension H (box) x W (box). Fill in the blanks with the measurements you will use.

H (box) = _____________ W (box) = _____________

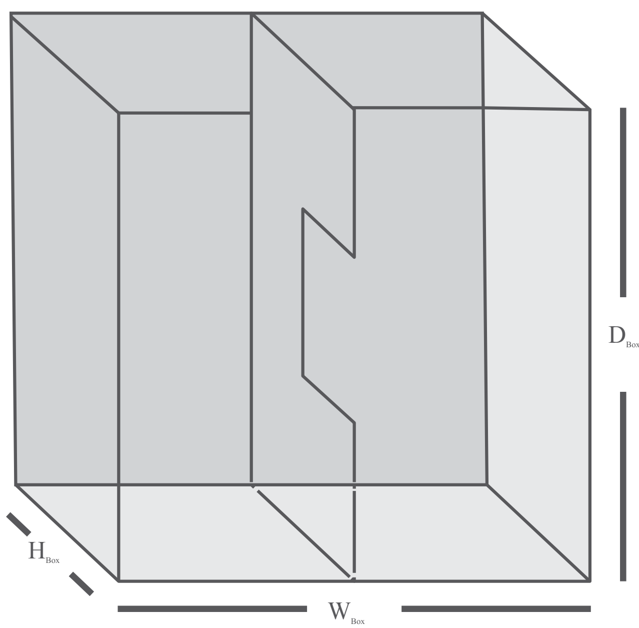
- Make the top and bottom by cutting two pieces of cardboard with the dimensions W (box) x D (box).

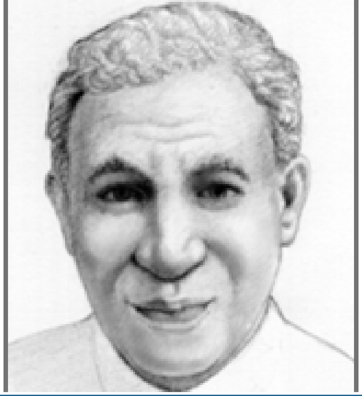
W (box) = _____________ D (box) = _____________

- Cut a hole in the middle divider (which you cut already) that a **heat sink** can fit into. It will be easiest if the **heat sink** is resting on the bottom of the box, so the hole should be on the bottom of the board. Use the W (**heat sink**) dimension from above to cut the hole. It should look something like this:



- Tape the pieces together, but keep the top off. (Tip: Instead of tearing off pieces of tape one at a time, tear off a two-foot section first, attach one end to the table, and tear off little pieces from that—things will go faster!)
- Use the diagram below as a reference. Place the middle piece in last to determine whether it fits snugly, but do not tape it in place yet; you will do this later when you fit the Peltier cooling unit in place.

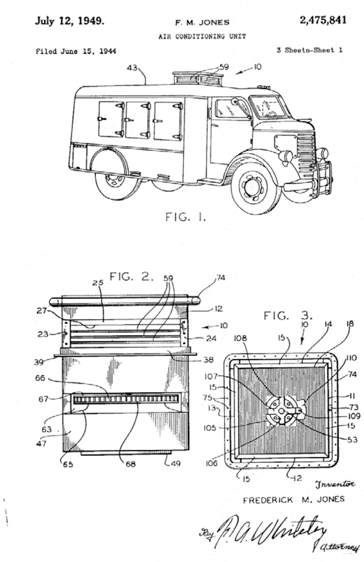




Credit: Lemelson-MIT

INVENTION SPOTLIGHT

Frederick McKinley Jones was an African American inventor who taught himself mechanical and electrical engineering. In the mid-1930s, he noticed that truck drivers were frustrated with the spoiling of food stemming from melting ice in their trucks. He designed and patented a portable air-cooling unit for trucks carrying perishable food. Jones founded the U.S. Thermo Control Company, which grew substantially during World War II, helping to preserve blood, medicine and food. Jones earned over 60 patents during his lifetime. [Learn more here](#).



Air conditioning unit for truck.

Credit: USPTO

TESTING THE PELTIER COOLING UNIT

1. Have students return to the pages in their guides from the last meeting, when they tested the Peltier tiles. How long did the tiles resting on the table stay cold? Can they explain why they did not stay cold for very long?

2. Ask students to predict how their Peltier tiles will perform today, after being attached to the **heat sink** fan. Explain that they will compare the performance of the tile with and without the **heat sink**, to determine if adding a heat sink will lead to better performance inside the lunchbox.

- Record the time. How much time has elapsed since you first connected your Peltier cooling unit to the power supply?

- Lightly touch the surface of your Peltier cooling unit. How does it feel?

- Lightly touch the surface of the **heat sink** fan. How does it feel?

- Use the infrared thermometer and record the temperature of the surface of both the tile and the **heat sink**. If the tile has **condensation** beading up on it, wipe it away first with a paper towel.

Tile temperature: °C **Heat sink** temperature: °C

Time: ________min________sec

- Record the final temperature of the tile after X minutes, with X being the number of minutes that have passed. Final tile temperature: °C

Number of minutes that have passed:

- Record the final temperature of the **heat sink**

  fan. Final **heat sink** temperature: °C

- Compare the final temperature of the Peltier tile today with the final temperature of the Peltier tile during the last meeting. How do they differ? Final tile temperature today: °C

Final tile temperature last meeting: °C

- Compare the beginning and final temperatures of the **heat sink** today. How do they differ? Beginning **heat sink** temperature: °C

Final **heat sink** temperature: °C

EDUCATOR NOTE

Distribute the indoor/ outdoor thermometers to teams.

Students should observe a dramatic increase in the length of time the tile remains cold, and quite cold at that, compared to the Peltier tile alone that they tested in Meeting 4. They also should notice that the **heat sink** feels warmer at the end of this time period than it did at the beginning. If they were to remove the Peltier tile at this time, the hot side would not be nearly as hot as it was during the last meeting. That's because the heat from the tile moved into the **heat sink**.

The **heat sink** fan is made of metal, a thermally conductive material. This **heat sink** helps heat transfer from one side of the Peltier tile to the other side, allowing heat to continually move from a high temperature surface to a lower temperature surface. The shape of the **heat sink** contributes to this function; it is made of numerous fins, much like a radiator. This increases the surface area the heat can flow to, and ultimately the fan transfers heat to the air by thermal conduction and convection.

ASSEMBLING THE LUNCHBOX

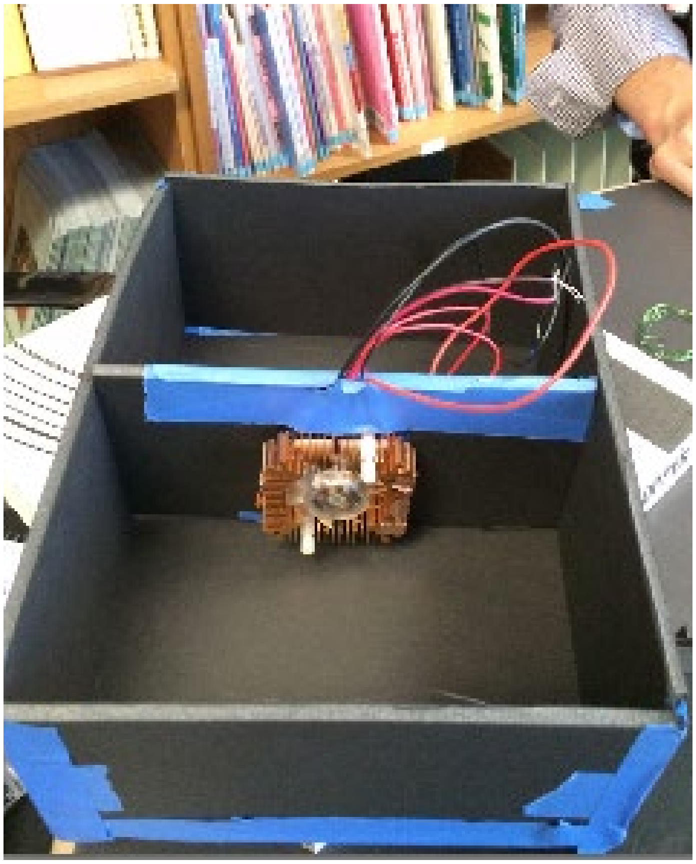
1. Fit the Peltier cooling unit (the fans connected to the Peltier tile) into the middle divider you cut out earlier, so that the tile roughly lines up with the cardboard and both of the fans face outwards.

Credit: Ross Bloomfield

This student is aligning a Peltier cooling unit inside the cardboard divider.

Note: Students in this photo and photos on the subsequent pages used foam core for their box instead of cardboard.

- Place the divider with the Peltier cooling unit inside the box. Your battery holder should be connected to the Peltier cooling unit. If you notice gaps where the cardboard divider meets the walls of the box, seal them off with tape. It should look something like this (right):



Credit: Jennifer Cutraro

A proof-of-concept lunchbox, showing a Peltier cooling unit situated so that cooled air circulates on one side and warmed air circulates on the other.

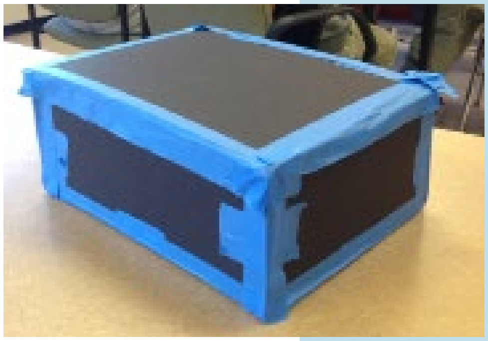
- Place the base of the indoor/outdoor thermometer inside the warm side of the lunchbox and the probe on the cool side. Record the initial temperature of each side.

Credit: Energy Institute

- Warm side temperature: °C

- Cool side temperature: °C

- Place the top on the box and seal all the sides with tape when you have confirmed that the fans are on and the tile is cooling (you should be able to feel the **heat sink** on the cold side cooling down fairly quickly). It should look like this:



Credit: Sophie Landay

PROTOTYPING WITH PELTIER TILES

1. Explain to students that they will watch a short video about another potential use for Peltier tiles. Read aloud the text below, or have students read it before they watch the video.

Peltier tiles hold promise for cooling applications in portable devices—or in places where there might not be electricity—because of their small size and solid construction. Inventor and tinkerer Eric William shows one such application in **this video**:

- What problem did Eric identify?
- What solution did he propose?
- How did he prototype and test his idea?
- Did his device work? Why or why not?
- How does he suggest he might improve on this prototype?
- Eric subtitles his video "Fail." What does he mean, and how does he use this "fail" as a way to improve his design?

2. Explain to students that inventors embrace failure and learn from failure. Often they also try to "break" a design to test its failure limits. How does this example show how we can learn from failure?

WRAP UP

Have students reconvene with their teams. Review the following steps, which are also in their guides.

- With your team, return to your lunchbox. Open the lid, and immediately record the temperatures shown on the indoor/ outdoor thermometer.

Warm side final temperature: °C

Cool side final temperature: °C

- How do these temperatures compare to the initial temperatures?
- Is this what you expected to see? Why or why not?
- If not, what might be some reasons?

Refer back to the video and answer the following questions in your guides:

- What are some of the ideas Eric proposed for why his invention didn't work as he expected?
- How does he plan to troubleshoot these problems?
- Can you use any of his suggestions to improve on your invention? How?

SELF ASSESSMENT

Collect the completed self-assessments as exit slips when students leave.

INDICATORS OF A SUCCESSFUL MEETING

Students demonstrate an understanding of thermoelectric cooling and **heat sinks**. They also understand how to safely measure, cut, and build with cardboard. They applied this understanding by designing and building a proof-of-concept lunchbox with heated and cooled compartments.

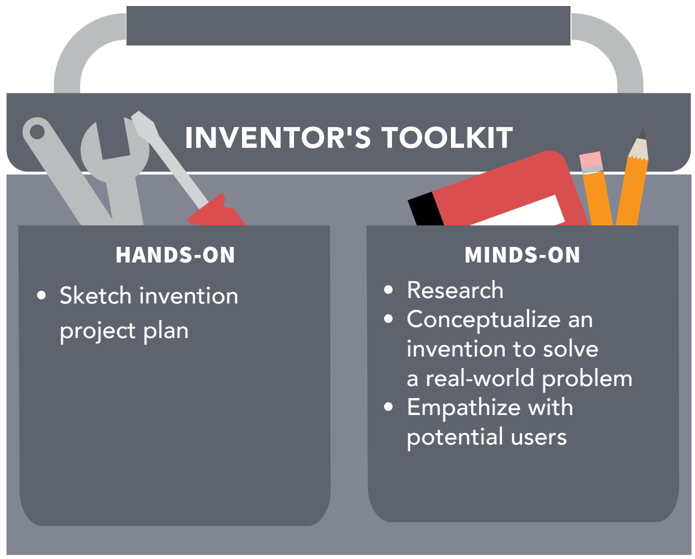
NOTES

U CONTROL

MEETING 6: INVENTION EXTENSION

KEY TERMS

Empathy (n): The ability to understand and share the feelings of others.



Tools

- Writing utensils

Materials

- Student Guides
- Computer for research
- Self-Assessments

Procedure

- Introduction to Invention Challenge
- Review Real-World Examples
- Brainstorm Invention Ideas
- Brainstorm Solutions
- Make a Plan
- Self Assessment

INTRODUCTION TO INVENTION CHALLENGE

Read the following aloud to students. This section gives students more information about the Invention Challenge.

Sit back and reflect on the new toolkit of skills you have acquired in this unit. You have new minds-on skills such as working in teams and under standing the design process, the prototyping process, heat transfer, heat conductors and insulators, and the role of heat in everyday life. You have gained hands-on skills such as making circuits, cutting and stripping wire, cutting cardboard, and wiring together a Peltier tile, a battery holder, and heat sink fans.

Invention is centered on **empathy** and fulfilling people's needs. How could you use your new skills to solve a real problem? Your challenge is to select a person or group of people with a need and apply your skills to invent a solution.

Students will conceptualize a project. Your ideas have the possibility of becoming an InvenTeams project in future years!

Before you decide WHAT to invent, you must research a real need and determine WHO you will be helping. You can think locally, regionally, nationally, or even internationally. If you choose to look internationally, you can research the needs of a particular country or region to develop a product that may be useful. Perhaps your school already has a partnership with a "sister city" in another country.

For additional information on problems/needs in other countries, explore the **World Bank** website.

REVIEW REAL-WORLD EXAMPLES

Review as a class the examples of purposeful inventions on the following pages.

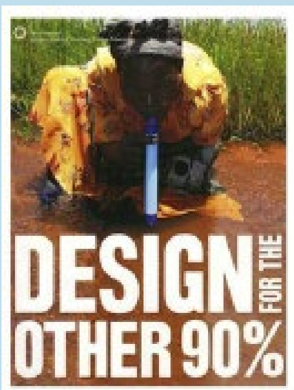
Example 1

Product designer Ian Tansley was working on sustainable development projects in Africa and Asia when he saw the need for better technologies to cool vaccines and other medicines in places lacking electricity. A walk around a frozen lake got him thinking about a seeming puzzle: If hot water rises and cold air sinks, why is there ice at the top of a lake and not the bottom? The phenomenon is explained

EDUCATOR NOTE

Extend the Learning

Explore the book Design for the Other 90%, by Cynthia E. Smith, to read about projects that help the 5.8 billion people in the world who have little or no access to the products and services many of us take for granted.



EDUCATOR NOTE

After Reading These Examples

Give students a few minutes after reading each example to record their ideas in their guides.

by some of the unique physical properties of water, which he applied to invent a new type of cooling technology. He teamed up with entrepreneur Peter Saunders to start the company **Sure Chill, Ltd.**, which specializes in solar-powered refrigerators that use this technology.

Read more about his invention here.

Discuss as a Class

What are some of the problems of conventional refrigeration highlighted in this article? Can you think of any other low-cost solutions for transporting goods that need to be refrigerated or otherwise cooled? What would the product do? How would it meet a user's needs? Who might benefit from this solution?

Example 2

High school student Ann Makosinski came up with an innovative application for Peltier tiles. She used one to convert heat from the body into electricity to power a flashlight. Her invention, the hollow flashlight, won the 2013 Google Science Fair competition for her age category.

Read her full Google Science Fair entry here.

Discuss as a Class

What are some of the future applications of Peltier tiles that Makosinski describes in her science fair entry? What were some challenges she faced while working on this project, and how did she address those challenges? In what ways could you use her idea to improve upon your Peltier-cooled lunchbox?

Example 3

Do you ever notice how, when you get out of bed in the morning, the spot where you'd been sleeping feels warmer than the rest of your bed? That's because your body produces heat as a byproduct of metabolism, all of the chemical processes that keep your body running. Inspired by this simple fact, engineers Klas Johansson and Karl Sundholm invented a system to capture that heat and use it to heat a nearby office building. Read more about using body heat to keep buildings warm here.

Discuss as a Class

How did Sundholm and Johansson come up with their idea? How does their invention expand on the people-powered heating used at Minnesota's Mall of America, which recycles the body heat given off by the mall's shoppers? Can you think of other ways to capture, store, and reuse body heat? How would you use this heat?

BRAINSTORM INVENTION IDEAS

1. Remind students that as they brainstorm invention ideas, they need to think first about WHO their invention will help.

2. Tell students that the most successful brainstorms are the ones in which all ideas, even wacky ones, are proposed, and all ideas are accepted. You never know when a wacky idea will inspire a great invention! Take a few minutes to brainstorm invention ideas using the blank pages in your student guide. After you've come up with ideas, rejoin as a team and share your ideas. Brainstorm new ideas together. Remember to think of ways to apply the new minds-on and hands-on skills you have learned, such as building circuits and understanding heat transfer, and think of specific users and their needs. For example, could you build a cooler that uses fans and **evaporative cooling**? Could you create a low-cost, battery-operated cooler for aid workers in developing countries to keep vaccines or other medications cool during transport by harnessing and using the heat generated by Peltier tiles?

BRAINSTORM SOLUTIONS

1. Once teams have decided on needs they'd like to address, have them use SCAMPER to brainstorm design solutions.

2. Explain that SCAMPER is a process for coming up with solutions. It is based on the notion that many new things are modifications of something that already exists. Each letter in the acronym represents a different way students can arrange the characteristics of what is challenging them to help come up with new ideas:

S = **Substitute** *(playing basketball with a softball)*

C = **Combine** *(toothbrush combined with a pencil to create a new product)*

A = **Adapt** *(how would you eat your spaghetti without a utensil?)*

M = **Magnify** *(how would your chair function if its legs were wider and longer?)*

P = **Put to Other Uses** *(could your fork be used as a comb?)*

E = **Eliminate** *(could you play tennis without a racket?)*

R = **Rearrange** *(what if the laces of a shoe were placed on the bottom and not the top?)*

3. Say that to use the SCAMPER technique, you would first state the problem you would like to solve. Then, ask questions about it using the SCAMPER checklist.

4. Have students do some personal brainstorming using SCAMPER. Afterward, they should discuss their ideas with their teams and streamline them. They should select one idea (or a combination of multiple ideas) to take to the next step.

MAKE A PLAN

1. Remind students that all ideas are good ideas. They should record all ideas in their guides.

2. Encourage students to ask themselves the following questions to make sure they are on target:

- Is the product offering something useful and unique?
- Are you excited and motivated to develop your idea?
- What new tool and/or material skills would you need to learn?
- If the product meets a local need, would a community group, municipality, university, or company want to get involved with the project?
- Who will benefit from the invention? Is there a user clearly identified?

EDUCATOR NOTE

During Invention Planning

Walk around the room and make sure progress is being made. It would be ambitious for all teams to complete the worksheet pages by the end of the meeting. Ask them to continue researching and working on their ideas outside of meeting time many of us take for granted.

3. Have teams use the invention worksheet in their guides to document and sketch their idea. This is a version of what high school InvenTeams use in their project proposals.

4. Have teams share their ideas with the class in a culminating celebration of their work. Encourage students to **apply for InvenTeams grants** if they want to continue this work!

SELF ASSESSMENT

Collect the completed self-assessments as exit slips when students leave.

INDICATORS OF A SUCCESSFUL MEETING

Students brainstorm a technological invention idea to meet a real-world need, incorporating new skills from this unit. They conceptualize and plan their new invention ideas. Planning can continue beyond the unit.

NOTES

INVENTION CHALLENGE BRAINSTORM

For this brainstorm, it's important that you get ALL of your ideas down, especially the wacky ones! You never know when a wacky idea will turn into a great invention.

WHO will you help?

WHAT will you invent?

What problem do you want to solve?

S = Substitute
(Playing basketball with a softball.)

C = Combine
(Toothbrush combined with a pencil to create a new product.)

A = Adapt
(How would you eat your spaghetti without a utensil?)

M = Magnify
(How would your chair function if the legs were wider and longer?)

P = Put to Other Uses
(Could your fork be used as a comb?)

E = Eliminate
(Could you play tennis without a racket?)

R = Rearrange (or Reverse)
(What if shoelaces were placed on the bottom and not the top?)

INVENTION WORKSHEET

Our JV InvenTeam members are:

The product we are inventing is: ______________________________

to: ______________________________

____

It is useful for: ______________________________

____

because: ______________________________

____

____

It is unique because: ______________________________

____

It functions by: ______________________________

____

____

The tools we need are: ______________________________

____

The materials we need are: ______________________________

____

____

The estimated total cost of our invention is: ______________________________

CO_E_121420

LEMELSON-MIT

JV InvenTeams™

The Lemelson-MIT Program congratulates ____________________

on completing the Chill Out unit of JV InvenTeams on ____________

You did a wonderful job as an inventor and building a proof-of-concept lunchbox with heated and cooled compartments!

Thanks for all your contributions to the team.

Award for ________________________________

CHILL OUT

Signed,

____

Your JV InvenTeam Educator

engineering

invention

iteration

modification

patent

PhD

cold

convection

conduction

energy

electromagnetic waves

heat

heat transfer

kinetic energy

radiation

temperature

thermal conductor

thermal insulator

non-renewable resource

biomimicry

photon

sustainable design

thermal mass

wavelength

heat wave

- -

humidity

- -

urban heat island effect

metabolism

infrared radiation

evaporation

evaporative cooling

permeable

porous

thermoelectric

alternator

ambient

condensation

heat sink

empathy

Chill Out
Massachusetts Science and Technology/Engineering Standards - Middle School

Meeting	Science Standards	Engineering Standards	Cross-Cutting Concepts	Practices
Meeting 1: Invention Introduction		6.MS.ETS1-1 6.MS.ETS1-6 6.MS.ETS2-2 6.MS.ETS1-7 6.MS.ETS3-4 6.MS.ETS2-4	• 6th G - Structure & Function • 7th G - Systems & Cycles • 8th G - Cause & Effect	• Asking Questions & Defining Problems • Constructing Explanations & Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, & Communicating Information
Meeting 2: What is Heat?	7.MS.PS3-5 7.MS.PS3-6 7.MS.PS3-4	6.MS.ETS1-1 6.MS.ETS2-1 6.MS.ETS1-6	• 6th G - Structure & Function • 7th G - Systems & Cycles • 8th G - Cause & Effect	• Asking Questions & Defining Problems • Developing & Using Models • Analyzing & Interpreting Data • Constructing Explanations & Designing Solutions
Meeting 3: Keep Your Cool	7.MS.PS3-3 7.MS.PS3-5	6.MS.ETS1-1 6.MS.ETS1-6 6.MS.ETS2-1 6.MS.ETS2-2 6.MS.ETS2-3 6.MS.ETS1-7	• 6th G - Structure & Function • 7th G - Systems & Cycles • 8th G - Cause & Effect	• Asking Questions & Defining Problems • Developing & Using Models • Planning & Carrying Out Investigations • Analyzing & Interpreting Data • Constructing Explanations & Designing Solutions
Meeting 4: Removing Heat	7.MS.PS3-3 7.MS.PS3-4 7.MS.PS3-5	6.MS.ETS1-6 6.MS.ETS2-1 6.MS.ETS1-4	• 6th G - Structure & Function • 7th G - Systems & Cycles • 8th G - Cause & Effect	• Analyzing & Interpreting Data • Developing & Using Models • Constructing Explanations & Designing Solutions
Meeting 5: Peliter Prototyping		6.MS.ETS2-2 6.MS.ETS2-3	• 6th G - Structure & Function • 7th G - Systems & Cycles • 8th G - Cause & Effect	• Asking Questions & Defining Problems • Constructing Explanations & Designing Solutions
Meeting 6: Invention Extension			• 6th G - Structure & Function • 7th G - Systems & Cycles • 8th G - Cause & Effect	• Asking Questions & Defining Problems • Constructing Explanations & Designing Solutions

Standards alignment conducted by graduate students at Boston College's Lynch School of Education

Chill Out
Massachusetts Science and Technology/Engineering Standards - High School

Meeting	Science Standards	Engineering Standards	Cross-Cutting Concepts	Practices
Meeting 1: Invention Introduction		HS.ETS1-3 HS.ETS1-6 HS.ETS2-1		• Asking Questions & Defining Problems • Constructing Explanations & Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, & Communicating Information
Meeting 2: What is Heat?		HS.ETS1-3 HS.ETS1-6		• Asking Questions & Defining Problems • Developing & Using Models • Analyzing & Interpreting Data • Constructing Explanations & Designing Solutions
Meeting 3: Keep Your Cool		HS.ETS1-2 HS.ETS1-3 HS.ETS1-6		• Asking Questions & Defining Problems • Developing & Using Models • Planning & Carrying Out Investigations • Analyzing & Interpreting Data • Constructing Explanations & Designing Solutions
Meeting 4: Removing Heat		HS.ETS1-2 HS.ETS1-3		• Analyzing & Interpreting Data • Developing & Using Models • Constructing Explanations & De-signing Solutions
Meeting 5: Peliter Prototyping		HS.ETS1-1 HS.ETS1-3		• Developing & Using Models • Constructing Explanations & Designing Solutions • Analyzing & Interpreting Data
Meeting 6: Invention Extension		HS.ETS1-6		• Asking Questions & Defining Problems • Constructing Explanations & Designing Solutions

Standards alignment conducted by graduate students at Boston College's Lynch School of Education

Chill Out
Next Generation Science Standards - Middle School

Meeting	Science Standards	Technology/Engineering Standards	Cross-Cutting Concepts	Practices
Meeting 1: Invention Introduction	ETS1.A ETS1.B	MS.ETS1-1 MS.ETS1-2	• 6th G - Structure & Function • 7th G - Systems & Cycles • 8th G - Cause & Effect	• Asking Questions & Defining Problems • Constructing Explanations & Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, & Communicating Information
Meeting 2: What is Heat?	ETS1.A ETS1.B	MS.ETS1-1 MS.ETS1-2	• 6th G - Structure & Function • 7th G - Systems & Cycles • 8th G - Cause & Effect	• Asking Questions & Defining Problems • Developing & Using Models • Analyzing & Interpreting Data • Constructing Explanations & Designing Solutions
Meeting 3: Keep Your Cool	ETS1.B ETS1.C	MS.ETS1-1 MS.ETS1-4 MS.PS3-3	• 6th G - Structure & Function • 7th G - Systems & Cycles • 8th G - Cause & Effect	• Asking Questions & Defining Problems • Developing & Using Models • Planning & Carrying Out Investigations • Analyzing & Interpreting Data • Constructing Explanations & Designing Solutions
Meeting 4: Removing Heat	ETS1.A ETS1.B PS3.A PS3.B	MS.PS3-3	• 6th G - Structure & Function • 7th G - Systems & Cycles • 8th G - Cause & Effect	• Analyzing & Interpreting Data • Developing & Using Models • Constructing Explanations & Designing Solutions
Meeting 5: Peliter Prototyping	ETS1.B ETS1.C	MS.ETS1-4	• 6th G - Structure & Function • 7th G - Systems & Cycles • 8th G - Cause & Effect	• Developing & Using Models • Constructing Explanations & Designing Solutions • Analyzing & Interpreting Data
Meeting 6: Invention Extension	ETS1.A ETS1.B	MS.ETS1-1	• 6th G - Structure & Function • 7th G - Systems & Cycles • 8th G - Cause & Effect	• Asking Questions & Defining Problems • Constructing Explanations & Designing Solutions

Standards alignment conducted by graduate students at Boston College's Lynch School of Education

Chill Out
Next Generation Science Standards - High School

Meeting	Science Standards	Technology/Engineering Standards	Cross-Cutting Concepts	Practices
Meeting 1: Invention Introduction	ETS1.A ETS1.B	HS.ETS1-3	• Structure & Function	• Asking Questions & Defining Problems • Constructing Explanations & Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, & Communicating Information
Meeting 2: What is Heat?	ETS1.A ETS1.B	HS.ETS1-3	• System & System Models • Energy & Matter • Stability & Change • Patterns	• Asking Questions & Defining Problems • Developing & Using Models • Analyzing & Interpreting Data • Constructing Explanations & Designing Solutions
Meeting 3: Keep Your Cool	ETS1.B ETS1.C	HS.ETS1-2 HS.ETS1-3	• Structure & Function • Cause & Effect • Systems & System Models • Energy & Matter	• Asking Questions & Defining Problems • Developing & Using Models • Planning & Carrying Out Investigations • Analyzing & Interpreting Data • Constructing Explanations & Designing Solutions
Meeting 4: Removing Heat	ETS1.B PS3.A PS3.B		• System & System Models • Energy & Matter • Cause & Effect • Patterns • Influence of Science, Engineering, and Technology of Society & the Natural World	• Analyzing & Interpreting Data • Developing & Using Models • Constructing Explanations & Designing Solutions
Meeting 5: Peliter Prototyping	ETS1.B ETS1.C	HS.ETS1-2 HS.ETS1-3	• System & System Models • Energy & Matter • Cause & Effect • Influence of Science, Engineering, and Technology of Society & the Natural World	• Developing & Using Models • Constructing Explanations & Designing Solutions • Analyzing & Interpreting Data
Meeting 6: Invention Extension	ETS1.A ETS1.B	HS.ETS1-1	• Influence of Science, Engineering, and Technology of Society & the Natural World	• Asking Questions & Defining Problems • Constructing Explanations & Designing Solutions

Standards alignment conducted by graduate students at Boston College's Lynch School of Education

WARNING: THE MATERIALS, TOOLS, AND EQUIPMENT INCLUDED IN THIS KIT ARE NOT APPROPRIATE FOR USE BY CHILDREN UNDER AGE 11 AND SHOULD ONLY BE USED WITH PROPER TRAINING AND ADULT SUPERVISION.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT), INCLUDING THE LEMELSON-MIT PROGRAM, MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND CONCERNING THE CONDITION, QUALITY, PERFORMANCE, OR SUITABILITY OF ANY OF THE MATERIALS, TOOLS AND EQUIPMENT INCLUDED IN THIS KIT, AND HEREBY DISCLAIMS ALL REPRESENTATIONS AND WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, AND THE ABSENCE OF LATENT OR OTHER DEFECTS, WHETHER OR NOT DISCOVERABLE. TO THE EXTENT PERMISSIBLE BY LAW, IN NO EVENT SHALL MIT BE LIABLE FOR CLAIMS OR DAMAGES OF ANY KIND, INCLUDING DIRECT, INDIRECT, AND CONSEQUENTIAL DAMAGES. KITS ARE PROVIDED FOR USE BY JV INVENTEAM USERS AT THEIR SOLE RISK.

It is the responsibility of the JV InvenTeam educator to completely review the manufacturer’s manual(s) of the power tool(s) and/or associated equipment included in this kit and inspect all tools and equipment prior to each use, to ensure that they are safe for operation.

Note: As required by the manufacturer’s manual, follow all operating instructions provided, including use of the appropriate personal protective equipment, for the safe operation of the tools or equipment. WATCH General Shop Safety video with the students for additional safety rules to follow for the use of hand tools.

copy or phonorecord of the Work You distribute, publicly display, publicly perform, or publicly digitally perform. You may not offer or impose any terms on the Work that restrict the terms of this License or the ability of a recipient of the Work to exercise the rights granted to that recipient under the terms of the License. You may not sublicense the Work. You must keep intact all notices that refer to this License and to the disclaimer of warranties. When You distribute, publicly display, publicly perform, or publicly digitally perform the Work, You may not impose any technological measures on the Work that restrict the ability of a recipient of the Work from You to exercise the rights granted to that recipient under the terms of the License. This Section 4(a) applies to the Work as incorporated in a Collective Work, but this does not require the Collective Work apart from the Work itself to be made subject to the terms of this License. If You create a Collective Work, upon notice from any Licensor You must, to the extent practicable, remove from the Collective Work any credit as required by Section 4(d), as requested. If You create a Derivative Work, upon notice from any Licensor You must, to the extent practicable, remove from the Derivative Work any credit as required by Section 4(d), as requested.

b. You may distribute, publicly display, publicly perform, or publicly digitally perform a Derivative Work only under: (i) the terms of this License; (ii) a later version of this License with the same License Elements as this License; or, (iii) either the unported Creative Commons license or a Creative Commons license for another jurisdiction (either this or a later license version) that contains the same License Elements as this License (e.g. Attribution-NonCommercial-ShareAlike 3.0 (Unported)) ("the Applicable License"). You must include a copy of, or the Uniform Resource Identifier for, the Applicable License with every copy or phonorecord of each Derivative Work You distribute, publicly display, publicly perform, or publicly digitally perform. You may not offer or impose any terms on the Derivative Works that restrict the terms of the Applicable License or the ability of a recipient of the Work to exercise the rights granted to that recipient under the terms of the Applicable License. You must keep intact all notices that refer to the Applicable License and to the disclaimer of warranties. When You distribute, publicly display, publicly perform, or publicly digitally perform the Derivative Work, You may not impose any technological measures on the Derivative Work that restrict the ability of a recipient of the Derivative Work from You to exercise the rights granted to that recipient under the terms of the Applicable License. This Section 4(b) applies to the Derivative Work as incorporated in a Collective Work, but this does not require the Collective Work apart from the Derivative Work itself to be made subject to the terms of the Applicable License.

c. You may not exercise any of the rights granted to You in Section 3 above in any manner that is primarily intended for or directed toward commercial advantage or private monetary compensation. The exchange of the Work for other copyrighted works by means of digital file-sharing or otherwise shall not be considered to be intended for or directed toward commercial advantage or private monetary compensation, provided there is no payment of any monetary compensation in connection with the exchange of copyrighted works.

d. If You distribute, publicly display, publicly perform, or publicly digitally perform the Work (as defined in Section 1 above) or any Derivative Works (as defined in Section 1 above) or Collective Works (as defined in Section 1 above), You must, unless a request has been made pursuant to Section 4(a), keep intact all copyright notices for the Work and provide, reasonable to the medium or means You are utilizing: (i) the name of the Original Author (or pseudonym, if applicable) if supplied, and/or (ii) if the Original Author and/or Licensor designate another party or parties (e.g. a sponsor institute, publishing entity, journal) for attribution ("Attribution Parties") in Licensor's copyright notice, terms of service or by other reasonable means, the name of such party or parties; the title of the Work if supplied; to the extent reasonably practicable, the Uniform Resource Identifier, if any, that Licensor specifies to be associated with the Work, unless such URI does not refer to the copyright notice or licensing information for the Work; and, consistent with Section 3(b) in the case of a Derivative Work, a credit identifying the use of the Work in the Derivative Work (e.g., "French translation of the Work by Original Author," or "Screenplay based on original Work by Original Author"). The credit required by this Section 4(d) may be implemented in any reasonable manner; provided, however, that in the case of a Derivative Work or Collective Work, at a minimum such credit will appear, if a credit for all contributing authors of the Derivative Work or Collective Work appears, then as part of these credits and in a manner at least as prominent as the credits for the other contributing authors. For the avoidance of doubt, You may only use the credit required by this Section for the purpose of attribution in the manner set out above and, by exercising Your rights under this License, You may not implicitly or explicitly assert or imply any connection with, sponsorship or endorsement by the Original Author, Licensor and/or Attribution Parties, as appropriate, of You or Your use of the Work, without the separate, express prior written permission of the Original Author, Licensor and/or Attribution Parties.

e. For the avoidance of doubt, where the Work is a musical composition:

i. Performance Royalties Under Blanket Licenses. Licensor reserves the exclusive right to collect whether individually or, in the event that Licensor is a member of a performance rights society (e.g. ASCAP, BMI, SESAC), via that society, royalties for the public performance or public digital performance (e.g. webcast) of the Work if that performance is primarily intended for or directed toward commercial advantage or private monetary compensation.

ii. Mechanical Rights and Statutory Royalties. Licensor reserves the exclusive right to collect, whether individually or via a music rights agency or designated agent (e.g. Harry Fox Agency), royalties for any phonorecord You create from the Work ("cover version") and distribute, subject to the compulsory license created by 17 USC Section 115 of the US Copyright Act (or the equivalent in other jurisdictions), if Your distribution of such cover version is primarily intended for or directed toward commercial advantage or private monetary compensation.

f. Webcasting Rights and Statutory Royalties. For the avoidance of doubt, where the Work is a sound recording, Licensor reserves the exclusive right to collect, whether individually or via a performance-rights society (e.g. SoundExchange), royalties for the public digital performance (e.g. webcast) of the Work, subject to the compulsory license created by 17 USC Section 114 of the US Copyright Act (or the equivalent in other jurisdictions), if Your public digital performance is primarily intended for or directed toward commercial advantage or private monetary compensation.

5. Representations, Warranties and Disclaimer

UNLESS OTHERWISE MUTUALLY AGREED TO BY THE PARTIES IN WRITING, LICENSOR OFFERS THE WORK AS-IS AND ONLY TO THE EXTENT OF ANY RIGHTS HELD IN THE LICENSED WORK BY THE LICENSOR. THE LICENSOR MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND CONCERNING THE WORK, EXPRESS, IMPLIED, STATUTORY OR OTHERWISE, INCLUDING, WITHOUT LIMITATION, WARRANTIES OF TITLE, MARKETABILITY, MERCHANTIBILITY, FITNESS FOR A PARTICULAR PURPOSE, NONINFRINGEMENT, OR THE ABSENCE OF LATENT OR OTHER DEFECTS, ACCURACY, OR THE PRESENCE OF ABSENCE OF ERRORS, WHETHER OR NOT DISCOVERABLE. SOME JURISDICTIONS DO NOT ALLOW THE EXCLUSION OF IMPLIED licenses terminated provided such individuals or entities remain in full compliance with those licenses. Sections 1, 2, 5, 6, 7, and 8 will survive any termination of this License.

a. Subject to the above terms and conditions, the license granted here is perpetual (for the duration of the applicable copyright in the Work). Notwithstanding the above, Licensor reserves the right to release the Work under different license terms or to stop distributing the Work at any time; provided, however that any such election will not serve to withdraw this License (or any other license that has been, or is required to be, granted under the terms of this License), and this License will continue in full force and effect unless terminated as stated above.

8. Miscellaneous

a. Each time You distribute or publicly digitally perform the Work (as defined in Section 1 above) or a Collective Work (as defined in Section 1 above), the Licensor offers to the recipient a license to the Work on the same terms and conditions as the license granted to You under this License.
b. Each time You distribute or publicly digitally perform a Derivative Work, Licensor offers to the recipient a license to the original Work on the same terms and conditions as the license granted to You under this License.
c. If any provision of this License is invalid or unenforceable under applicable law, it shall not affect the validity or enforceability of the remainder of the terms of this License, and without further action by the parties to this agreement, such provision shall be reformed to the minimum extent necessary to make such provision valid and enforceable.
d. No term or provision of this License shall be deemed waived and no breach consented to unless such waiver or consent shall be in writing and signed by the party to be charged with such waiver or consent.
e. This License constitutes the entire agreement between the parties with respect to the Work licensed here. There are no understandings, agreements or representations with respect to the Work not specified here. Licensor shall not be bound by any additional provisions that may appear in any communication from You. This License may not be modified without the mutual written agreement of the Licensor and You.

LEMELSON-MIT
Celebrating invention, inspiring youth