STUDENT GUIDE

Name

School

Grade
JV InvenTeams™ - Electronic Textiles

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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](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](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 high school 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 to 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 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 units 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.

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

- solves world problems like finding clean sources of energy and treating unsafe water;
- 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, 8, 9 and 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

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 facilitatating 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 for the purposes of JV InvenTeams. 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 you 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! You 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 you, 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, you 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 you 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 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 (what if the laces of a shoe were placed on the bottom and not the top?)

The SCAMPER technique, you will first state the problem you would like to solve – this defines the challenge. After determining the challenge, it’s then a matter of asking questions about using SCAMPER to guide you. No idea is a “good” or “bad” idea at this point.

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://uspto.gov/](http://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](https://govtrack.us/congress/bills/113/hr3309).
Unit Summary for Students

In this unit, you will use your creativity to make wearable electronic textiles that light-up and serve a specific purpose.

You will first learn how batteries generate electricity and build your own battery cell using sanded pennies and a vinegar solution. You will also learn about conductors and insulators to guide you toward an understanding of open and closed circuits. You will build simple circuits in your design guide using conductive copper tape and surface-mount LEDs. You will learn how to handsew for the purpose of using conductive thread in a textile design. Finally, you will create a wearable light-up textile using conductive thread and felt. You will devise your own invention using electronics in the final meeting.

This unit encompasses a number of new minds-on and hands-on skills for you to add to your expanding toolkits. Minds-on skills include learning about the history of electronics and sewing, and continued practice exploring the design process. Hands-on skills include building a battery, creating a closed circuit, recognizing conductive and insulating materials, hand sewing, and a general understanding of electronics. You will be encouraged at the end of the unit to conceptualize an invention that meets a real-world need.

Learning Principles

Design Process
Electronics
Circuitry
Batteries
Materials
Hand sewing
Meeting Synopses

1  Invention Introduction

Introduction to invention and JV InvenTeams. Do warm-up activities and discuss invention. Play “Four Corners” to determine your strengths for team assignment.

2  Batteries 101

Learn about batteries and the flow of electricity. Undertake a penny battery project.

3  Copper Tape Designs

Practice building a simple circuit using copper tape and surface-mount LEDs in your guides.

4  Sewing & Electronic Textile Activity

Watch a sewing tutorial and practice sewing using thread. Design an electronic textile project and begin sewing your project.

5  Finish Textiles & Get Feedback

Continue sewing your electronic textile project. Brainstorm a new invention using your new skills in the latter half of the meeting.

Optional meeting(s) between 4 and 5

The educator may teach you how to use Arduino, an open source electronics platform of hardware and software.

6  Invention Extension

Conceptualize a new invention in small teams using minds-on and hands-on skills.
Electronic Textiles
Meeting 1: Invention Introduction

**Procedure**

- Get Your JV InvenTeams Guide
- Introduction to Invention and Problem Solving
- Design a Cell Phone Stand
- Think About Your Invention
- Watch 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

**Your Guide**

1. You will use your JV InvenTeams guide as an invention guide. This guide will be a portfolio of your work and ideas.

2. The grid paper and blank paper at the end of each meeting can be used to sketch, brainstorm, and document ideas.
Introduction to Invention and Problem Solving

1. We all run into challenges on a daily basis. You will now get a taste of what being an inventor means by coming up with ideas to address some of these problems.

2. Your educator has written down some problems on strips of paper. You will work with a team to build a solution to one of these problems using everyday materials.

3. After you receive your problem, use the recycling bin to find building materials and work with your team to devise a quick invention to meet your need.

4. When you are finished, take turns sharing your simple solutions with the full group. Some questions to ask other groups include:
   • How would you change your invention if you had more time?
   • How would you change your invention if you had a bigger budget?

5. 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.

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.
Electronic Textiles  
Meeting 1: Invention Introduction (cont.)

**Design a Cell Phone Stand**

1. Do you ever get annoyed by your phone not being able to stand up on its own? Inventors think outside of the box and create prototypes of their ideas using everyday materials.

2. Your challenge is to invent a low-cost cell phone stand using recycled materials like cardboard. You can also use duct tape.

3. Before you start, 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 you are having difficulty coming up with your own design, check out [Josh Ramos’ Cardboard Phone Stand](#).

**Think About Your Invention**

1. What do you like about the stand you made?

2. How would you change your design if you wanted to watch a video in the landscape format (sideways)?

3. Where are the speakers on your phone? How might you use the placement of the cardboard or other materials to improve the sound?

4. Share your design with another student. Write their feedback below:

5. How would you incorporate yours and their comments in your next
design? Describe this next design iteration in words or pictures.

Throughout the JV InvenTeams initiative you will learn about new tools and materials through invention activities like this one. After successfully meeting these challenges, you will think of iterations to improve your design.

Watch Some Invention Videos

1. Each year, teams of undergraduate and graduate students apply for the Lemelson-MIT Student Prize. Check out some cool videos from previous winners and finalists:
   - Julie Bliss Mullen’s invention brings clean water to people everywhere (2:00)
   - Chen Wang, Chandani Doshi, Grace Li, Jessica Shi, Charlene Xia, Tania Yu’s invention makes life easier for the blind (2:30)
   - Ramesh Raskar’s inventions improve people’s lives (4:06)

2. 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, engaging, and/or healthier.

Research an Invention

1. Identify an object in the room.

2. We often take the daily products 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 object you see today.

3. You will conduct research on inventions using Google Patent Search. Google Patents lists 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.

VIDEO NOTES

As you watch the videos, write down some thoughts you have about them here:

1. General thoughts:

2. How can failure turn out to be a good thing?

3. What failure have you learned the most from?

INVENTION PROFILE

MIT alumna Alison Wong invented Keyprop™, a simple solution to the problem of keeping your smart phone propped up. Check out a video of her invention: Invention Profile: Keyprop.
Electronic Textiles
Meeting 1: Invention Introduction (cont.)

   • 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. Think about a timeline of your daily routine. If you could improve one product or process during your typical day, what would it be?

   1. _____________________
   2. _____________________
   3. _____________________

   How could you improve these things?

   _____________________
   _____________________
   _____________________
   _____________________
   _____________________
   _____________________
   _____________________
   _____________________
   _____________________
   _____________________

2. In your group, discuss the following:
   • 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 application 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. Watch the MIT Design Process Videos.

2. Draw a visual model or outline below that will help you remember the steps of the design process as you invent something.

Set Rules and Develop Teams

1. The JV InvenTeams initiative is all about hands-on fun. To make this possible, here are a few important rules to follow:
   • 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. Diverse teams are successful teams

3. Play a game called “Four Corners” to help the educator create balanced teams. Instructions are on the next page.

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.
Teams of inventors include people with different interests and skills. In order to organize into teams, think about your own interests and skills.

Draw lines from the items on the left to the best-matching description on the right.

**Types of Team Members**

**Tinkerer:** I like to take things apart and build things.

**Talker:** I like to talk to people and I enjoy public speaking.

**Doodler:** I like to draw things and express my thoughts through drawing.

**Organizer:** I like to organize people and things.

**Your Interests and Skills**

Sounds most like me

Sounds almost like me

Sounds a little like me

Sounds least like me

The corners of your classroom will be marked with the four types of team members. Go to your "sounds most like me" description of yourself. Your educator will make balanced teams using this information.
Procedure

- Watch Lemelson-MIT videos
- Introduction to Batteries and Circuits
- Make a Penny Battery
- Explore Conductivity
- Self-Assessment

Watch Lemelson-MIT Videos

1. Each year, teams of undergraduate and graduate students apply for the Lemelson-MIT Student Prize. Check out a few videos of previous finalists who had projects involving electronics.
   - Natasha Wright’s Solar-Powered Desalination System (2:36) Natasha was a 2017 Lemelson-MIT Student Prize Winner. She invented a system that desalinates water for off-grid water production in communities in Indian and Gaza.
   - Arnav Kapur’s AlterEgo (2:13) Arnav was a 2019 Lemelson-MIT Student Prize Winner. Arnav’s invention changes how we interact with computers.
   - Tony Tao’s Locust (1:59) Tony was 2017 Lemelson-MIT Student Prize Winner. Tony’s invention furthers atmospheric science by being able to deploy multi-sensor UAV networks in midair.

2. 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 healthier.

Reflect on the Videos

1. What impressed you about these inventions?

_____________________________________________________________________________

2. How did these inventions use electronics?

_____________________________________________________________________________

_____________________________________________________________________________

3. Use the margin to make a list of electronic products you use everyday. Share your list with a neighbor and rank them according to what you think are the simplest versus the most complex.

4. Have you ever worked with electronics? What did you work on?

_____________________________________________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

Introduction to Batteries and Circuits

1. You’ll need a basic understanding of **batteries and circuits**, the foundation of electricity, before inventing with electronics. Sometimes the best way to understand something is to try it out!

2. Your educator will divide you into pairs and distribute a battery, some copper tape, scissors, and an **LED** to each pair.

3. You have a few minutes to use these materials to try to light up your LED.

4. If you get your LED to light, try to figure out at least one additional way to light up the LED using the same materials.

5. Answer the reflection questions below and on the next page:

If your LED is (or is not) lighting up, why do you think this is?
Electronic Textiles
Meeting 2: Batteries 101 (cont.)

What questions do you have about how this circuit works?

6. Share your ideas and questions with the class.

7. The reading below will explain the basics of how circuits work and will hopefully help you answer some of your questions.

How Does a Circuit Work?

In an electric circuit, charges flow in a closed loop. The rate of the flow of charge is called current. When your LED lit up earlier, you harnessed this current to transform electrical energy into light energy.

But what is a charge, how does it flow, and how do we use this flow to light up bulbs?

Electric charges are everywhere. Electrons are negatively charged. Protons are positively charged. When these charges balance each other out, we don’t really notice them.

Charges flow when there is a separation between positively-charged particles and negatively-charged particles.

Lightning is an example of this. In thunderstorms, the lower portion of a cloud becomes negatively-charged, while the upper portion becomes positively-charged. This difference in charge sets up an electric field, within which the charges seek to regain balance. Lightning is the flow of electricity from one charged area to the other, and serves to balance the charges within the cloud.

INVENTOR PROFILE

Could you imagine a world without electricity? Thomas Edison is arguably the greatest inventor of the modern era. He developed a complete electrical distribution system for light and power among a vast array of other electricity inventions. Learn more about Edison and his 1,093 patents here: Inventor Profile: Thomas Edison.

Source: en.wikiquote.org

Source: wikipedia.com
In an electric circuit, the battery provides the charge separation needed to create a flow of charge. Here’s how that works:

<table>
<thead>
<tr>
<th></th>
<th>cathode</th>
<th>anode</th>
</tr>
</thead>
<tbody>
<tr>
<td>(+)</td>
<td></td>
<td>(-)</td>
</tr>
</tbody>
</table>

Most batteries have an anode, marked negative (-), and a cathode, marked positive (+). Electrons collect at the anode when a chemical reaction occurs in the battery. This sets up a charge separation between the anode and the cathode. Normally, the charges would balance themselves out by flowing (like lightning) from the anode to the cathode. The battery is designed, however, so that there is no convenient path through the battery for charges to flow.

Charges can only flow when the battery is added to a circuit that connects the anode to the cathode using materials that the charge can flow through.

By placing an LED in the path of the electric current, you can use some of the current’s energy to light up the bulb.

It is important to recognize that in an electric circuit, the energy is initially supplied by the battery in the form of chemical energy. The circuit is a tool that allows you to convert this chemical energy into electrical energy, which you can then transform into light energy as you illuminate your LED.

Once the chemical energy in the battery is depleted, the separation of charge disappears, and the current stops flowing. This is why people often switch off battery-powered devices when they are not using them. Batteries have a limited life!

Laboratory crash tests show ways to improve the safety of lithium-ion batteries used in electric and hybrid cars. Read more here: [Extend the Learning: Lithium-Ion Battery Crash Tests](#).

Tesla Motors, Inc. is an American company that designs, makes, and sells electric cars. The Tesla Roadster, seen to the left, was the first fully electric sports car.
Electronic Textiles
Meeting 2: Batteries 101 (cont.)

Follow-Up Questions

1. Revisit your list of questions about circuits with your partner. Use information in the reading to help you answer your questions.

2. Take some time to successfully light up your LED if you haven’t yet done so. Once you have gotten yours to light, respond to the questions below:

How would you explain how this circuit works to a ten-year old?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

What questions do you still have about how this circuit works?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Italian physicist Count Alessandro Volta first discovered the electrochemical process in 1799 when he created a simple battery from metal plates and brine-soaked paper. Read more about Volta here: History: Count Alessandro Volta.

Now you know where the term “voltage” comes from!
Explore Conductivity

1. Remember that charges can only flow when the battery is added to a circuit that connects the anode to the cathode using materials that the charge can flow through.

2. Materials that charge can flow through easily are called conductors. Materials that charge can not flow through easily are called insulators.

3. Look at the chart below. Based on your LED circuit, during which a current passed through copper tape, which of these materials do you think are conductors? Why do you think so?

<table>
<thead>
<tr>
<th>Object</th>
<th>Conductor</th>
<th>Insulator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper clip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chalk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eraser</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum foil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Object of choice 1:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Object of choice 2:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Object of choice 3:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Select three items from the chart that you would like to test for conductivity.

5. Work in pairs to test out the conductivity of some of the materials in the chart. Use your LED circuits to test with by making a break in the copper tape and placing the material in the gap. If the material is a conductor, the LED should light up.

6. How do you think a switch works? Switches temporarily interrupt the circuit with an insulator or a break in the wire. Try to make a switch in your circuit.
Current, Voltage, and Energy

* This section is adapted from the High-Low Tech Group at MIT.

1. Remember that the flow of charge in a circuit is called an electric current, which is measured in **amps**.

2. All batteries have a **voltage** rating and amp-hour rating. The voltage tells you how many volts your battery can supply and the amp-hour rating tells you how much current it can supply.

3. Together, these ratings tell you how much energy is stored in the battery. This lets you know both how much energy you can use and gives you an idea of how long the battery will last.

4. You have been using a 3-volt coin cell battery with an amp-hour rating of .25 amp-hours. This means that the battery can supply .25 amps of current at 3 volts for 1 hour before it dies.

5. The circuits you built to light up the LED used about .025 amps of current (about 1/10th of .25 amps). This means that your battery should last about 10 hours.

6. Review the chart below comparing two battery types:

<table>
<thead>
<tr>
<th>battery type</th>
<th>amps required (amps, A)</th>
<th>amp-hour rating (amp-hours, Ah)</th>
<th>battery will last (hours, h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3V coin cell</td>
<td>.025 A</td>
<td>.25 Ah</td>
<td>.25/.025 = 10h</td>
</tr>
<tr>
<td>3V camera Battery (Energizer EL1CREP)</td>
<td>.025 A</td>
<td>.75 Ah</td>
<td>.75/.025 = 30 h</td>
</tr>
</tbody>
</table>

HIGH SCHOOL CONNECTION

The Richland Two Institute of Innovation InvenTeam (Columbia, SC) invented a system of interlocking solar modules to power a photocopier for a school in Sare Bilaly, Senegal. The modules snap together and trickle charge to two deep cycling pure gel 12-volt batteries. The module was designed using sustainable materials and locally accessible materials so it can be assembled, replicated, and repaired by the students of Sare Bilaly themselves. To learn more, check out High School Connection: Richland Two Institute of Innovation.
Make a Penny Battery

1. Have you ever gone shopping for a battery? Whether it’s an AA for a remote or a rechargeable battery for a laptop, you know they can be expensive.

2. You will now have the chance to build a battery out of pennies! Your lab-made battery should be powerful enough to light up a small, high-intensity LED.

3. Your educator will divide you into small groups.

4. Follow the instructions on the next page to build a penny battery with your team.

INVENTOR PROFILE

Professor Angela Belcher is the Head of the Biological Engineering Department and a materials chemist at MIT. Belcher won the 2013 $500,000 Lemelson-MIT Prize. Belcher draws inspiration from nature and has invented a high-powered, biologically based battery. The battery is inexpensive to produce and nontoxic. Currently it can power a laser pointer and an LED light, although Belcher’s goal is to scale the battery to run a hybrid car. Learn more here: Inventor Profile: Angela Belcher.
Electronic Textiles
Meeting 2: Batteries 101 (cont.)

Instructions for Building a Penny Battery

1. Work with your team to assemble the following supplies:
   - 5-10 pennies from post 1982 (these have a zinc interior, which is important)
   - 5-10 square cut-outs of paper towel (the size of a penny)
   - White vinegar in a cup
   - 5mm red LED with two wire legs coming out of the bottom

2. Watch Video Tutorial: Five-Cent Battery. (2:17)

3. Follow the steps below to assemble your penny battery:
   - Each person should sand one side of a few pennies until the outer (copper) layer is removed. You will notice a change in color from bronze to silver. This can be hard work by hand, so consider safely using a rotary tool with a sanding attachment.
   - Dip the paper towel squares in vinegar until they are saturated. The vinegar is an acidic liquid that allows the chemical reaction between each metal surface to occur.
   - Place a vinegar-soaked square on top of the zinc (sanded) side of one penny, and then stack the other four pennies and squares on top in the same pattern. You can use some duct tape or rubber bands to secure the battery in place.
   - Place the entire stack on a few strips of copper tape.
   - Place the longer wire of the LED against the surface of the top penny and the other wire against the bottom. Does the LED turn on? If so, you successfully completed a circuit!

SAFETY
Wear safety glasses and a dust mask while sanding with a rotary tool.
• Use the **multimeter** to test the voltage of your battery if it didn’t work. Is there enough voltage to power the LED?

• You may want to try adding additional sanded pennies to your stack.

**Follow-Up Questions**

What would happen if you didn’t place the copper and zinc sides of the pennies facing one another?

________________________________________________________________________

________________________________________________________________________

Why do you think the vinegar solution is important?

________________________________________________________________________

________________________________________________________________________

Why do you think the battery only works when the longer wire of the LED is touching the top penny?

________________________________________________________________________

________________________________________________________________________

**NOTE**

**Troubleshooting**

If your lab-made battery isn’t turning on the LED, here are some troubleshooting questions:

• Are you sure the longer wire is touching the top penny and not the other way around?

• Were each of the squares soaked in the vinegar solution?

• Were the pennies sanded effectively to allow the zinc to come through?

• Did you try adding additional pennies (up to 10) in your stack?
MEETING 3

Electronic Textiles
Meeting 2: Copper Tape Designs

KEY TERMS

Parallel Circuit (n): A closed circuit in which the current divides into two or more paths before recombining to complete the circuit.

Textile (n): A type of cloth or woven fabric.

Procedure

• Meet Leah Buechley
• Build a copper tape circuit
• Brainstorm light-up designs
• Introduction to parallel circuits
• Brainstorm uses for light-up textiles
• Meet Analisa Russo
• Self-Assessment

Meet Leah Buechley

1. Leah Buechley is an electrical engineer who directed the High-Low Tech research group at MIT’s Media Lab. Watch Leah Buechley’s TED Talk (6:34) to hear her ideas about “sketching” with electronics.

2. Reflect on the video by responding to the following questions:

Have you ever seen electronics used in artwork? Give examples.

What project or use of electronics most impressed you in this video?
How could one of these visual techniques also be used to solve a real world problem?

Build a Copper Tape Circuit

1. You learned about batteries and circuits in the last meeting. You will apply these hands-on skills in this meeting to light up your design guides and prepare to make wearable electronic **textiles** in the subsequent meetings.

2. Jie Qi is a designer, educator, inventor and entrepreneur based in Tokyo who studied Media Arts and Sciences at MIT. She integrates art and science through her unique copper tape activity. Create your own light-up paper designs following Jie’s instructions below.

Prepare the Paper.
- Turn to the second sheet of grid paper in the back of this meeting.
- Fold one of the corners and trace the coin cell battery on either side.
- Label the side under the flap with a (+) so you later remember to put your battery positive-side down.

Lay Down the Copper Tape.
- Note that electrical connections between the LEDs, switches, and coin cell battery are made with copper tape, represented by grey lines in the template.
- Lay down copper tape as shown in the template. **Be careful! The edges of the tape are sharp.**
- Make sure the tape extends through the coin cell outlines so it will be touching the battery.
- Fold the tape (think wrapping paper) to make the corners.
- Ensure that there is a tiny break in the tape (as demonstrated by the tiny yellow diamond on the template. This is where you will place the surface-mount LED.

The edges of the copper tape are very sharp and should be handled with caution. Safety gloves may provide some added protection when you are cutting copper tape.
Electronic Textiles
Meeting 3: Copper Tape Designs (cont.)

Place the LED.
- Tell students that they need to determine which side of the LED is the (+) side and which is the (–) side before they add it to their circuit. Remind students that electrons move from negative to positive. This means that the (–) side of their LED needs to be attached to the (–) side of the battery and the (+) side needs to be attached to the (+) side of the battery. The (–) side of surface-mount LEDs is often marked with a dot, a line, an arrow, or green coloring. Note that surface-mount LEDs (represented by the yellow diamond) are very tiny and can be challenging to work with.

LEDs come in cartridge strips as shown above.
- Pull back the plastic seal and the LEDs will come out.
- Use clear tape or tweezers to lift an LED and place it on your paper.

Add the Battery.
- Secure the battery by placing it under the fold and clipping it with a small binder clip.
- Make sure the tape is touching the battery on the (+) end.
- You will know if the circuit is complete because the LED will light up.
Brainstorm Light-Up Designs

1. Jie Qi creates intricate circuits with copper tape and incorporates them into light-up designs.

2. Check out Jie’s light-up greeting card in this image. When you press on the heart, the circuit closes, and the cheeks light up red! Jie used a pressure sensor under the heart so you can control the brightness of the light based on how hard you press.

3. Try this yourself by placing a piece of paper over your light-up circuit. Draw a design on this paper that incorporates the light from the LED shining through.

4. Brainstorm some designs that could incorporate one or more lights. Some ideas include:
   - Traffic light
   - Eyes of a cartoon character
   - Illuminated flowers of different colors
   - Light-up cards (check out these Light-Up Diwali Cards)

INVENTOR PROFILE

Jie Qi earned her PhD from the Massachusetts Institute of Technology in Media Arts and Sciences. She co-founded Chibitronics and worked in electronics design at the Eyebeam Art and Technology Center. Her work blends electronics, art, and technology to create engaging viewing experiences. She also has played a leading role in the development of Patent Pandas, a website to help educate others about Patent Law. To learn more, visit Inventor Profile: Jie Qi.
Introduction to Parallel Circuits

1. What if you want to use multiple lights? A parallel circuit is a closed circuit in which the current divides into two or more paths before recombining to complete the circuit.

2. These diagrams show parallel circuits that power three lights.

3. Wiring in parallel means that each LED will receive the total voltage that the power supply is outputting. However, wiring in parallel will drain your power supply faster because the LEDs end up drawing more current from the power supply. It also only works if all the LEDs you are using have the same power specifications.

Brainstorm Uses of Light-Up Textiles

1. Like paper, you can also light-up textiles!

2. You will use conductive thread in the next meeting - like you used conductive copper tape - to sew circuits onto felt. The felt can take any form and the sewable LEDs can be placed anywhere along the pattern.

3. Brainstorm some ideas for a wearable light-up device that serves a purpose and meets a real need besides decoration. Start sketching ideas in the graph paper section of your guide.
Questions to Discuss with a Partner

What activities or settings require small lights?

________________  ________________          ________________
________________  ________________          ________________
________________  ________________          ________________

When would a light source be helpful to you for seeing better in the dark?

________________________________________________________

When would a light source be helpful for enabling others to see you?

________________________________________________________

What devices (e.g., umbrella or iPhone) can you think of that you could improve by adding a light-up feature?

________________  ________________          ________________
________________  ________________          ________________

Visual design is an important component for appealing to the user. How could you integrate artwork, like Jie, into your useful design?

________________________________________________________

Here is an example of a wristband that provides a light source and incorporates a fire-breathing dragon (red light) into the design.
Electronic Textiles
Meeting 3: Copper Tape Designs (cont.)

Meet Analisa Russo

Dr. Analisa Russo is the Technical Community Manager at Formlabs, a 3D printing technology company, former graduate student in Materials Science and Engineering at the University of Illinois at Urbana-Champaign, and former member of the Lewis Research Group at Harvard University.

Dr. Russo’s research focused on rollerball pen writing with conductive silver ink for paper electronics. This is another way to create light-up designs on paper. Instead of copper tape, she used silver ink. Silver is also a conductive material. Paper is an increasingly popular material for electronic devices because it is lightweight, disposable, and inexpensive. The silver ink-filled pen is a tool that anyone can use, even those who are new to designing circuits.

Her interest in developing this system for science, technology, engineering, and math (STEM) education and circuit prototyping led her to co-found Electroninks Writeables, a company that commercialized her conductive silver ink technology and developed Circuit Scribe, a conductive ink-filled rollerball pen for drawing paper-based circuits. Circuit Scribe has applications in device prototyping, electronic art, and STEM education.

Originally from Iowa City, Iowa, Analisa didn’t know she liked electronics until college. When she was a kid, she spent a lot of time playing music with instruments such as the piano, viola, and clarinet. Instruments are designed beautifully, which got her interested in how things work and eventually led her into materials engineering.
Questions and Answers from Analisa

Who were your role models as a kid?
“The person who I looked up to most was my older brother, who is also an engineer.”

Did you do any tinkering or inventing at a young age?
“When I was younger, I spent a lot of time playing music (piano, viola, and clarinet). Instruments are really tactile so I think that got me interested in materials science.”

How did you get interested in electronics?
“I didn’t learn much about electronics until college. As an undergraduate, I had a research job at the MIT Media Lab, where I learned how to build circuit boards and program. I found the process of making tangible things, including electronics, very satisfying. I still have an interest in building circuits, but I’m even more interested in the materials that they are made from and in creating new tools for other makers to use.”

What advice can you give kids who want to become inventors?
“Start making things! Working on skills like sewing or cooking, even if they seem low-tech, will help you learn how to plan a project from start to finish and get you thinking creatively.”
Electronic Textiles
Meeting 4: Sewing & Electronic Textiles

KEY TERMS

Short circuit (n): Accidental contact between two points in an electric circuit that have a potential difference.

Trace (n): Thread connections between electronic components.

SAFETY
Sewing needles have sharp ends so use caution as you learn how to thread a needle and sew. Threaders are provided to help you get started.

INVENTOR’S TOOLKIT

Hands-on
- Learn how to hand-sew
- Create wearable electronic textiles

Minds-on
- Apply knowledge of circuitry in a new way

Procedure

- Introduction to sewing
- Sewing practice
- Decide on a design
- Create wearable electronic textiles
- Self-Assessment

Introduction to Sewing

1. Do you know how to sew by hand? By machine? How did you learn? Do you think sewing is a useful skill in today’s world?

2. Sewing is a useful skill to have in everyday life, from mending holes in a favorite sweater to sewing hems in pants that are too long. It’s a particularly useful skill for inventors and designers who work extensively with fabric or other textiles.
Sewing Tutorial

1. Watch the Hand Sewing Video Tutorial (7:37), which provides a demonstration of hand sewing.

2. You will extend your understanding of electronics and circuitry to construct a wearable electronic design in this meeting and the next one. You will sew special LEDs and batteries onto felt using conductive thread.

Sewing Practice

1. Now that you know how to get started with hand sewing, you will spend some time practicing with cotton thread; your educator will give you materials. Later, you will use conductive thread, which is more expensive and slightly harder to manipulate.

2. Often, the hardest part is getting the thin thread through the small needle eye and tying a knot. Use the visuals on the next page to help you get started.
Electronic Textiles
Meeting 4: Sewing & Electronic Textiles (cont.)

Sometimes making a small loop in the thread helps to insert a frayed thread into the eye of the needle:

Source: mcnett.com

Decide on a Design

1. Turn to the electronic textile designs you brainstormed in the last meeting.

2. Think about what it would be like to create one of your designs out of felt. Felt is limited in size and surface area. Do you need to modify your design?

3. Your design should serve some purpose such as increasing visibility in the dark. Some items that could be lit up include:

   • Bracelet
   • Umbrella
   • Hat
   • Cell phone holder

Source: chickenscratchny.com
4. Work with a partner to get some feedback on your design. Keep track of feedback in your guide. Ask questions like:
   • Does it meet a real need?
   • Is the project feasible with limited time?

5. Interview prospective users (other classmates) to get additional feedback on the design.

Create Wearable Electronic Textiles

1. You will have the remainder of this meeting and part of next meeting to complete your project.

2. Will you be creating a simple circuit or a parallel circuit for your design? If you only need one light, then sewing a simple circuit will suffice. You should use a parallel circuit to power multiple lights and increase the challenge level.

3. Here are a few things to keep in mind as you get started:
   • Each of the thread connections between the components is called a trace. Your circuit has two traces: the (+) trace that connects the (+) side of the battery holder to the (+) side of the LED and the (-) trace that does the same on the other side.
   • You can incorporate traces into the look of your design by sewing in straight, curvy, or zigzag lines.
   • Identify the small holes on either side of the battery holders and LEDs. You will use these holes to sew the battery and LEDs into your circuit.
   • Remember that you need to connect the (+) tab on the battery holder to the (+) side of the LED, and the (-) tab on the battery to the (-) side of the LED.
   • If the (+) and (-) traces touch each other directly, this creates a short circuit. When this happens, the power supply releases a huge burst of energy. Short circuits drain batteries and prevent LEDs from illuminating.

Patents can get complicated if two or more inventors are developing similar products around the same time. This is what happened with the sewing machine. The debate over who invented the first sewing machine still continues. Learn about Mr. Singer and Mr. Howe here: Patent Spotlight: Singer vs. Howe.
Electronic Textiles
Meeting 4: Sewing & Electronic Textiles (cont.)

4. Use the instructions and visuals below, adapted from the light-up bookmark activity in *Sew Electric* by Leah Buechley and Kanjun Qiu. Illustrations are by Sonja de Boer. If you are sewing a parallel circuit, refer to the instructions on page 33 of your Student Guide.

Get Started

1. Cut your felt into your desired shape. You can also join a few pieces of felt to make a larger piece.

2. Cut two feet of conductive thread and thread it onto your needle.

3. Stitch the (+) tab of the battery holder to the felt: push your needle up through the fabric next to the (+) tab of the holder. Tug on your needle to make sure you don’t leave any excess thread on the underside of your fabric.

4. Push the needle through the (+) hole to create a loop around the (+) tab and secure the battery holder to the fabric. Pull the thread through tightly to make a snug connection between the thread and the tab. Repeat this process a few times.

5. (Optional) Put a small amount of fabric glue on the knot on the underside of the fabric to make sure the knot doesn’t unravel.

6. Trim the knot close to the battery holder.

7. Sew the trace from the (+) side of the battery holder to the (+) side on the LED. You will use the basic sewing technique you practiced, weaving the thread between the front and back of the felt.

8. Pause after every few stitches to check for loose or tangled threads. Check both the front and back of the felt to make sure there aren’t any tangles, knots, or wrinkles.
9. Once you reach the LED, make at least 3 tight loops around its (+) tab in the same way you attached the battery holder.

10. Tie a knot to complete this trace. Make sure your knot is on the back side of the felt so it won’t obscure your design.

11. Repeat the same steps as above to sew the (–) side of the battery holder to the (–) side of the LED. While you’re sewing, don’t let the (–) trace touch or come close to the (+) trace. Beware of loose ends or knots, as well.

12. Test the circuit to make sure it is complete. Slide the coin cell battery into the holder. The (+) side of the battery should face up as you put it in. Flip the switch on the holder from off to on to test it out. Hopefully it lights up! Keep troubleshooting if it doesn’t.

Sewing Parallel Circuits for Multiple Lights

1. You will need to sew a parallel circuit if your design includes the use of multiple lights.

2. The diagram on the next page shows a parallel circuit. Note that all of the (+) tabs are sewn together and all of the (–) tabs are sewn together.

3. Stitch the (+) tab of the new LED to the (+) trace of the original circuit and the (–) tab of the new LED to the (–) trace of the original circuit. Where the new (+) trace intersects the old (+) trace, loop the new trace’s thread several times around the old trace’s thread before tying a knot, trimming it, and securing it with fabric glue (optional). Do the same with the negative side. Use the following visuals to help guide you:

Sewing Note

You want to avoid the knots and wrinkles shown in the images to the left. Check your work carefully after every stitch to ensure you are keeping the thread and fabric smooth.
Electronic Textiles
Meeting 4: Sewing & Electronic Textiles (cont.)

EXTEND THE LEARNING

Wearable electronics is a growing field. Explore some fascinating products that are new to the market by checking out the links below:

- **Extend the Learning: Wearable Electronics**
- **Extend the Learning: Wearable Technology and Fashion**

Source: readwrite.com
The DIY Girls is a 2017 Lemelson-MIT InvenTeam grant recipient that invented a solar powered tent for individuals experiencing homelessness. The DIY Girls InvenTeam had a strong desire to address the needs of the increased homeless population in Los Angeles, so they created a prototype that provided homeless individuals access to LED lighting, a cell phone charger, and a UVC LED sanitation system to disinfect the inside of the tent. The team learned to sew to build the housing prototype from a material that is UV resistant with insulating and breathability characteristics. Watch this video to learn more about the DIY Girls InvenTeam: High School Connection: DIY Girls InvenTeam (2:33).
**Meeting 5: Finish Textiles & Get Feedback**

**Procedure**
- Complete your wearable electronic textile
- Share feedback
- Meet Carmichael Roberts
- Self-Assessment

**Complete Your Wearable Electronic Textile**

1. You will use the first part of today's meeting to finish your wearable electronic design from last meeting.

2. Use the instructions and visuals from Meeting 3 to guide your work.

3. If you finish early, use the Extend the Learning section to the left to inspire improvements to your design.

**KEY TERMS**

**Invest (v):** To offer money with the plan of achieving a profit.

**Venture (n):** An undertaking that involves risks.
Share Feedback

1. Your educator will place you in a team of four. This will be your team for the rest of the unit.

2. Make sure everyone on the team gets to share their project and receive constructive feedback on their work. Use the table on the next page to guide your conversation.

3. Talk as a team to determine the pros and cons of each electronic textile project.

Professor Trisha L. Andrew is an Associate Professor of Chemistry and Chemical Engineering at the University of Massachusetts Amherst. She directs the Wearable Electronics Lab. Dr. Andrew and her colleagues developed a new technique for creating sewable, weavable, electrically heated material. One application of this new technique is a pair of gloves that keep fingers as warm as the palm of the hand. Learn more here: College Connection: Dr. Trisha Andrew
Electronic Textiles
Meeting 5: Finish Textiles & Get Feedback (cont.)

Use this table to guide your team’s discussion of each other’s projects.

<table>
<thead>
<tr>
<th>Person A</th>
<th>Person B</th>
<th>Person C</th>
<th>Person D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Name of project</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intended user and purpose</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Does it light up?</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Does it address the need? How?</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>How could you improve the project?</strong></td>
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</tbody>
</table>
Meet Carmichael Roberts

Carmichael Roberts started his career as a technologist and now invests in companies that use chemistry, materials science, and materials engineering in innovative ways. Together with his son, Carmichael Roberts III, he spoke to a TEDxBeaconStreet audience about innovative stretchy electronics that can be placed on and removed from the skin like tattoos or stamps. They can be used to monitor workouts and general health. Watch the presentation: TEDxBeaconStreet - Carmichael Roberts (11:29).

Carmichael Roberts is the Co-Founder and Managing Partner of Material Impact, a company that seeks out novel materials and grows them into great products and enduring companies that solve real-world problems. Carmichael is also a partner at North Bridge Venture Partners, where he helps inventors build companies that make new products. His primary industry areas of interest include medical, energy and electronics. Carmichael focuses on very early stage ventures from university inventions, including helping founders launch companies from the ground up.

Along with creative inventor George Whitesides, Carmichael cofounded Diagnostics For All, Inc., a non-profit organization that is using an innovative materials platform to make low cost diagnostics for poor and rural populations in developing nations. Carmichael also served as an advisor to the former United States Secretary of Energy, Ernest Moniz. He is on the Board of Trustees of Duke University and Berklee College of Music, and on the Boards of Overseers of the Boston Symphony Orchestra and the Museum of Science in Boston.

Carmichael received his B.S. and Ph.D. in organic chemistry from Duke University and was a National Science Foundation Fellow in Harvard University’s Departments of Chemistry and Chemical Biology. He earned his M.B.A. from the MIT Sloan School of Management. In 1999, Dr. Roberts was named by MIT’s Technology Review as one of the world’s top 100 young innovators.
Questions and Answers from Carmichael

Who were your role models and mentors as a kid?
“I had no one in my family who had a background in science as I grew up in New York City. Most people had jobs in the city that had more to do with business. My first mentor was a retired college professor named Dr. Sawyers who decided to spend a few years teaching grade school science to youngsters. He convinced me that I could be a scientist. I will never forget him. As for role models, I grew up when hip-hop and rap were being “invented” on the streets in NYC. There was an entrepreneurial vibe that convinced me that you can create your own technology, business and career. No one was cleverer than Russell Simmons who built a record label and business called Def Jam. It may sound weird but he was my role model that convinced me that I can do entrepreneurial science if he could build an industry.”

Did you do any tinkering or inventing at a young age?
“My family had limited resources so most toys that I got for birthdays and Christmas were viewed as precious commodities. Still, if it was something electronic, I would eventually open it up to see how it worked. I would routinely rebuild and rewire things just because it was fun to do. Keep in mind that inventing does not always mean technology. You can invent new business models as well. Even at a young age, I came up with many different business ideas and tested them quite often. I was somewhat fearless in this regard.”

How did you get interested in biostamps and other “stretchy electronics”?
“In college I met some extremely clever technologists who were young and crazy inventive—just like me! Perhaps at the top of the list was my buddy John Rogers. We stayed in contact as friends for years after leaving the University. When John invented “stretchy electronics,” the two of us began to brainstorm applications for products. We realized that skin is stretchy so why not put the electronics right on your body? The first version looked like a postage stamp so we called it a biostamp. Cool stuff.”
What advice can you give kids who want to become inventors?
“Find your passion—whatever topics—and never let them go. Your best ideas are never over. Even when you come up without something special, you will do it again. And remember that collaboration is the best way to accelerate innovation. You do not need to do everything by yourself.”

COLLEGE CONNECTION

Yoel Fink is an MIT Professor of Material Science. He develops clothing fibers with embedded functional properties. Fink and his team imagine clothes that can respond to a person’s body temperature or monitor their health. Learn more here: College Connection: Yoel Fink
Electronic Textiles
Meeting 6: Invention Extension

Procedure

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

Introduction to Invention Challenge

1. You will conceptualize a project using the hands-on and minds-on skills you have developed within this unit. Although you have been working only with LEDs, there are other electronic components you can incorporate, such as buzzers, motors, and sensors.

2. Although time and resources will limit the design process to conceptualization, you can continue working on your projects outside of meeting time. The most useful and unique ideas have the possibility of becoming InvenTeam projects in future years.

3. Your most important task today is to identify a real need and conduct research before jumping into project development.

KEY TERMS

Acronym (n): An abbreviation formed from the initial letters of other words and pronounced as a word.
Review Real-World Examples

Example 1: “Lion Lights”

Watch the [Lion Lights TED Talk](https://www.ted.com/talks/13agedboy-invent-solar-powered-lion-scare-lights) (7:21) to learn about Richard Turere and his invention.

Richard Turere, age 13, identified a problem in his daily life and came up with an innovative solution. Hungry lions were threatening his family’s cattle farm in Kitengela, Kenya. He learned that lions are afraid of moving lights. He fitted flashing LED lights onto poles, which were wired to an old car battery powered by a solar panel. His invention not only helped save his cattle, but also saved lions from being killed by angry farmers. His invention is now being implemented all over Kenya.

Is there a lighting need in your community? How might you think of the environmental impact when figuring out your project?

Example 2: Directional Jacket

Leah Buechley from the Media Lab at MIT invented a directional turn signal jacket for bikers and other athletes on the road. Her invention incorporates Arduino programming.

How can you use wearable electronics (sound or light) to improve safety on sidewalks or roads? Jot down some ideas in the margin.

Example 3: Vibrating Vest for the Visually Impaired

Read [Vibrating Vest for the Visually Impaired](https://www.gizmag.com/17986/vibrating-vest/) to learn about a vibrating vest that is designed to help visually impaired people get around safely.
Electronic Textiles
Meeting 6: Invention Extension (cont.)

Example 4: Solar Textiles

The Portable Light Project uses solar cells in clothes to bring electricity to billions of people worldwide without power. Tiny solar cells are inserted into shirts and bags produced by local communities in developing countries. Clean energy and lighting is integrated with textile production, made by the people who will use them.

Inventions often build on other inventions and combine various processes and materials. Inventors must continue to learn new skills and techniques to build their toolkits of knowledge. How can you integrate your knowledge electronics and sewing? Jot down some ideas in the margin.

Identify a Need

1. Sit back and reflect on the new toolkit of skills you have acquired in this unit. You have practiced minds-on skills such as working in teams and understanding electronic circuits. You have gained hands-on skills such as sewing and creating light-up textiles. Invention is centered on empathy and fulfilling people’s needs.

2. **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.

3. 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 the latter, 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.

4. For additional information on problems/needs in other countries, you and your team can explore the [World Bank](https://www.worldbank.org) website.
5. Share your ideas with your team and work together to brainstorm new ones. Try to apply your hands-on and minds-on toolkits as you brainstorm. For example, how can electronics and textiles be integrated to make something new and useful?

6. Use the Invention Challenge Brainstorm to develop and track your team’s ideas about needs you would like to address.

Brainstorm Solutions

1. Once your team has decided on a need you’d like to address, you can use SCAMPER to brainstorm design solutions.

2. 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 you can arrange the characteristics of what is challenging you, 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 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?)

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

HIGH SCHOOL CONNECTION

The Newton North InvenTeam (Newton, MA) from 2013 invented a pedestrian alert system to be used in Addis Ababa, Ethiopia, to alert drivers of crossing pedestrians and help them safely cross the road. The system was designed with the aesthetics of Ethiopian culture and incorporates Arduino programming. Learn more here: High School Connection: Newton North High School.

Members of the Newton North team with Representative Joe Kennedy from Massachusetts

One of the pedestrian crossing columns
Electronic Textiles
Meeting 6: Invention Extension (cont.)

4. Do some personal brainstorming using SCAMPER on the next page and record your ideas.

5. Discuss your ideas with your team and streamline them. Work with your team to select one idea to take to the next step.

Make a Plan

1. Remember that all ideas are good ideas. You should record all ideas in your guide.

2. Ask yourself the following questions to make sure you are on target:
   • Is the product offering something useful and unique?
   • Who will benefit from the invention? Is there a user clearly identified?
   • Does your project incorporate electronic textiles in some way?
   • Are you excited and motivated to develop your idea?
   • What additional research would you need to conduct?
   • 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?

3. Use the invention worksheet in your guide to document and sketch your idea. This worksheet is a version of what high school InvenTeams use in their project proposals. When you are finished, share your work with your class!

4. If you are interested in continuing this work, consider applying for an InvenTeams grant!
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
_______________________________________________________________
(short description of what it does)

______________________________________________________________

It is useful for __________ because _______________________________.
(the user) (description of the need or problem)

It is unique because ____________________________________________
(description of how it's different from other solutions)

______________________________________________________________

It functions by _________________________________________________
(description of how it works)

______________________________________________________________

The tools we need are:

____________     _____________   _______________  _______________

The materials we need are:

____________     _____________   _______________  _______________
____________     _____________   _______________  _______________
____________     _____________   _______________  _______________
____________     _____________   _______________  _______________

The estimated total cost of our invention will be: $ ________________
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?
My Thoughts

Student Name

Date
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